Journal of the K.R. Cama Oriental Institute
ISSN: 0970-0609

TREND AND GROWTH ANALYSIS OF GST COLLECTION IN INDIA

Latika Sharma

Research Scholar, University School of Management, Kurukshetra University, Kurukshetra

Dr. Jai Kishan Chandel

Assistant Professor, Institute of Management Studies, Kurukshetra University, Kurukshetra

Dr Mukta Jain

Associate Professor, Dyal Singh College, Karnal

ABSTRACT

The Government of India added a milestone by unifying all the indirect taxes (center and state level) and introduced 'Goods and Services Tax (GST)' on 1st July 2017. Introduction of reforms in any taxation system removes the limitations in the existing tax system. Thus, it helps to broaden the scope and collection of taxes. There has been phenomenal growth in overall GST collection in India since introduction of GST. Considering this background, the present study has been conducted to identify the long term trend and growth in the GST collection among states and union territories (UTs) in India. The study is based on data of five years i.e. July 2017 to March 2022 from official secondary sources. The results of regression analysis revealed trend and growth inequalities among different states and Union Territories (UTs). Only 13 states/UTs demonstrated a significant positive trend in the GST Collection. However, only 6 states/UTs demonstrated a significant positive annual growth in GST collection. Daman and Diu is the only UT showing insignificant negative trend and annual growth. Findings revealed variation in the revenue performance of states/UTs in India.

KEYWORDS: GST, growth, tax collection, trend.

INTRODUCTION

In India, government derive significant portion of revenue through taxes (Sharma, 2019). These resources are used to fuel the growth and development activities in the economy. Deficiencies in the taxation system make it easy for the taxpayers to avoid and evade the tax obligations. Consequently, it negatively affects the revenue generation and mobilization capacity in a country. The complexities and limitations in the indirect tax system persuaded the government to bring biggest reform in the history of indirect tax structure of India. Thus, "Goods and Services Tax (GST)" came into picture.

GST got the parliamentary assent on 8th September 2016 but came into force on 1st July 2017. The GST is also known as modified VAT. The GST is unified, multistage, destination based consumption tax levied on supply of goods and services in India, with few deviations. India follows the dual system of GST. It has four variants; 'Central Goods and Services Tax' (CGST), 'State Goods and Services Tax' (SGST), 'Integrated Goods and Services Tax' (ICST) 'Union Territory Goods and Services Tax' (UTGST). Compensation cess was also introduced to compensate the loss in the tax revenue suffered by states as consequent of new tax reform.

Following the GST effectuation, it was presumed that it will help in the increase of the tax collection/revenue (Sandhu & Atwal, 2019; Nayyar & Singh, 2018; Mahante, 2016). Various studies have been conducted over the years in India and abroad that claimed that tax reforms have significantly impacted the revenue generation in the country. In Indian, various studies have been conducted to measure the impact of GST on the overall and state/UT wise GST

Principal
Dyal Singh College
KARNAL

2024

Dr. Mukta

Research Paper

No. 78

RR
(extra copy)

Journal

of

THE K R CAMA ORIENTAL INSTITUTE

THE K R CAMA ORIENTAL INSTITUTE

Mumbai

2024

ISSN 0970 - 0609

Principal
Dyal Singh College
KARNAL

...plinary and Multidisciplinary Research (JIMR)
...56-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary ...

CONTENTS

1. **A STUDY ON THE IMPLEMENTATION OF ANDROID OPERATING SYSTEM**
By Sunil Kumar Patel.....1

2. **THE CONTRIBUTION OF LOGIC PROGRAMMING TO ARTIFICIAL INTELLIGENCE**
By Mrs. Shakila Siddavatam, Mrs. Namita Nitin Amrutkar, Mrs. Madhuri Mukul Modak, Ms. Sana Kausar Fayaz Nallamandu.....6

3. **A REVIEW OF NUTRITIONAL ABNORMALITIES, COMPLICATIONS, AND OPTIMIZATION IN THE CIRRHOTIC PATIENTS**
By Manparvesh Singh Chahal, Dr. sukriti.....11

4. **IMPACT OF FLOOD AND RIVER BANK EROSION ON THE LIVELIHOOD OF THE RIVERINE PEOPLE: A CASE STUDY OF RAHMARIA RIVERINE AREA, DIBRUGARH DISTRICT, ASSAM**
By Prof Sanjib Kr Dutta.....17

5. **IMPLEMENTATION OF DATA MINING METHODS IN CYBER SECURITY**
By Fatima Rafique sheikh, Kamil Khan.....31

6. **TREND AND GROWTH ANALYSIS OF GST COLLECTION IN INDIA**
By Latika Sharma, Dr. Jai Kishan Chandel, Dr Mukta Jain.....37

7. **A STUDY ON EFFECT OF US VOLATILITY INDEX ON INDIAN VOLATILITY INDEX**
By CA Niyati Shah, Dr. (CA) Darshana Khakhar.....44

8. **CUSTOMER SATISFACTION IN THE BANKING SECTOR: A COMPREHENSIVE REVIEW**
By Ms. Richa Agarwal, Professor (Dr.) Seema Sharma.....49

9. **IMPACT OF WORKING CAPITAL MANAGEMENT ON LIQUIDITY AND PROFITABILITY OF PHARMACEUTICAL INDUSTRY – A CASE STUDY OF CIPLA LTD**
By Dr. Chindam Sathyanarayana, Mrs. M. Anuradha, M.S Rachana.....64

10. **NEW EDUCATION POLICY'S BENEFITS AND LIMITATIONS: A CRITICAL STUDY**
By Arpita Gupta.....82

11. **INTERTEXTUAL TRANSFORMATIONS: THE JOURNEY OF BIOGRAPHIES TO BIOPICS**
By Ms. Fathima Sullami T.A, Dr. Salia Rex.....87

12. **STUDY OF PERCEPTION ABOUT THE GENDER DIVERSITY IN ROAD TRANSPORT COMPANIES PUNE**
By Prof. Indrani Chandrakiran Salve, Prof. Dr. Sheena Abraham Varghese.....93

Principal
Dyal Singh College
KARNAL

शोध–प्रभा (ISSN: 0974-8946)
(A REFERRED & PEER- REVIEWED QUARTERLY RESEARCH JOURNAL)

A STUDY OF INVESTOR'S ATTITUDE TOWARDS MUTUAL FUNDS AS AN INVESTMENT OPTION

DR. MUKTA JAIN

Associate Professor, Department of Commerce, Dyal Singh College, Karnal, Haryana

ca.jainmukta@gmail.com

ABSTRACT

Mutual fund as an investment avenue provides a platform to the investor who does not want to take high risk on their hard-earned investment. In India, mutual fund industry is growing rapidly and this industry has emerged as an important segment of the financial market of India, especially in channelizing and mobilizing the savings of millions of individuals into the investment in equity and debt instruments. Mutual fund investment is less risky than investing directly in stocks and is therefore a safer option for risk averse investors. A competent fund manager should analyse investor behaviour, perception, and attitude and understand their needs and expectations to gear up the performance to meet investor expectations and requirements.

Also, the mutual fund industry today is one of the most preferred investment options of all over the world. It plays a crucial role in the economic development of a country. Mutual fund active involvement can be seen by their dominant presence in the money market as well as the capital market. They are also found very active in the stock market by way of ensuring stability as a supplier of large funds through steady absorption of floating stocks. Investors invest directly in individual securities or indirectly through a financial intermediary. Study intends to identify the usage of schemes and level of risk on the basis of their income level. The findings of the study indicate that the majority of the selected respondents have used open ended schemes with moderate risk.

Keywords -- Investors Attitude, Investment Alternative, Mutual Fund, Risk and Return, Suitable stage, Schemes

Principal
Dyal Singh College
KARNAL

Dr. Mukta

Research Paper

UGC CARE LISTED

ISSN: 0974-8946

अनुसंधान - प्रकाशन - विभागीया - त्रैमासिकी शोध - पत्रिका

(A REFEREED & PEER- REVIEWED QUARTERLY RESEARCH JOURNAL)

Vol. 51, Issue-1 (October- December) 2023

प्रधानसम्पादक:

प्रो.रमेशकुमारपाण्डेय:

कुलपति:

सम्पादक:

प्रो. शिवशंकरमिश्र:

शोधविभागाध्यक्ष:

सहसम्पादक:

डॉ. ज्ञानधरपाठक:

शोधसहायक :

श्रीलालबहादुरशास्त्रीराष्ट्रियसंस्कृतविश्वविद्यालय

नवदेहली - 110016

Principal
Dyal Singh College
KARNAL

1	वराह पुराण में प्रयुक्त संयुक्त क्रिया रूप	डॉ० बबलू शर्मा, मूर्ति	1-11
2	The Portrayal of American Society in Jack Kerouac's *On the Road*	Dr Ritu Sharma	12-18
3	महाकवि भास तथा कालिदास की कृत्तियों में नारी पात्र : एक विमर्श	डॉ॰ बबलू शर्मा, सरिता देवी	19-25
4	राधाचरितम् महाकाव्य में राजधर्म	डॉ॰ बबलू शर्मा, कोयल	26-30
5	पण्डित मिथिलेश शर्मा की रचनाओं में राष्ट्रीय–चेतना : एक विमर्श	कृष्णा, डॉ. बबलू शर्मा	31-34
6	A STUDY OF INVESTOR'S ATTITUDE TOWARDS MUTUAL FUNDS AS AN INVESTMENT OPTION	DR. MUKTA JAIN	35-46
7	Employment Pattern of Rural and Urban Sectors of Haryana	Pooja, Dr. Rajesh Kundu	47-67
8	Maintenance and Welfare of Parents and Senior Citizens: Issues and Challenges	Dr. Jyoti Rani	68-75
9	लैंगिक समानता और महिला सशक्तिकरण : एक अध्ययन	डॉ. बबीता, पुनम	76-84
10	District Wise Analysis of Sex Ratio In Haryana 1981 To 2011	Sabeet	85-95
11	SEX RATIO AND CHILD SEX RATIO: A STUDY OF HARYANA STATE	Satish Kumar	96-103
12	*Oleander Girl:* The New Indian Girl.	NITEE DUHAN, RASHMI MALIK	104-111
13	वंदना शुक्ल के उपन्यास मगहर की ' में आंचलिकता 'सुबह	डॉ रामरती, संगीता	112-118

Principal
Dyal Singh College
KARNAL

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886| UGC CARE II
Vol. 19 Issue 03, March- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

"Crisis Resilience: Building Organizational Preparedness in the Face of Adversity"

Dr. Mukta Jain, Associate Professor
Department of Commerce, Dyal Singh College, Karnal.
ca.jainmukta@gmail.com

Abstract:

Crises, which are typically connected to natural disasters, comprise a wider range of incidents that endanger public health, corporate image, and economic viability. Notwithstanding their source, crises require quick thinking and effective action because they can jeopardise these essential aspects. Within the realm of business, crises materialise as situations that endanger the survival of the organisation, profitability, and stakeholder well-being. Corporate crises are not uncommon, ; statistical evidence indicates a considerable prevalence, which is further exacerbated by the long-lasting impact of COVID-19. The necessity of proactive crisis management becomes apparent when considering the possible occurrence of crises and their power to lead to business collapse. Organisations may effectively navigate uncertainty. and alleviate adversities by cultivating resilience and readiness. Therefore, crisis management becomes critical to maintaining organisational integrity and continuing to operate in the face of ever-evolving impediments.

Keywords:*Crisis management, resilience, organizational response, proactive measures, corporate survival, stakeholder welfare.*

Introduction:

When we hear the word "crisis," visuals of natural disasters like earthquakes or tsunamis that leave a trail of devastation and ruin in their wake usually come to mind. But a closer look shows that crises aren't limited to apocalyptic catastrophes; they can also involve an array of situations and events. Indeed, crises can take many different forms and, whether they originate inside or outside, they pose a threat to the public's health, a company's reputation, and its financial viability.

Principal
Dyal Singh College
KARNAL

J Opt
https://doi.org/10.1007/s12596-023-01307-6

RESEARCH ARTICLE

Self-focusing of rippled *q*-Gaussian laser beams in plasmas: effect of relativistic nonlinearity

Naveen Gupta[1] · S. B. Bhardwaj[2] · Rohit Johari[1] · A. K. Alex[1] · Suman Choudhry[1] · Devinder Singh[3]

Received: 4 May 2023 / Accepted: 8 July 2023
© The Author(s), under exclusive licence to The Optical Society of India 2023

Abstract Theoretical investigation on self-focusing of *q*-Gaussian laser beam propagating through underdense plasma has been presented. The optical nonlinearity of plasma has been modeled by the relativistic mass nonlinearity of plasma electrons in the field of laser beam. Using variational theory approach, semi-analytical solutions of the wave equations for the fields of main beam and that of ripple have been obtained. Emphasis has been put on the evolutions of the intensities of main beam and that of ripple.

Keywords *q*-Gaussian · Laser ripple · Variational theory · Clean energy · Self-focusing

Introduction

Since the 1930s, when scientists began to realize that the sun and other stars are powered by nuclear fusion, their thoughts turned toward recreating this process in the laboratory for the viable energy production. Because fusion can use atoms present in ordinary water as a fuel, harnessing the process could assure future generations of adequate electric power [1]. The ultimate stakes are so high, fusion will produce no harmful emissions—no sooty pollutants, no nuclear waste and no greenhouse gases. All the stars and the sun use their strong gravitational pull to compress nuclei to high densities. In addition, temperatures in the sun are extremely high, so that the positively charged nuclei have enough kinetic energy to overcome their mutual electrostatic repulsion and draw near enough to fuse. However, such resources are not readily available on the earth. The particles that fuse most easily are the nuclei of deuterium and tritium. To fuse even deuterium and tritium, hydrogen gas has to be heated intensely and also has to be confined long enough that the particle density multiplied by the confinement time exceeds 10^{14} seconds per cubic centimeter. Since the 1950s, fusion research has focused on two ways of achieving this number: inertial confinement and magnetic confinement.

The strategy of inertial confinement fusion (ICF) is to shine a symmetrical array of powerful laser beams onto a spherical capsule containing a D-T mixture. The laser beams vaporize the surface of the pellet that explodes outward. To conserve momentum, the inner sphere of fuel simultaneously shoots inward just like the recoil of a gun when the bullet is fired. Although the fuel is compressed for only a brief moment (about 10^{-10} second), extremely high densities of almost 10^{25} particles per cubic centimeter can be obtained [2, 3].

For the successful realization of ICF, it is highly necessary that the fuel pellet should be heated uniformly. However, due to the nonuniform irradiance (intensity ripples) over the cross sections of the laser beams, the pellet is not heated uniformly that derives an instability known as Rayleigh–Taylor (RT) instability [4–6]: Whenever a not-very-dense fluid (like air) pushes on a denser fluid (like water), the situation is inherently unstable. If the interface between the two fluids is having any imperfection like bumps or divots, then these imperfections will immediately grow with time.

This fundamental instability can even be observed in everyday kitchen scenarios. It may be difficult to imagine an instability in the kitchen, but consider the following question: Why does not the water stay in a glass when you invert it? At first glance, the answer may seem obvious:

✉ Naveen Gupta
naveens222@rediffmail.com

[1] Lovely Professional University, Phagwara, India

[2] S U S Govt. College, Indri, Karnal, India

[3] Dyal Singh College, Karnal, India

Published online: 06 August 2023

Spri
Principal
Dyal Singh College
KARNAL

Gravity pulls the water down and causes it to spill onto the floor. However, upon closer examination, the answer is not as straightforward. Atmospheric pressure adds complexity to the question. Every exposed surface in contact with air experiences pressure. The weight of the atmosphere exerts pressure from all directions, compressing us. Every square inch of our skin is subjected to 14.7 pounds of air pressure pushing against us. We may not notice it because our bodies are accustomed to it, but this force is significant, capable of crushing a steel can under suitable conditions. It is also more than enough to support a glass filled with water and prevent the liquid from pouring out. You can try a simple experiment yourself (over a sink, of course). Fill a glass to the brim with water. Place a smooth, rigid piece of cardboard over the mouth of the glass and invert it. Carefully release the cardboard. If done gently enough, you will observe that the water remains inside the glass. The cardboard is not holding the water in place. It is not tightly sealed to the glass; even a slight touch will dislodge the cardboard and cause the water to escape. Moreover, the water is not defying gravity by some miraculous means. It is supported by the air pressure. The upward force of the atmosphere, at 14.7 pounds per square inch, is significantly stronger than the downward force exerted by the water in the glass, which amounts to only a few ounces per square inch. When these two forces clash, the upward push of the atmosphere prevails, and the water stays put. Surprisingly, the forces are so imbalanced that you would need an exceptionally tall glass of water, around thirty feet high, for the downward weight of the water to equal the upward pressure from the atmosphere. With such a substantial discrepancy between forces, the question becomes far less trivial: Why does not water remain in a glass when it is turned upside down? The water spills out due to an effect called the Rayleigh–Taylor instability. Whenever a less dense fluid (such as air) pushes against a denser fluid (such as water), it creates an intrinsically unstable situation. If the interface between the two fluids contains any imperfections, such as bumps or divots, those imperfections rapidly grow larger. When you invert a glass of water, even if you do so carefully, the liquid's surface exhibits a few crests and troughs. In a fraction of a second, these crests expand, transforming into large drooping tendrils of water hanging down from the surface, while the troughs deepen and allow significant pockets of air to penetrate the glass. The tendrils break, the air pockets detach, and the entire glass of water spills out onto the floor. This phenomenon exemplifies the Rayleigh–Taylor instability in action.

It is almost as if the laser scientists are trying to invert a glass so carefully that the surface of the water inside would not ripple at all. In ICF as the fuel pellet is compressed, it becomes denser and denser. Long before it is hot and dense enough to fuse, it will be much denser than whatever mean is being used to compress it. A less dense substance, i.e., laser beams are being used to squash and contain a much denser one, and hence, the situation will get prone to Rayleigh–Taylor instabilities. Any tiny imperfections on the interface between the plasma and the laser beams pushing on the plasma will grow with time. Even an almost perfectly spherical pellet of deuterium–tritium will quickly become distorted, squirting tendrils in all directions (Fig. 1). Just as RT instability ruins any attempt to keep water in an inverted glass by means of air pressure, it seriously damages ICF machine's ability to compress and contain fusion plasma by means of laser beams. Thus, it becomes essential to investigate the behavior of intensity ripples over the cross section of laser beams during their propagation through plasmas.

Intensity ripples in a laser system are due to spontaneous emissions [7, 8]. Each spontaneously emitted photon adds to the coherent field (established by stimulated emissions) a small field component whose phase is random, and thus perturbs both amplitude and phase in a random manner. The net result is that the intensity profile of the laser beam exhibits fluctuations in the form of ripples (Fig. 2).

An extended physical analogy can be helpful in comprehending the involved mechanisms. The oscillations of the electromagnetic field bear resemblance to the movements of a playground swing. Similar to the motion of a light wave, the swing's oscillation exhibits a specific frequency (the number of cycles or round trips the swing completes within a given time frame) and amplitude (the height reached by the swing in each cycle). The relative motion of two children on swings, like that of two light waves, is described in terms of their relative phase: If both children reach the highest point of their swing simultaneously in each cycle, they are swinging in phase. On the other hand, if they reach the peak at different times, they are said to be out of phase to some extent.

Let's consider a scenario where a child on a playground decides to operate a swing in a slightly unconventional manner. Instead of following the conventional method of leaning back and then forward once in each cycle, the child chooses to either stand on the seat or squat down at different moments during the swing's cycle. If the child squats as the swing approaches the highest point of its motion and stands up when the swing is closest to the ground (thus exerting effort against the centrifugal force), they will be injecting additional energy into the swing's motion, thereby amplifying it. Consequently, the swing will reach greater heights in every cycle. Conversely, if the child squats when the swing is nearest to the ground and stands up as it rises, they will diminish the swing's motion, resulting in reduced height in each subsequent cycle.

In our analogy, the pumping motion performed by the child exhibits two significant characteristics. Firstly, the child stands and squats twice during each round trip of the swing. In more technical terms, the frequency of the pumping action is twice the frequency of the swing's motion.

Principal
Dyal Singh College
KARNAL

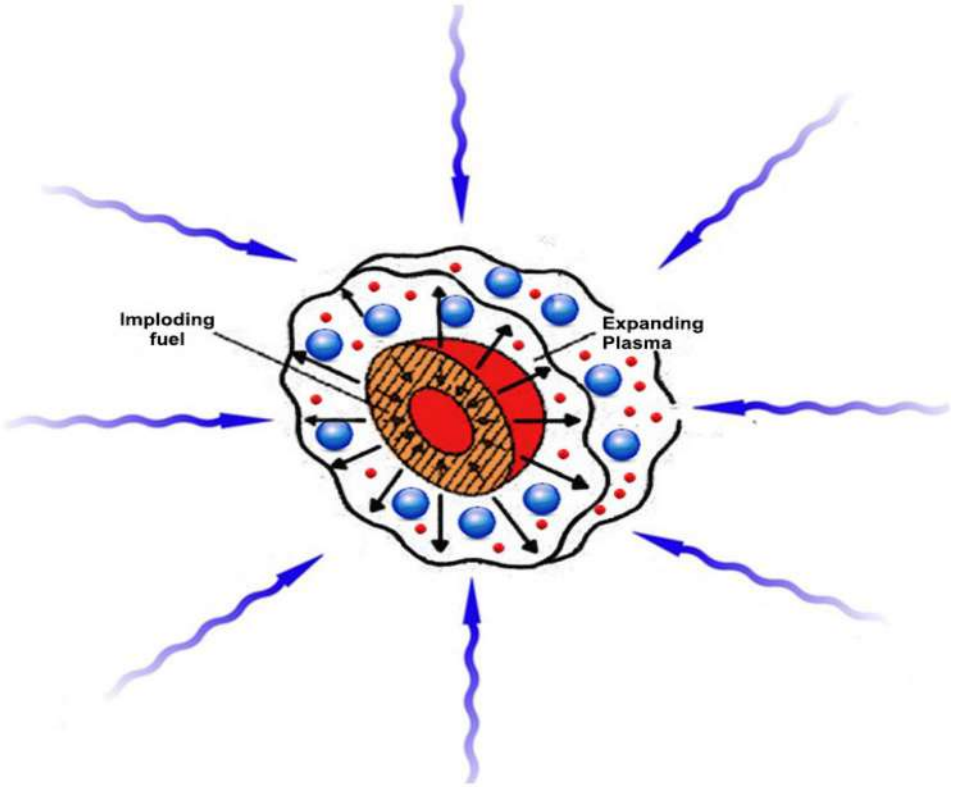


Fig. 1 Rayleigh–Taylor instability in ICF

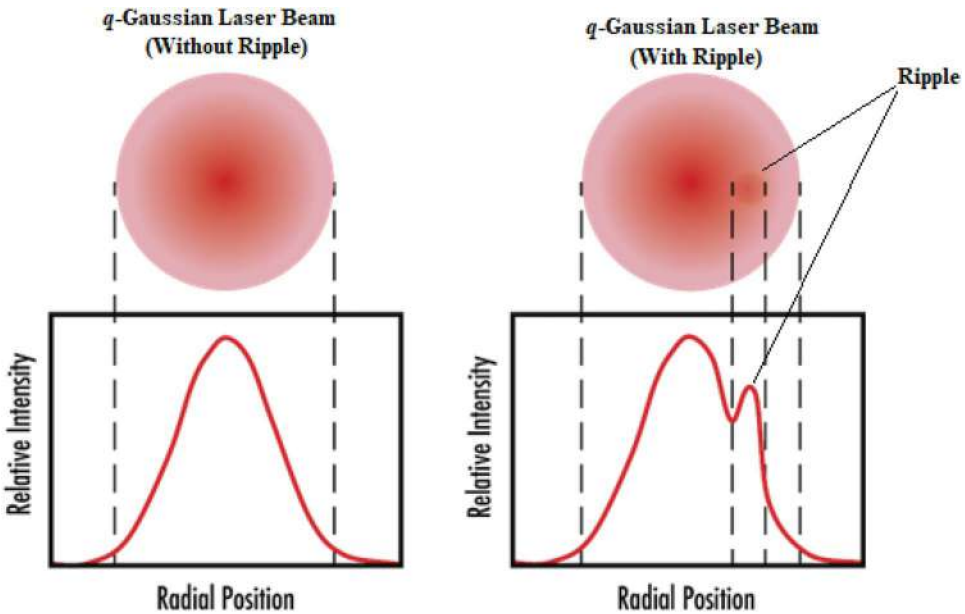


Fig. 2 Intensity ripple on laser beam

Secondly, the swing's motion can be either amplified or diminished based on the relative phase of the child's standing and squatting positions, specifically whether the child stands or squats at the highest point of the swing's cycle.

Similarly, a comparable pumping action can be applied to a light wave that is confined within an elongated cavity equipped with mirrors at both ends. Assuming the length of the cavity precisely matches a whole number of wavelengths of the light, the confined wave undergoes interference with itself upon reflection from each end of the cavity. Consequently, the wave resonates as a standing wave, akin to how a sound wave resonates within an organ pipe.

Principal
Dyal Singh College
KARNAL

Let's consider a scenario where it becomes feasible to oscillate the mirror at one end of the cavity back and forth, thus altering the cavity's length at precisely twice the frequency of the light wave. By consistently modifying the cavity's length in this manner, energy would be either added to or subtracted from the light wave as it reflects off the mirror. Similar to the child's pumping motion, the mirror's vibration would either amplify or diminish the light wave's intensity, depending on the relative phase between the mirror's vibration and the oscillation of the light wave. If the mirror's motion aligns with the appropriate phase of the light wave's oscillation, the wave is amplified, resulting in a strengthened oscillating electromagnetic field. Conversely, if the mirror's motion aligns with the complementary phase, the wave is de-amplified, causing the oscillating electromagnetic field to weaken.

Returning to our analogy, envision an entire playground filled with children, each on their respective swings. They are all swinging at the same frequency but are not synchronized in phase. At any given moment, some children may be near the top of their swing cycle while others are closer to the ground. Now, suppose a teacher enters the playground and uses a megaphone to shout "Stand… squat… stand… squat…" at exactly twice the frequency of the children's swinging. When the teacher shouts "Stand," some children will be near or at the bottom of their swing cycle, while others will be near or at the top. Those who stand near the bottom during the teacher's command will amplify the motion of their swings, whereas those who stand near the top will de-amplify the motion of their swings.

Gradually, the children who stand near the bottom of their swing cycle will start swinging with significantly greater amplitude than before, while those who stand near the top will experience minimal swinging. Consequently, the playground will feature a group of children swinging at much higher heights, almost perfectly in phase with one another and synchronized with the teacher's commands. Meanwhile, there will be another group of children who essentially cease swinging, despite continuing to stand and squat. In our analogy, these children correspond to spontaneously emitted photons those add up to stimulatedly emitted photons in the form of intensity ripples.

It is well known fact that laser beams differing in intensity profiles behave differently in plasmas [9–12]. However, the literature review reveals the fact that most of the earlier investigations on self-focusing of rippled laser beams in plasmas have been carried out for ideal Gaussian laser beams [13–18]. In contrast with this picture, the experimental investigations on the irradiance profile of Vulcan petawatt laser at Rutherford Appleton laboratory [19] reveal that the actual irradiance over the cross section of the laser beam is not ideally Gaussian. A significant amount of laser energy was found to be lying outside the half-width full maximum of the laser beam. The best irradiance profile that fits into the experimental data [20] is Tsallis q-Gaussian distribution [21]. To best of author's knowledge to earlier investigation on self-focusing of rippled laser beams in plasmas has been reported for q-Gaussian laser beams. Thus, the aim of this paper is to give first theoretical investigation on self-focusing of rippled q-Gaussian laser beams in plasmas with relativistic optical nonlinearity.

Relativistic nonlinearity of plasma

Consider the propagation of a laser beam with angular frequency ω_0 and wave number k_0 through a plasma with equilibrium electron density n_0. The dielectric function of such a plasma can be written as

$$\epsilon = 1 - \frac{\omega_p^2}{\omega_0^2}$$

where

$$\omega_p^2 = \frac{4\pi e^2}{m_e} n_0 \tag{1}$$

is the equilibrium plasma frequency, (m_e, e) being the electronic mass and charge, respectively.

The laser beam is having sharp intensity ripples over its cross section. The electric filed vector of such a laser beam can be written as

$$\boldsymbol{E} = (A_0 + A_r) e^{\imath(k_0 z - \omega_0 t)} \boldsymbol{e_x} \tag{2}$$

where A_0 is the amplitude of the field of main beam, and A_r is that of intensity ripple. Under the intense field of the laser beam, the oscillations of the plasma electrons become relativistic, and the mass m_e of the electron in Eq. (1) needs to be replaced by $m_0\gamma$, where m_0 is the rest mass of electron, and γ is the relativistic Lorentz factor and is related to laser field amplitude as [22]

$$\gamma = \sqrt{1 + \beta E E^{\star}} \tag{3}$$

where $\beta = \frac{e^2}{m_0^2 \omega_0^2 c^2}$ is the coefficient of relativistic nonlinearity and

$$EE^{\star} = A_0 A_0^{\star} + A_r A_r^{\star} + 2A_0 A_r \cos(\theta_p) \tag{4}$$

θ_p being the phase difference between the fields of main beam and intensity ripple.

Thus, in the presence of laser beam, the dielectric function of plasma gets modified as

Principal
Dyal Singh College
KARNAL

$$\epsilon = 1 - \frac{\omega_{p0}^2}{\omega_0^2}\left(1 + \beta A_0 A_0^\star\right)^{-\frac{1}{2}} \tag{5}$$

where

$$\omega_{p0}^2 = \frac{4\pi e^2}{m_0} n_0$$

is the equilibrium plasma frequency. Thus, the relativistic effects make the index of refraction of plasma intensity dependent which, in turn, due to the spatial dependence of the amplitude structure of the laser beam, resembles to that of graded index fiber. Separating the dielectric function of plasma into linear (ϵ_0) and nonlinear (ϕ) parts as

$$\epsilon = \epsilon_0 + \phi\left(EE^\star\right) \tag{6}$$

we get

$$\epsilon_0 = 1 - \frac{\omega_{p0}^2}{\omega_0^2} \tag{7}$$

and

$$\phi\left(EE^\star\right) = \frac{\omega_{p0}^2}{\omega_0^2}\left\{1 - \frac{1}{(1+\beta EE^\star)^{\frac{1}{2}}}\right\} \tag{8}$$

Evolution of beam widths of laser beam

The wave equation governing the evolution of amplitude A of the main beam is

$$\iota\frac{\partial A_0}{\partial z} = \frac{1}{2k_0}\nabla_\perp^2 A_0 + \frac{k_0}{2\epsilon_0}\phi\left(A_0 A_0^\star\right)A_0 \tag{9}$$

Being nonlinear in nature, linear combination of two solutions is not a solution of this equation. In other words, superposition principle does not apply to Eq. (9). Due to the non-applicability of superposition principle, Eq. (9) does not possess any closed form analytical solution. The only way to get physical insight is to use numerical methods or semi-analytical methods. In the present investigation, we have used a semi-analytical technique known as variational method [23–27] to obtain the solution of Eq. (9). This method converts the problem of solving a partial differential equation to that of solving a set of coupled ordinary differential equations. These ordinary differential equations govern the evolution of the various parameters of interest. In case of self-focusing of laser beam, the parameter of interest is the beam width of the laser beam. According to this method, Eq. (9) is a variational problem for action principle based on Lagrangian density

$$\begin{aligned}\mathcal{L}_M =& \iota\left(A_0\frac{\partial A_0^\star}{\partial z} - A_0^\star\frac{\partial A_0}{\partial z}\right) + \left|\nabla_\perp A_0\right|^2 \\ &- \frac{\omega_{p0}^2}{c^2}\int^{A_0A_0^\star}\left\{1 - \frac{1}{\left(1+\beta AA_0^\star\right)^{\frac{1}{2}}}\right\}d\left(A_0A_0^\star\right)\end{aligned} \tag{10}$$

In the present investigation, we have considered the trial function of the form

$$A_0(x,y,z) = \frac{E_{00}}{f}\left\{1 + \frac{r^2}{qr_0^2f^2}\right\}^{-\frac{q}{2}} \tag{11}$$

Here E_{00} is the axial amplitude of the field of the laser beam, and r_0 is the initial beam width of the main laser beam. The phenomenological parameter q is related to the deviation of amplitude structure from ideal Gaussian profile and is termed as deviation parameter. The value of deviation parameter q varies from laser to laser and can be obtained by fitting into the experimental data for a given laser system. f is the currently undetermined, real function of longitudinal coordinate z. Upon multiplication with r_0, it gives the instantaneous spot size of the laser beam. Thus, the function f is termed as dimensionless beam width parameter.

Substituting the trial function given by Eq. (11) in Lagrangian density and integrating over the entire cross section of the laser beam, we get the reduced Lagrangian as $L_M = \int \mathcal{L}_M d^2r$. The corresponding Euler–Lagrange equation

$$\frac{\mathrm{d}}{\mathrm{d}z}\left(\frac{\partial L_M}{\partial\left(\frac{\partial f}{\partial z}\right)}\right) - \frac{\partial L_M}{\partial f} = 0 \tag{12}$$

gives

$$\begin{aligned}\frac{\mathrm{d}^2 f}{\mathrm{d}z^2} =& \frac{1}{2\mathrm{k}_0^2\mathrm{r}_0^4}\frac{1}{f^3}\left(1-\frac{1}{\mathrm{q}}\right)\left(1-\frac{2}{\mathrm{q}}\right) \\ &\left[\left(1+\frac{1}{\mathrm{q}}\right)^{-1} + \left(<\mathrm{L}_1> \frac{<L_1>}{E_{00}^2}f^2 + 2\frac{\mathrm{E}_{00}^2}{f^3}\frac{\partial <\mathrm{L}_1>}{\partial f}\right)\right]\end{aligned} \tag{13}$$

where

Principal
Dyal Singh College
KARNAL

$$< L_1 \geq \frac{\omega_{p0}^2}{c^2} \int \left(\int_0^{A_0 A_0^\star} \left\{ 1 - \frac{1}{\left(1 + \frac{\beta E_{00}^2}{f^2}\left(1 + \frac{r^2}{q r_0^2 f^2}\right)^{-q}\right)^{\frac{1}{2}}} \right\} \mathrm{d}\left(A_0 A_0^\star\right) \right) \mathrm{d}^2 r$$

Equation (13) can be written as

$$\frac{d^2 f}{d\xi^2} = \frac{\left(1 - \frac{1}{q}\right)\left(1 - \frac{2}{q}\right)}{\left(1 + \frac{1}{q}\right)} \frac{1}{f^3} - \left(1 - \frac{1}{q}\right)\left(1 - \frac{2}{q}\right)\left(\frac{\omega_{p0}^2 r_0^2}{c^2}\right)\frac{\beta E_{00}^2}{f^3} I \tag{14}$$

where

$$I = \int_0^\infty u^3 \left(1 + \frac{u^2}{q}\right)^{-2q-1} \left(1 + \frac{\beta E_{00}^2}{f^2}\left(1 + \frac{u^2}{q}\right)^{-q}\right)^{-\frac{3}{2}} du$$

$$\mathrm{d}\prime = \mathrm{d}k_0 r_0^2$$

$$\xi = \frac{z}{k_0 r_0^2}$$

Equation (14) is the differential equation governing the evolution of beam width of the q-Gaussian laser beam during its journey through the plasma. The first terms on the right hand side of this equation correspond to the linear propagation of the laser beam, i.e., its propagation through vacuum or through the media whose index of refraction is independent of the intensity of the laser beam. The second terms on the R.H.S of this equation correspond to the nonlinear response of the medium.

Evolution of beam width of intensity ripple

Wave equation for the intensity ripple over the cross section for the laser beam is given by

$$\iota \frac{\partial A_r}{\partial z} = \frac{1}{2k_0}\nabla_\perp^2 A_r + \frac{k_0}{2\epsilon_0}\phi\left(EE^\star\right)A_r + \frac{k_0}{2\epsilon_0}\left[\phi\left(EE^\star\right) - \phi\left(A_0 A_0^\star\right)\right]A_0 \tag{15}$$

The Lagrangian density corresponding to this equation can be written as

$$\mathcal{L}_M = \iota\left(A_r \frac{\partial A_r^\star}{\partial z} - A_r^\star \frac{\partial A_r}{\partial z}\right) + \left|\nabla_\perp A_r\right|^2 - \frac{\omega_{p0}^2}{c^2}\int^{A_r A_r^\star} \left\{1 - \frac{1}{(1 + \beta EE^\star)^{\frac{1}{2}}}\right\} d\left(A_r A_r^\star\right) - \frac{\omega_{p0}^2}{c^2}\int^{A_0 A_0^\star} \left(\left\{1 - \frac{1}{(1 + \beta EE^\star)^{\frac{1}{2}}}\right\} - \left\{1 - \frac{1}{\left(1 + \beta A_0 A_0^\star\right)^{\frac{1}{2}}}\right\}\right) d\left(A_0 A_0^\star\right) \tag{16}$$

In the present investigation, we have assumed Gaussian irradiance profile of the intensity ripple riding over the cross section of the laser beam. Such an intensity ripple can be modeled as

$$E_r E_r^\star = \frac{E_{r00}^2}{g^2} e^{-\left(\frac{r^2}{r_r^2 g^2}\right)} \left(\frac{r}{r_r g}\right)^{2n} \tag{17}$$

Here r_r is the initial width of the ripple, *andg* is the dimensionless beam width parameter of the ripple. The constant n gives the position of intensity ripple from the axis of the main beam. As the value of n increases, the intensity ripple shifts away from the beam axis.

Using the same procedure as that of Sect. "Relativistic nonlinearity of plasma", we get the following equation for the evolution of beam width of the intensity ripple

$$\begin{aligned} \frac{d^2 g}{d\xi^2} = {} & \left(\frac{r_0}{r_r}\right)^4 \frac{1}{(n+1)g^3} - \left(\frac{\omega_{p0} r_0}{c}\right)^2 \left(\frac{r_0}{r_r}\right)^4 \\ & \frac{1}{g\Gamma(n+1)}\left(2\beta E_{00}^2 \left(\frac{r_0}{r_r}\right)^{2n}\left(\frac{f}{g}\right)^{2n+2} R_1 \right. \\ & + \beta E_{00} E_{r00}\left(\frac{r_0}{r_r}\right)^n \left(\frac{f}{g}\right)^{n+1} \cos\theta_p R_2 \\ & \left. - \beta E_{00} E_{r00}\left(\frac{r_0}{r_r}\right)^n \left(\frac{f}{g}\right)^{n+1} \cos\theta_p R_3 \right) \end{aligned} \tag{18}$$

where

Principal
Dyal Singh College
KARNAL

$$R_1 = \int_0^\infty u^{2n+1} G(E_{00}, E_{r00}) e^{-\frac{1}{2}\left(\frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2} \left[n + 1 - \frac{r_0^2 f^2}{r_r^2 g^2} u^2\right] \mathrm{d}u \qquad G(E_{00}, E_{r00}) = \left[1 - \frac{1}{(1 + X(f,g))^{\frac{1}{2}}}\right]$$

$$R_2 = \int_0^\infty u^{n+1} G(E_{00}, E_{r00}) e^{-\frac{1}{2}\left(\frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2} \left(1 + \frac{u^2}{q}\right)^{-\frac{q}{2}} \left[n + 2 - \left(1 + \frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2\right] \mathrm{d}u$$

$$X(f,g) = \frac{\beta E_{00}^2}{f^2}\left(1 + \frac{u^2}{q}\right)^{-q} + \frac{\beta E_{r00}^2}{g^2}\left(\frac{r_0 f}{r_r g}\right)^{2n} u^{2n} e^{-\left(\frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2} + 2\frac{\beta E_{00} E_{r00}}{fg}\cos\theta_p \left(\frac{r_0 f}{r_r g}\right)^n u^n e^{-\frac{1}{2}\left(\frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2} \left(1 + \frac{u^2}{q}\right)^{-\frac{q}{2}}$$

$$R_3 = \int_0^\infty u^{n+1} e^{-\frac{1}{2}\left(\frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2} \left(1 + \frac{u^2}{q}\right)^{-\frac{q}{2}} \left[1 - \frac{1}{\left(1 + \frac{\beta E_{00}^2}{f^2}\left(1 + \frac{u^2}{q}\right)\right)^{\frac{1}{2}}}\right] \left[n + 2 - \left(1 + \frac{r_0^2 f^2}{r_r^2 g^2}\right)u^2\right] \mathrm{d}u$$

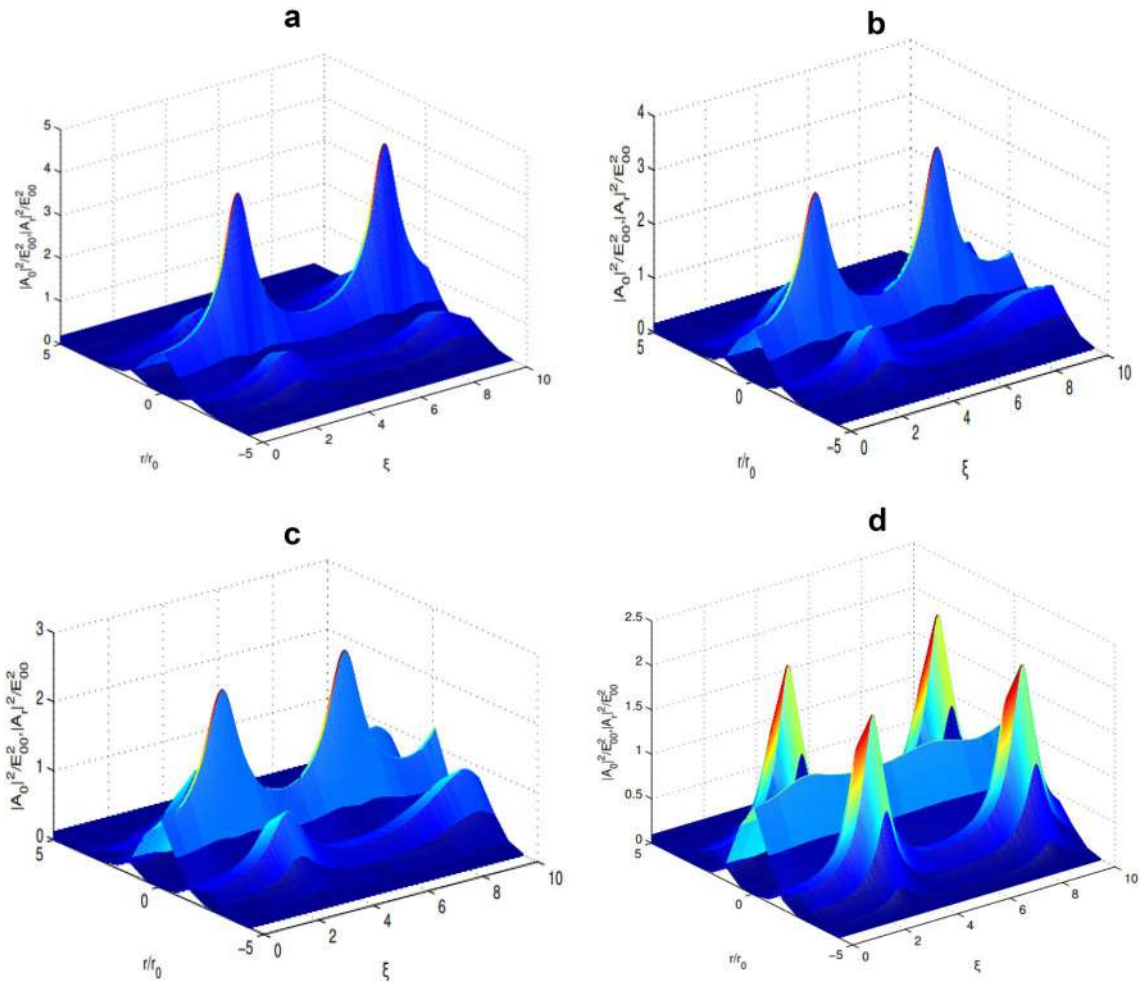


Fig. 3 Evolution of intensities of laser beam and ripple with distance of propagation for $q = (3, 4, 5, \infty)$, $\beta E_{00}^2 = 2$, $\beta E_{r00}^2 = 0.15$, $\frac{\omega_{p0}^2 r_0^2}{c^2} = 6$ and $n = 1$

Principal
Dyal Singh College
KARNAL

Equation 18 governs the evolution of beam width of intensity ripple with distance of propagation, during the propagation of laser beam through plasma. It can be seen that the behavior of beam width of the intensity ripple is highly dependent on the propagation characteristics of the main beam. This is due to the fact that due to the laser-induced relativistic nonlinearity in the optical properties of plasma, the intensity ripple gets coupled to the main beam and is thus, strongly influenced by it. But as the overall power of ripple is quite less than that of main beam, it cannot affect the propagation of main beam but the main beam affects the propagation characteristics of the ripple.

Results and discussion

In the present investigation, Eqs. (14) and (18) have been solved numerically for following set of laser plasma parameters:

$$\omega_0 = 1.78 \times 10^{15} \frac{\text{rad}}{\text{sec}}, r_0 = 10\,\mu m, \frac{r_r}{r_0} = 0.1, \theta_p = \frac{\pi}{6}$$

and

$$q = (3, 4, 5, \infty),$$
$$\beta E_{00}^2 = (1, 1.5, 2, 2.5),$$
$$\frac{\omega_{p0}^2 r_0^2}{c^2} = (6, 9, 12, 15),$$
$$\beta E_{r00}^2 = (0.15, 0.20, 0.25, 0.30),$$
$$n = (0, 1, 2, 3)$$

Under the boundary condition that at the plane of incidence, the laser beam is collimated, i.e., it is having plane wave front. Mathematically, this condition can be expressed as

$$\frac{\mathrm{d}f}{\mathrm{d}\xi}|_{\xi=0} = \frac{\mathrm{d}g}{\mathrm{d}\xi}|_{\xi=0} = 0; f(\xi = 0) = g(\xi = 0) = 1$$

Figure 3 illustrates the effect of deviation parameter q of the main laser beam on evolution of normalized intensities of the main laser beam and that of ripple during the propagation of laser beam through the plasma. Here, the central lobes represents the intensity of the main beam, and the surrounding lobes represent that of ripple riding over the cross section of main beam. It can be seen that intensities of the main beam as well as that of ripple evolve in an oscillatory manner during the propagation of the laser beam through the plasma. These oscillations in their intensities are due to their periodic focusing/defocusing arising as a consequence of saturation nature of relativistic nonlinearity. Initially due to laser-induced relativistic nonlinearity, the beam widths of the laser beam and that of ripple start decreasing and hence their intensities start increasing that further enhances the relativistic nonlinearity. When the intensities of the laser beam and ripple becomes too high, the mass of plasma electrons in the illuminated portion of plasma gets saturated. Hence, now the laser beam propagates as if it is propagating through vacuum. Hence, after attaining minimum possible beam widths, the spot size of the main beam and that of ripple bounces back. These processes keep on repeating themselves giving an oscillatory behavior to the intensities of the laser beam and that of ripple.

The plots in Fig. 3 indicate that with increase in the value of deviation parameter q of the main laser beam, there is decrease in the extent of self-focusing of the main laser beam but along with that there is increase in the extent of self-focusing of ripple. This is due to the fact that most of the energy of laser beams with larger value of q is concentrated around a narrow region around the beam axis. Hence, off-axial rays of these beams give a little contribution to the optical nonlinearity of plasma. As the self-focusing of the laser beam is a consequence of the optical nonlinearity of plasma, increase in deviation parameter q reduces the extent of self-focusing of the main beam. The increase in the extent of self-focusing of ripple with increase in the deviation parameter q of the main beam is due to the fact that as the value of deviation parameter q increases, the intensity of the main beam converges toward the beam axis that makes the axial part of the ripple stronger. Thus, increase in deviation parameter q of the main laser beam leads to the enhancement of self-focusing of the ripple.

The plots in Fig. 4 illustrate the effect of intensity of the main beam on evolution of the intensities of main beam and that of ripple during the propagation of the laser beam through plasma. It can be seen that with increase in the intensity of main beam, the extent of self-focusing of laser beam as well as that of ripple gets increased. This is due to the fact that increase in intensity of main beam enhances the relativistic nonlinearity of plasma that, in turn, results in deeper focusing of laser beam and ripple riding over its cross section.

The plots in Fig. 5 depict the effect of plasma density on the self-focusing of main beam and intensity ripple. It can be seen that the effect of increase in plasma density is to increase the extent of self-focusing of laser beam as well as of intensity ripple. The underlying physics behind this effect is that increase in plasma density means increase in number of electrons contributing to the relativistic nonlinearity of plasma. Thus, increase in plasma density enhances the self-focusing of main beam and that of ripple.

Figure 6 illustrates the effect of initial intensity of laser ripple on self-focusing of both the ripple and laser beam. It

Principal
Dyal Singh College
KARNAL

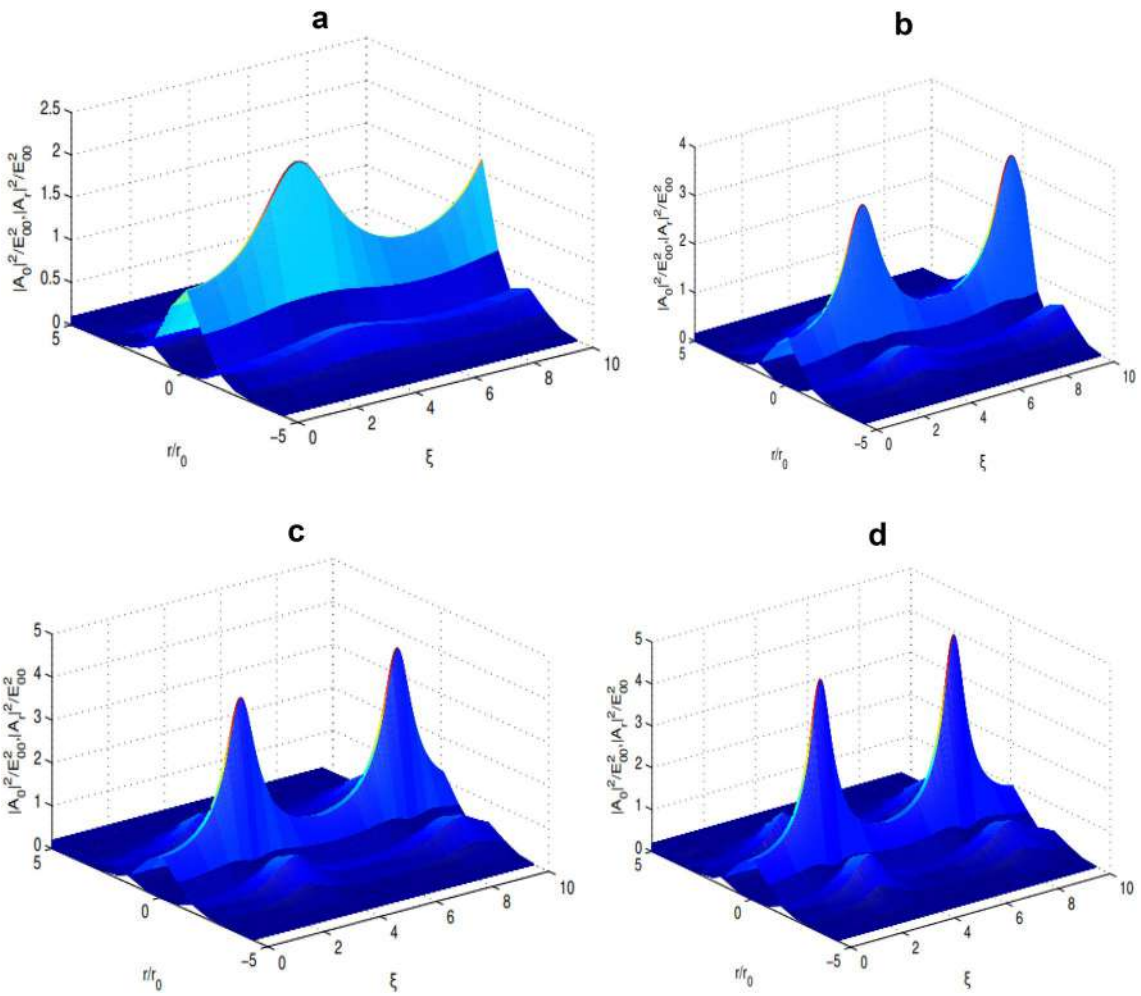


Fig. 4 Evolution of intensities of laser beam and ripple with distance of propagation for $q = 3$, $\beta E_{00}^2 = (1, 1.5, 2, 2.5)$, $\beta E_{r00}^2 = 0.15$, $\frac{\omega_{p0}^2 r_0^2}{c^2} = 6$ and $n = 1$

can be seen that with increase in initial intensity of the ripple, the extent of self-focusing of ripple increases, but there is no extent on self-focusing of main beam. The underlying physics behind this fact is that ripples with higher initial intensity produce more relativistic nonlinearity in the optical properties of plasmas, and thus, they get focused more. But, overall being very much weaker than the main beam, the propagation characteristics of ripple do not affect that of main beam, i.e., main beam can influence the intensity ripple due to its nonlinear coupling with the ripple, but being very much stronger than ripple main beam is not influenced by the ripple. Thus, increase in initial intensity of ripple has no effect on the self-focusing of the main beam.

Figure 7 depicts the effect of position of intensity ripple from the beam axis on extent of self-focusing of main beam and that of ripple. It can be seen that as the ripple shifts away from the beam axis, extent of its self-focusing increases; however, there is no effect on self-focusing of the main beam. This is due to the fact that as the position of peak intensity of ripple shifts away from the beam axis, the intensity gradient between the beam axis and position of intensity maximum of the ripple increases. This forms graded index fiber kind of structure into the plasma for the propagation of ripple. Due to the formation of this plasma channel, the extent of self-focusing of ripple increases, as the ripple shifts away from beam axis.

Principal
Dyal Singh College
KARNAL

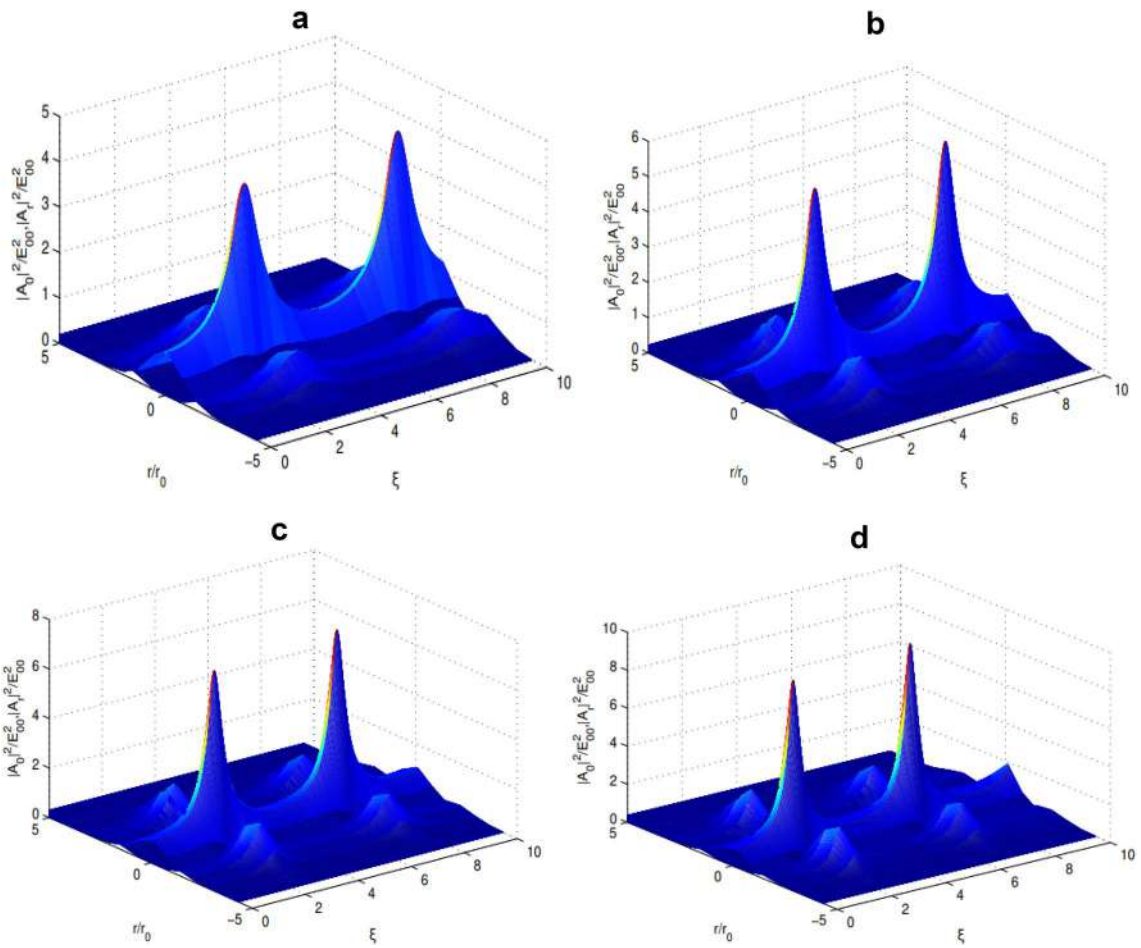


Fig. 5 Evolution of intensities of laser beam and ripple with distance of propagation for $q = 3$, $\beta E_{00}^2 = 2$, $\beta E_{r00}^2 = 0.15$, $\frac{\omega_{p0}^2 r_0^2}{c^2} = (6, 9, 12, 15)$ and $n = 1$

Conclusions

In conclusion, we have investigated the dynamics of rippled q-Gaussian laser beam propagating through under dense plasma. Effect of self-focusing of the main beam on the growth of intensity ripple riding over the cross section of the laser beam has been investigated in detail. It has been observed that the growth of intensity ripple is significantly affected by the irradiance profile of the laser beam. As the irradiance over the cross section of the main beam converges toward ideal Gaussian profile, the extent of its self-focusing gets reduced but the intensity ripple gets amplified. Hence, it can be concluded that ideal Gaussian laser beams are less suitable for ICF as they possess lesser focusing behavior as well as they amplify any perturbation in their irradiance profile. Thus, these beams will enhance the Rayleigh–Taylor instabilities during ICF.

Principal
Dyal Singh College
KARNAL

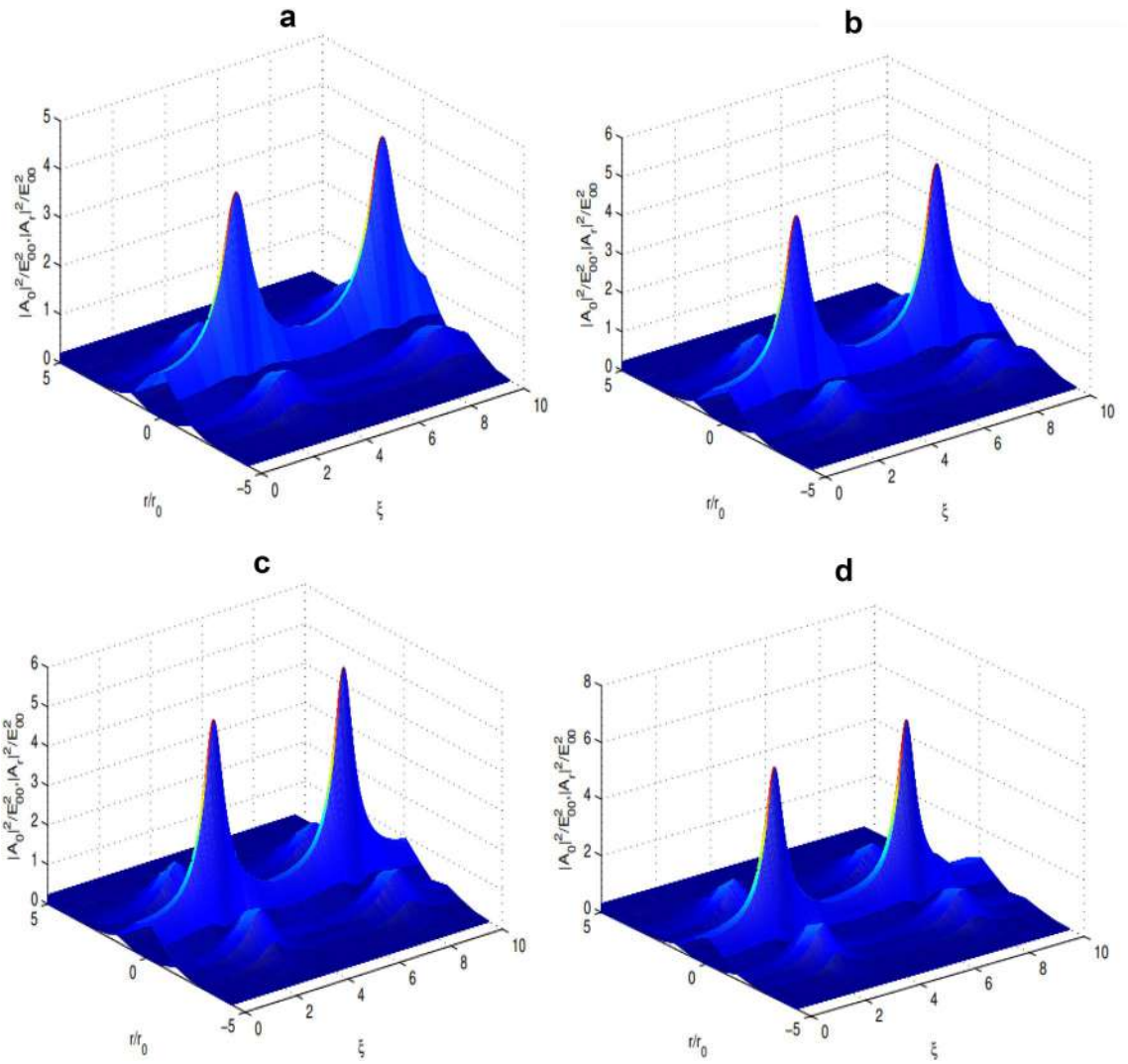


Fig. 6 Evolution of intensities of laser beam and ripple with distance of propagation for $q = 3$, $\beta E_{00}^2 = 2$, $\beta E_{r00}^2 = (0.15, 0.20, 0.25, 0.30)$, $\frac{\omega_{p0}^2 r_0^2}{c^2} = 6$ and $n = 1$

Principal
Dyal Singh College
KARNAL

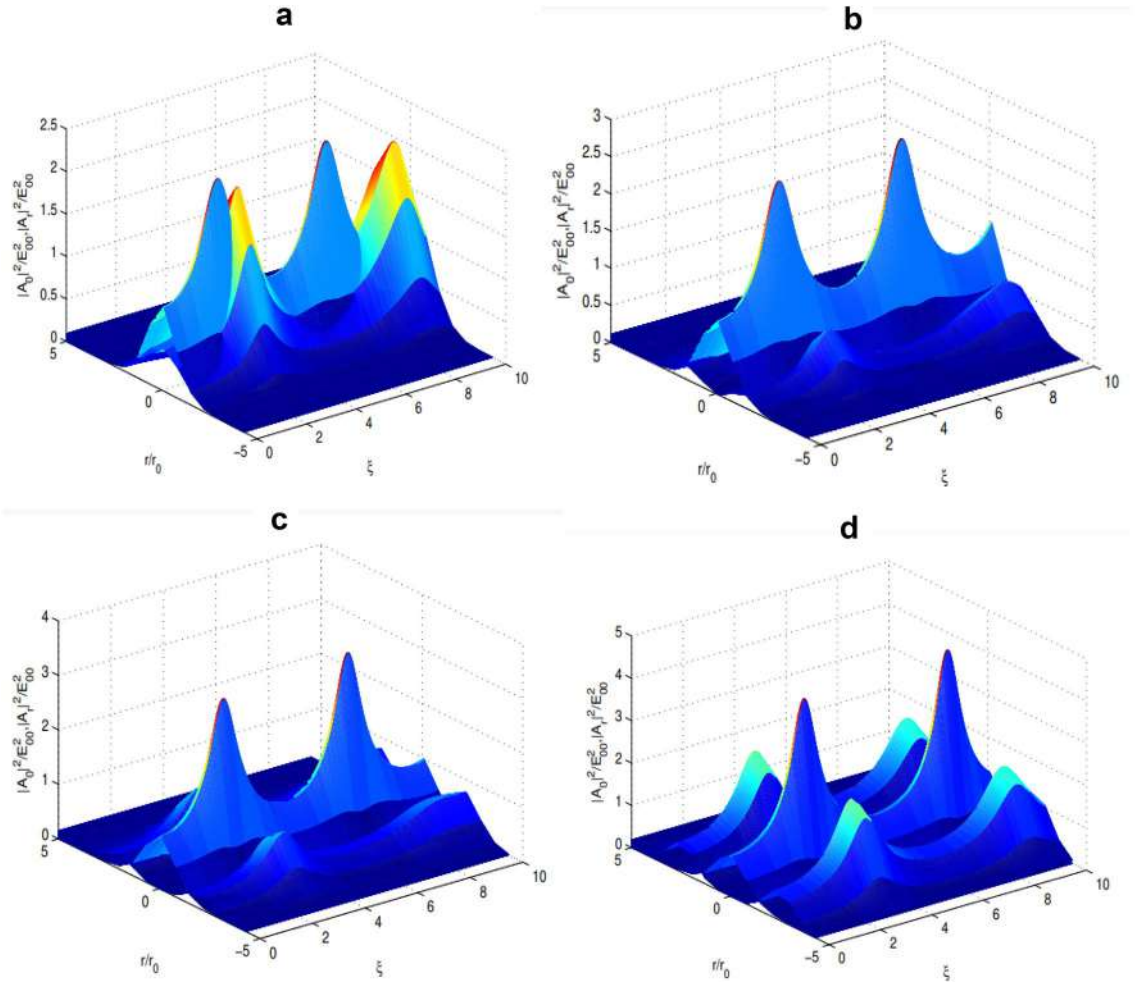


Fig.7 Evolution of intensities of laser beam and ripple with distance of propagation for $q = 3$, $\beta E_{00}^2 = 2$, $\beta E_{r00}^2 = 0.15$, $\frac{\omega_{p0}^2 r_0^2}{c^2} = 6$ and $n = (0, 1, 2, 3)$

Data availability The data that support the findings of this study are available within the article.

References

1. R.S. Craxton, K.S. Anderson, T.R. Boehly, V.N. Goncharov, D.R. Harding, J.P. Knauer, R.L. McCrory, P.W. McKenty, D.D. Meyerhofer, J.F. Myatt, A.J. Schmitt, J.D. Sethian, R.W. Short, S. Skupsky, W. Theobald, W.L. Kruer, K. Tanaka, R. Betti, T.J.B. Collins, J.A. Delettrez, S.X. Hu, J.A. Marozas, A.V. Maximov, D.T. Michel, P.B. Radha, S.P. Regan, T.C. Sangster, W. Seka, A.A. Solodov, J.M. Soures, C. Stoeckl, J.D. Zuegel, Direct-drive inertial confinement fusion: a review. Phys. Plasmas **22**, 110501 (2015)
2. M. Tabak, J. Hammer, M.E. Glinsky, W.L. Kruer, S.C. Wilks, J. Woodworth, E.M. Campbell, M.D. Perry, Ignition and high gain with ultrapowerful lasers. Phys. Plasmas **1**, 1626 (1994)
3. N. Gupta, Hot electron generation by self focused quadruple gaussian laser beams during inertial confinement fusion. Nonlinear Optics, Quantum Optics **55**, 63 (2022)
4. J.R. Freeman, M.J. Clauser, S.L. Thompson, Rayleigh-Taylor instabilities in inertial-confinement fusion targets. Nucl. Fusion **17**, 223 (1977)
5. J.D. Kilkenny, S.G. Glendinning, S.W. Haan, B.A. Hammel, J.D. Lindl, D. Munro, B.A. Remington, S.V. Weber, J.P. Knauer, C.P. Verdon, A review of the ablative stabilization of the Rayleigh-Taylor instability in regimes relevant to inertial confinement fusion. Phys. Plasmas **1**, 1379 (1994)
6. J. Sanz, Self-consistent analytical model of the Rayleigh-Taylor instability in inertial confinement fusion. Phys. Rev. Lett. **73**, 2700 (1994)
7. L. Videau, C. Rouyer, J. Garnier, A. Migus, Motion of hot spots in smoothed beams. J. Opt. Soc. Am. A **16**, 1672 (1999)
8. R. Kumar, K. Singh, T. Singh, Growth and stabilization of a laser ripple on laser beam in a collisionless unmagnetized plasma. Il Nuovo Cimento D **12**, 323 (1990)
9. N. Gupta, S. Kumar, Self-action effects of quadruple-Gaussian laser beams in collisional plasmas and their resemblance to Kepler's central force problem. Pramana **95**, 53 (2021)

Principal
Dyal Singh College
KARNAL

10. N. Gupta, S. Kumar, S. Chaudhry, S.B. Bhardwaj, S. Kumar, Potential well dynamics of self focusing of quadruple gaussian laser beams in thermal quantum plasma. Nonlinear Optics Quantum Optics **55**, 281 (2022)
11. A. Singh, N. Gupta, Second harmonic generation of self-focused Cosh-Gaussian laser beam in collisional plasma. Optik **127**, 5452 (2016)
12. A. Singh, N. Gupta, Beat wave excitation of electron plasma wave by relativistic cross focusing of cosh-Gaussian laser beams in plasma. Phys. Plasmas **22**, 062115 (2015)
13. G. Purohit, P.K. Chuhan, R.P. Sharma, H.D. Pandey, Effect of relativistic mutual interaction of two laser beams on the growth of laser ripple in plasma. Laser Part. Beams **23**, 69 (2005)
14. R. Gauniyal, P. Chauhan, P. Rawat, G. Purohit, Effect of self-focused rippled laser beam on the excitation of ion acoustic wave in relativistic ponderomotive regime. Laser Part. Beams **32**, 557 (2014)
15. M. Moshkelgosha, The effects of ripple characteristics on the simultaneous relativistic-ponderomotive self-focusing. Acta Phys. Pol. A **136**, 957 (2019)
16. M.S. Sodha, A. Sharma, G. Prakash, M.P. Verma, Growth of a ring ripple on a Gaussian beam in a plasma. Phys. Plasmas **11**, 3023 (2004)
17. S. Misra, S.K. Mishra, On focusing of a ring ripple on a Gaussian electromagnetic beam in a plasma. Phys. Plasmas **15**, 092307 (2008)
18. G. Purohit, P. Rawat, P. Chauhan, S.T. Mahmoud, Higher-order paraxial theory of the propagation of ring rippled laser beam in plasma: Relativistic ponderomotive regime. Phys. Plasmas **22**, 052116 (2015)
19. P.K. Patel, M.H. Key, A.J. Mackinnon, R. Berry, M. Borghesi, D.M. Chambers, H. Chen, R. Clarke, C. Damian, R. Eagleton, R. Freeman, S. Glenzer, G. Gregori, R. Heathcote, D. Hey, N. Izumi, S. Kar, J. King, A. Nikroo, A. Niles, H.S. Park, J. Pasley, N. Patel, R. Shepherd, R.A. Snavely, D. Steinman, C. Stoeckl, M. Storm, W. Theobald, R. Town, R. Van Maren, S.C. Wilks, B. Zhang, Integrated laser-target interaction experiments on the RAL petawatt laser. Plasma Phys. Controll. Fusion **47**, B833 (2005)
20. M. Nakatsutsumi, J.R. Davies, R. Kodama, J.S. Green, K.L. Lancaster, K.U. Akli, F.N. Beg, S.N. Chen, D. Clark, R.R. Freeman, C.D. Gregory, H. Habara, R. Heathcote, D.S. Hey, K. Highbarger, P. Jaanimagi, M.H. Key, K. Krushelnick, T. Ma, A. MacPhee, A.J. MacKinnon, H. Nakamura, R.B. Stephens, M. Storm, M. Tampo, W. Theobald, L. Van Woerkom, R.L. Weber, M.S. Wei, N.C. Woolsey, P.A. Norreys, Space and time resolved measurements of the heating of solids to ten million kelvin by a petawatt laser. New J. Phys. **10**, 043046 (2008)
21. C. Tsallis, Nonadditive entropy and nonextensive statistical mechanics-an overview after 20 years. Braz. J. Phys. **39**, 337 (2009)
22. A.I. Akhiezer, R.V. Polovin, Theory of wave motion of an electron plasma. Sov. Phys. JETP **3**, 696 (1956)
23. D. Anderson, M. Bonnedal, M. Lisak, Nonlinear propagation of elliptically shaped Gaussian laser beams. J. Plasma Phys. **23**, 115 (1980)
24. D. Anderson, M. Bonnedal, Variational approach to nonlinear self-focusing of Gaussian laser beams. Phys. Fluids **22**, 105 (1979)
25. S. Wang, Novel soliton solution of (3+1)-dimensional perturbed Burgers equation. Phys. A **622**, 128808 (2023)
26. S. Wang, Novel complex *N*-soliton and lump solutions for nonlocal breaking equation. Results Phys. **40**, 105839 (2022)
27. S. Wang, Novel multi-soliton solutions in (2+1)-dimensional PT-symmetric couplers with varying coefficients. Optik **252**, 168495 (2022)

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

Principal
Dyal Singh College
KARNAL

J Opt
https://doi.org/10.1007/s12596-024-01700-9

RESEARCH ARTICLE

Effect of self-focusing of bessel gauss laser beam on excitation of electron plasma wave in collisionless plasma with axial density ramp

Naveen Gupta[1] · Alex A K[1] · Rudra Partap[1] · Rohit Johari[1] · Devinder Singh[2]

Received: 11 January 2024 / Accepted: 25 January 2024
© The Author(s), under exclusive licence to The Optical Society of India 2024

Abstract A theoretical investigation has been conducted to analyze the dynamics of electron plasma waves (EPWs) induced by Bessel–Gauss laser beams in plasmas featuring an axial density ramp. The study involves evaluating how the self-focusing of the laser beam influences the power of the laser-excited EPWs. As the laser beam traverses the plasma, it triggers the generation of an EPW at the frequency ω_{ep}. This EPW, affected by the optical nonlinearity of the plasma, becomes nonlinearly coupled to the laser beam due to the ponderomotive nonlinearity of plasma electrons. Employing variational theory, semi-analytical solutions for the coupled nonlinear wave equations governing the pump wave and EPW have been obtained using the W.K.B approximation technique. The findings highlight a significant impact of the self-focusing effect of the pump beam on the power of the EPW.

Keywords Bessel–Gauss · Plasma waves · Variational theory · Self-focusing · Clean energy

Introduction

Plasma is a collection of charged particles, comprising both positive and negative ions, characterized by their high energy levels that resist easy combination. This state of matter is pervasive throughout the universe [1]. It appears as extremely hot, high-pressure gas in celestial bodies like the sun and stars, as well as in the rarefied gas present in interstellar space and the ionospheric envelope surrounding the Earth. On a more local scale, plasmas are evident in the intense reactions of burning fuel and in gas-discharge devices like neon signs. Physicists have extensively studied the various physical effects exhibited by plasmas over the course of approximately two centuries. Earlier investigations, especially those focusing on gas discharges, played a crucial role in uncovering the nature of electrons and providing insights into atomic structure [2].

The current emphasis on plasmas can be ascribed to two primary factors. Firstly, there is a technological motivation, placing importance on comprehending plasma behavior for the controlled release of thermonuclear energy [3–6]. This involves endeavors to reproduce, within artificially created plasmas, the nuclear reactions observed in the sun. Another technological goal is the advancement of magneto-hydrodynamic generators [7], wherein electric power is generated through the interaction of gas plasma jets with magnetic fields. The second overarching rationale for investigating plasmas is their significance in space and astrophysics. When a plasma is influenced by electromagnetic fields, the motion of its particles becomes non-random. A noteworthy outcome of this imposed order is that plasmas can propagate specific types of waves that share connections with electromagnetic waves but possess distinct and intriguing properties. These waves include high-frequency electron plasma waves [8, 9] (EPWs) and low-frequency ones referred to as ion acoustic waves [10, 11] (IAWs).

The electron plasma wave (EPW) excited through stimulated Raman scattering (SRS) displays an exceptionally high phase velocity, potentially leading to the generation of superthermal electrons in inertial confinement fusion (ICF). These penetrating electrons have the capacity to induce preheating of the fuel, thereby impeding the efficient compression required for achieving high gain [12]. As

✉ Naveen Gupta
naveens222@rediffmail.com

[1] Lovely Professional University, Phagwara, India

[2] Dyal Singh College, Karnal, India

Published online: 13 March 2024

Principal
Dyal Singh College
KARNAL

a superthermal electron escapes from the pellet, it imparts a net positive charge to the pellet. This positive charge attracts the outward-moving superthermal electron back toward the pellet, causing them to overshoot their original position and penetrate into the pellet core. Some of the most energetic electrons may undergo multiple oscillations through the pellet before collisions with the fuel ultimately decelerate them. The transfer of collisional energy to the fuel results in the preheating of the pellet, a phenomenon referred to as preheating [13]. Electron plasma waves are also implicated in various plasma instabilities, such as the Rayleigh–Taylor instability, which can impact the implosion dynamics. Managing these instabilities is crucial for achieving a symmetric and efficient compression of the fuel.

The electrostatic force of attraction between supra-thermal electrons and ions in the corona can induce outward acceleration of highly energetic ions. This acceleration causes the loss of energetic ions from the ablation layer, depleting laser energy that would otherwise contribute to driving the implosion process. Furthermore, superthermal electrons may have such an extensive range that collisions with "colder" electrons become less frequent. This decrease in collision rates reduces the heat transfer between the atmosphere and the pellet, leading to an insufficient implosion. This phenomenon is known as decoupling [14].

Observing electron plasma waves serves as a valuable diagnostic tool for assessing the condition of the compressed plasma. Alterations in the features of these waves, such as frequency shifts or damping, provide valuable insights into the temperature, density, and other properties of the compressed fuel. This information facilitates real-time adjustments to optimize fusion conditions.

Laser beams with varying irradiance across their cross-sections display distinct behaviors in plasmas [15]. However, a survey of the existing literature indicates that the majority of previous studies on nonlinear laser-plasma interactions have concentrated on laser beams featuring either an ideal Gaussian irradiance profile or a profile closely resembling Gaussian, such as q-Gaussian [16, 17]. There have been limited investigations into alternative beam profiles, including cosh-Gaussian [18], quadruple-Gaussian, or super-Gaussian laser beams. Notably, a recent category of laser beams known as Bessel–Gaussian laser beams has attracted the attention of researchers in the laser-plasma interactions field due to their non-diffracting characteristics.

Within the realm of optics, a quasi-monochromatic beam traversing a medium with a refractive index n along a given direction z can be understood as a composition of plane waves. Although all these plane waves share a common wave number $k = (\frac{n\omega_0}{c})$, they differ in angles relative to the direction of propagation. Consequently, each component travels at a distinct phase velocity concerning the direction of propagation. Consequently, each plane wave component accrues a unique phase, leading to the widening of the beam during its propagation. In general, the narrower the initial beam, the more pronounced the divergence. Therefore, the more one strives to tightly focus an optical beam, the quicker it will expand. This diffraction-induced broadening of optical beams presents a significant challenge in applications where laser intensity is a critical parameter of concern.

In recent years, there has been a notable focus on laser beams that can overcome diffraction, maintaining their intensity profile during propagation. An example of this is the Bessel beam [19]. The intensity profile of Bessel beams remains constant in free space because their plane wave components do not experience significant phase deviations in the propagation direction, as observed in regular beams like Gaussian beams that undergo beam broadening. However, a significant drawback to the practical implementation of such beam profiles is that Bessel beams have infinite energy, rendering them physically unattainable. Various solutions have been suggested to tackle this issue, with one of the most straightforward approaches being to truncate the Bessel beam at a specific radius, for instance, through Gaussian truncation, resulting in what is known as Bessel–Gauss beams.

To date, there has been no reported theoretical exploration regarding the excitation of electron plasma waves (EPW) by Bessel–Gaussian laser beams in plasmas. This paper, therefore, seeks to provide the initial theoretical investigation into the excitation of EPW by self-focused zeroth and first-order Bessel–Gauss laser beams in collisionless plasmas featuring an axial density ramp.

Optical nonlinearity of collisionless plasma

Consider the propagation of an intense laser beam with electric field vector

$$E(r, z, t) = A_0(r, z)e^{i(k_0 z - \omega_0 t)}e_x \tag{1}$$

through an axially inhomogeneous plasma whose equilibrium electron density is modeled as

$$n_0(z) = n_0^0(1 + \tan(\mathrm{d}z)) \tag{2}$$

Here, n_0^0 is the electron density at $z = 0$, i.e., the density at the plane of incidence, and constant d gives the measure of the rate of the increase in the electron density with distance. Hence, parameter d is termed as the slope of the ramp.

The nonuniform amplitude structure over the cross-section of the laser beam results in a transverse force, known as the ponderomotive force $F_p = -\frac{e^2}{4m\omega_0^2}\nabla\left(A_0 A_0^\star\right)$, acting on the plasma electrons. To understand the origin of ponderomotive force, imagine a roller coaster as a charged particle moving

Principal
Dyal Singh College
KARNAL

through a varying landscape of hills and valleys. The ups and downs of the roller coaster represent the changing electromagnetic field, and the forces experienced by the coaster mimic the ponderomotive force acting on charged particles.

Due to ponderomotive force, the plasma electrons start migrating from high-intensity regions of the illuminated region of the plasma toward the low-intensity regions. The resulting electron density of the plasma is given by

$$n(r,z) = n_0(z)e^{-\frac{e^2}{8m\omega_0^2 K_0 T_0}A_0A_0^\star} \tag{3}$$

where T_0 is the temperature of the plasma electrons and K_0 is the Boltzmann constant. The modified electron density, in turn, alters the dielectric function $\epsilon = 1 - \frac{4\pi e^2}{m\omega_0^2}n(r,z)$ of plasma as

$$\epsilon = 1 - \frac{\omega_{p^0}^2}{\omega_0^2}(1+\tan(\mathrm{d}z))e^{-\frac{e^2}{8m\omega_0^2 K_0 T_0}A_0A_0^\star} \tag{4}$$

Here, $\omega_{p0}^2 = \frac{4\pi e^2}{m}n_0^0$ corresponds to the unperturbed plasma frequency, i.e., the plasma frequency in the absence of the laser beam. Thus, the ponderomotive force on the plasma electrons, produced by the laser beam, makes the plasma refractive index dependent on the intensity which, in turn, due to the spatial dependence of the amplitude structure of the laser beam, resembles that of a graded-index fiber. Separating the dielectric function of the plasma into linear ϵ_0 and nonlinear $\phi\left(A_0A_0^\star\right)$ parts as $\epsilon = \epsilon_0 + \phi\left(A_0A_0^\star\right)$, we get

$$\epsilon = 1 - \frac{\omega_{p0}^2}{\omega_0^2} \tag{5}$$

$$\phi\left(A_0A_0^\star\right) = \frac{\omega_{p^0}^2}{\omega_0}\left[1-(1+\tan(\mathrm{d}z))e^{-\frac{e^2}{8m\omega_0^2 K_0 T_0}A_0A_0^\star}\right] \tag{6}$$

Self-focusing of laser beam

The model equation governing the evolution of a laser beam, propagating through a nonlinear medium characterized by the dielectric function of the form given by Eq. (6), is

$$2ik_0\frac{\partial A_0}{\partial z} = \nabla_\perp^2 A_0 + \frac{\omega_{p^0}^2}{c^2}\left[1-(1+\tan(\mathrm{d}z))e^{-\frac{e^2}{8m\omega_0^2 K_0 T_0}A_0A_0^\star}\right] \tag{7}$$

This equation has been obtained under the WKB approximation, which is valid if $\nabla_\perp\left(\frac{1}{\epsilon}\nabla_\perp\epsilon\right) << \mathrm{k}_0^2$. In physical terms, this signifies that the transverse gradient of the dielectric function is relatively small in comparison to the laser wavelength. This suggests that either the transverse variation of the dielectric permittivity is mild or the plasma is notably underdense.

Before delving into the solution of Eq. (7), it is essential to comprehend the physical mechanism and the roles played by the various terms within it. The initial term on the right-hand side (R.H.S) represents the diffraction broadening of the laser beam, while the second term stems from the nonlinear response of the medium to the pump beam. Depending on its sign, this term either amplifies or mitigates the diffraction broadening of the laser beam, earning it the designation of a nonlinear refractive term. Comparing Eq. (7) with the standard Schrödinger equation of quantum mechanics reveals that the first term is analogous to the kinetic energy of a particle with unit mass, and the second term is comparable to the potential energy of the particle within a given force field. Much like the Schrödinger equation, which articulates the conservation of energy by detailing the conversion between kinetic and potential energy, Eq. (7) serves as a mathematical framework describing the interplay between diffraction and nonlinear refraction.

Considering the refractive index as defined by Eq. (6), the wave equation governing beam propagation, namely Eq. (7), inherently becomes nonlinear. As a result, the superposition principle is not applicable to this equation, making its closed-form solution unattainable through conventional methods for solving partial differential equations (PDEs). To enhance our insight into the dynamics of optical beams, we employ a semi-analytical technique called variational theory [20, 21].

While numerical approaches like the split-step-Fourier method and FDTD method have been developed for solving the nonlinear Schrödinger equation (NLSE), the variational method possesses its own set of advantages. This method explicitly formulates the evolution equations for beam parameters, providing valuable insights into beam propagation. Particularly, advantageous is the Rayleigh–Ritz optimization-based variational method when dealing with the NLSE, especially in cases where an exact solution is either unavailable or too complex for comprehensive physical insight. Nevertheless, it does have limitations, particularly when the beam or pulse undergoes profile or shape transformations, presenting a primary drawback to an otherwise robust analytical tool. In our specific scenario, involving collisionless axially inhomogeneous plasma, we opt for the Bessel–Gauss beam profile due to its self-similar structure in plasmas and other nonlinear media. The effectiveness of this approximate analytical method hinges on the choice of the trial function, which is a straightforward analytical function with amplitude and phase profiles closely resembling the solution. Typically, it involves a finite number of variables

Principal
Dyal Singh College
KARNAL

controlling the shape and chirp of the beam, and these variables are usually functions of the propagation coordinate evolving based on system constraints. When the trial function is appropriately chosen, the method predicts results with high accuracy. The essence of this method lies in the selection of the trial function, which, in our case, is the Bessel–Gauss function as given by [22]:

$$A_0(r,z) = \frac{E_{00}}{f} e^{-\frac{r^2}{2r_0^2 f^2}} j_n\left(\mu \frac{r}{r_0 f}\right) \tag{8}$$

where E_{00} is the axial amplitude of the laser beam (i.e., the amplitude at the center $r = 0$), r_0 is the initial radius of the laser beam, j_n is the nth order Bessel function of first kind, and μ is the constant associated with Bessel function and is termed as transverse component of wave parameter. The function f is the key parameter of interest for the present investigation. It is a real function of the longitudinal coordinate z. Upon multiplication with r_0 , it gives the instantaneous radius of the laser beam and is therefore termed as dimensionless beam width parameter.

In order to see the effect of transverse component of the wave parameter μ on the irradiance over the cross-section of the laser beam, we have shown the variation of intensity of zeroth-order Bessel–Gauss laser beam with radial distance from its axis in Fig. 1 for different values of μ. In the context of a zeroth-order Bessel–Gauss laser beam, when the parameter μ is set to zero, it precisely corresponds to a Gaussian beam. Observably, as the transverse component of the wave parameter increases, the intensity of the Bessel–Gauss laser beam contracts toward its axis. Consequently, in comparison to Gaussian laser beams, Bessel–Gauss laser beams confine their intensity to a narrow region around their axis. This characteristic of zeroth-order Bessel–Gauss laser beams renders them particularly well suited for applications involving the heating effects of laser beams.

Figure 2 gives the comparison of the irradiance over the cross-sections of zeroth- and first-order Bessel–Gauss laser beams for μ=1. Observing the first-order Bessel–Gauss laser beam, it is evident that it features a central dark disk where the intensity is precisely zero, encircled by a bright ring. The irradiance profile of the first-order Bessel–Gauss laser beam bears a resemblance to that of dark hollow laser beams. The vortex structure inherent in first-order Bessel–Gauss laser beams makes them promising for applications that involve trapping atoms and neutral particles.

Figure 3 illustrates the effect of transverse component of wave parameter μ on the irradiance over the cross-section of first-order Bessel–Gauss laser beam. It can be seen that for first-order Bessel–Gauss laser beams with increase in the value of transverse component of wave parameter μ, the area of central dark region decreases and the brightness of the surrounding bright ring increases.

There are several reasons for selecting the Bessel–Gauss beam profile. Firstly, as our goal is to examine the propagation dynamics of Bessel–Gauss beams, it is essential to use the same as a trial function. Additionally, this beam profile exhibits significant differences in beam propagation dynamics. Secondly, and more importantly, both the order 'n' of the Bessel–Gauss beam and the transverse component 'μ' of the wave parameter play a crucial role in controlling diffraction and self-focusing of the beam. Therefore, by adjusting the order of the beam or the transverse component 'μ' of the wave parameter, the propagation dynamics of the laser beam can be manipulated. Beyond its fundamental research

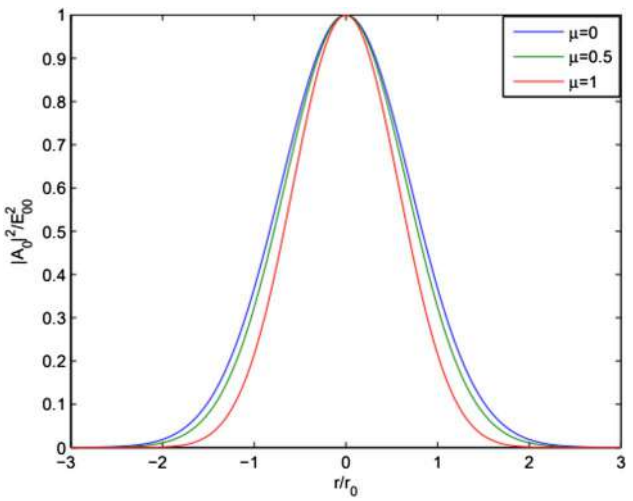


Fig. 1 Irradiance over the cross-section of zeroth-order Bessel–Gauss laser beams at $z = 0$ for different values of transverse component of wave parameter μ

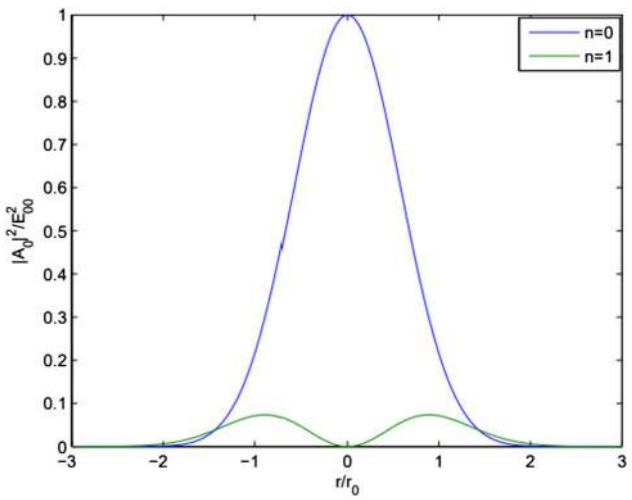


Fig. 2 Comparison between the irradiance profiles of the zeroth- and first-order Bessel–Gauss laser beams for $\mu = 0.5$

Principal
Dyal Singh College
KARNAL

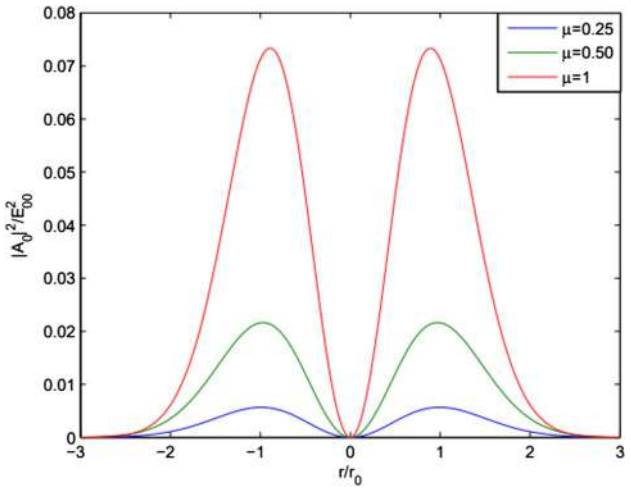


Fig. 3 Irradiance over the cross-section of zeroth-order Bessel–Gauss laser beams at $z = 0$ for different values of transverse component of wave parameter μ

interest, this beam profile holds potential significance in realizing tunable all-optical devices.

The essential stage of variational method is to find the Lagrangian density and hence reduced Lagrangian for the system. For our model, the Lagrangian density $\mathcal{L}$ is given by

$$\mathcal{L} = i\left(A_0\frac{\partial A_0^\star}{\partial z} - A_0^\star\frac{\partial A_0}{\partial z}\right) + \left|\nabla_\perp A_0\right|^2 - \frac{k_0^2}{2\epsilon_0}\int_0^{A_0A_0^\star}\phi(A_0A_0^\star)d(A_0A_0^\star) \tag{9}$$

Substituting the trial function given by Eq. (8) in Lagrangian density and integrating over the entire cross-section of the laser beam we get the reduced Lagrangian as $L = \int^{\mathcal{L}}\left(A_0, A_0^\star, \frac{\partial A_0}{\partial z}, \frac{\partial A_0^\star}{\partial z}\right)\mathrm{d}^2r$. The corresponding Euler–Lagrange equationsgives the differential equation governing the evolution of beam width of the Bessel–Gauss laser beam with distance of propagation as

$$\frac{\mathrm{d}}{\mathrm{d}z}\left(\frac{\partial L}{\partial\left(\frac{\partial f}{\partial z}\right)}\right) - \frac{\partial L}{\partial f} = 0$$

$$I_1\frac{\mathrm{d}^2f}{\mathrm{d}\xi^2} = \frac{1}{f^3}I_2 + \left(\frac{\omega_{p0}^2r_0^2}{c^2}\right)\left(1+\tan\left(\mathrm{d}'\xi\right)\right)\frac{\beta E_{00}^2}{f^3}\left(\mu I_3 - (n+1)I_4\right) \tag{10}$$

where

$$I_1 = \int_0^\infty te^{-t}\left[j_n\left(\mu\sqrt{t}\right)\right]^2\mathrm{d}t$$

$$I_2 = \int_0^\infty e^{-t}\left[\mu\left(j_{n-1}\left(\mu\sqrt{t}\right) - \frac{n}{\mu}j_n\left(\mu\sqrt{t}\right)\right) - \sqrt{t}j_n\left(\mu\sqrt{t}\right)\right]\mathrm{d}t$$

$$I_3 = \int_0^\infty te^{-2t}e^{-\frac{\beta E_{00}^2}{f^3}e^{-t}\left[j_n\left(\mu\sqrt{t}\right)\right]^2}\left[j_n\left(\mu\sqrt{t}\right)\right]^3 j_{n-1}\left(\mu\sqrt{t}\right)\mathrm{d}t$$

$$I_4 = \int_0^\infty te^{-2t}e^{e^{-\frac{\beta E_{00}^2}{f^3}e^{-t}\left[j_n\left(\mu\sqrt{t}\right)\right]^2}}\left[j_n\left(\mu\sqrt{t}\right)\right]^4\mathrm{d}t$$

$$\xi = \frac{z}{k_0r_0^2}$$

$$t = \frac{r^2}{r_0^2f^2}$$

Equation (10) indicates that variational theory has reduced the original problem of solving a nonlinear partial differential equation to that of solving an ordinary differential equation. Also, this reduced ordinary differential equation is also lacking from an exact closed-form solution, its approximate solution can be easily obtained by simple numerical techniques. In the present investigation, this equation has been solved with the help of Runge–Kutta fourth-order method for following set of laser-plasma parameters:

$$\omega_0 = 1.78\times10^{15}\mathrm{rad/sec}, r_0 = 10\mu\mathrm{m}, \beta E_{00}^2 = 3, \frac{\omega_{p0}^2r_0^2}{c^2} = 9$$

and for different values of n, μ, and d' viz.,

$$n = (0,1), \mu = (0, 0.25, 0.5, 1) \text{ and } \mathrm{d}' = (0.025, 0.030, 0.035)$$

under the boundary condition that at the plane of incidence the laser beam is having plane wavefront. Mathematically, this condition means that at $\xi = 0$:

$$f = 1$$

$$\frac{\mathrm{d}f}{\mathrm{d}\xi} = 0$$

The corresponding evolution of the beam with with distance of propagation through plasma has been depicted in Figures 4, 5, 6, and 7. It can be seen that inside the plasma medium the beam width of the laser beam shows oscillatory behavior over the longitudinal direction. This behavior of the laser beam can be explained by analyzing the role and origin of various terms contained in the evolution equation for the beam width, i.e., Eq. (11). The first terms on the right-hand side (R.H.S) of this equation that varies inversely as the cube of the beam width (i.e., as f^{-3}) is the spatial dispersive term that model the spreading of the laser beam in transverse directions as a consequence of the diffraction divergence. The second term on the right-hand side (R.H.S) of this

Principal
Dyal Singh College
KARNAL

equation, which exhibits a complex dependence on beam widths denoted as 'f,' arises as a consequence of the ponderomotive force exerted by the laser beam on plasma electrons. This term characterizes the nonlinear refraction of the laser beam. Due to the laser-induced nonlinearity within the plasma, the ensuing nonlinear refraction tends to counteract the effects of diffraction along both transverse directions. Consequently, as the laser beam travels through the plasma, a competition arises between the phenomena of diffraction and nonlinear refraction. The outcome of this competition dictates the ultimate behavior of the laser beam—whether it will converge or diverge. Therefore, a critical value of beam intensity exists (obtained by balancing the two terms on the right-hand side of Eq. 11), beyond which the beam converges along both transverse directions. In this study, the initial beam intensity is deliberately set greater than the critical intensity. This choice results in the initial narrowing of the laser beam's width. As the cross-section of the laser beam contracts, its intensity intensifies. Upon reaching excessively high intensity, the illuminated part of the plasma becomes nearly devoid of electrons. Consequently, the beam propagates as if through a vacuum. Similar to the diffraction experienced by an optical beam traversing a vacuum, the beam width of a laser beam moving through plasma, after reaching its possible minimum value, rebounds toward its original magnitude. As the laser beam width begins to expand, the interplay between diffraction broadening and nonlinear refraction recommences. This competition persists until 'f' achieves its maximum possible value. These processes cyclically repeat, resulting in the oscillatory behavior of the laser beam width.

Moreover, it has been noted that after each focal spot, both the maximum and minimum values of the beam width experience a downward shift. This phenomenon arises due to the increasing equilibrium electron density along the longitudinal distance. Consequently, the plasma index of refraction consistently decreases as the laser beam penetrates deeper into the plasma. This leads to an augmentation of the self-focusing effect, causing both the maximum and minimum values of the beam width to shift downward after each focal spot. Furthermore, there is an observed increase in the frequency of oscillations of the beam with distance. The underlying physics behind this observation lies in the fact that in denser plasma, the phase velocity of the laser beam is higher. As a result, the laser beam takes less time to undergo self-focusing in denser plasma, leading to an increase in the frequency of beam width oscillations.

The plots in Fig. 4 illustrate that as the value of the transverse component of the wave parameter μ increases, the degree of self-focusing of the zeroth-order Bessel–Gauss laser beam experiences a significant enhancement. This is attributed to the fact that for laser beams with a larger value of μ, a majority of the beam energy becomes concentrated

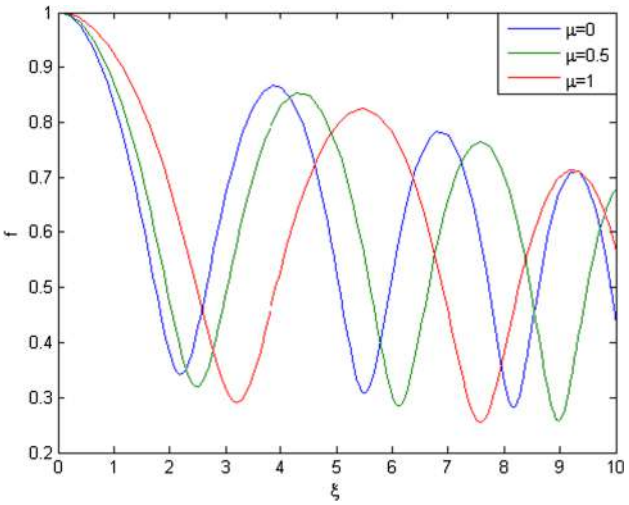


Fig. 4 Evolution of beam widths of zeroth-order Bessel–Gauss laser beams with distance of propagation through plasma for different values of μ and at fixed value of $d\prime$, i.e., $\mathrm{d}\prime = 0.025$

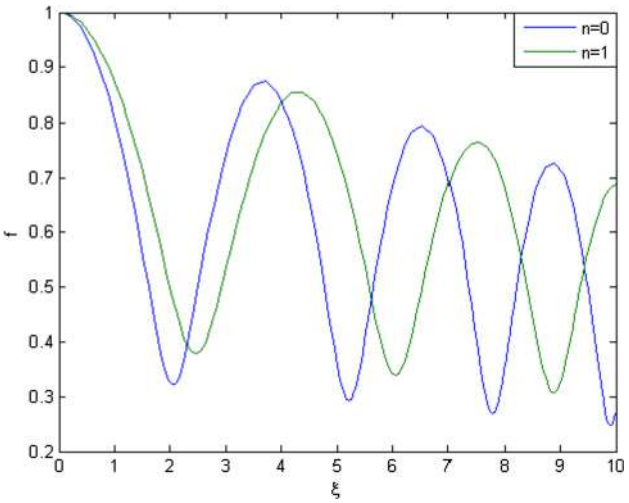


Fig. 5 Comparison between the extent of self-focusing of zeroth- and first-order Bessel–Gauss laser beams for $\mu = 0.25$ and $\mathrm{d}\prime = 0.025$

around a narrow region near the beam axis. Consequently, these beams contribute more significantly to the axial rays, which play a major role in the nonlinear refraction. As the phenomenon of self-focusing is a balance between the nonlinear refraction of the optical beam due to the optical nonlinearity of the medium, and axial rays play a crucial role in that process, an increase in the value of the transverse component of the wave parameter μ amplifies the extent of self-focusing of the laser beam.

To compare the behavior of zeroth-order and first-order Bessel–Gauss laser beams, we have solved Eq. (10) for $n=(0,1)$ with $\mu=0.25$. The corresponding evolution of beam widths for both beams is depicted in Fig. 5. It is evident that, in

Principal
Dyal Singh College
KARNAL

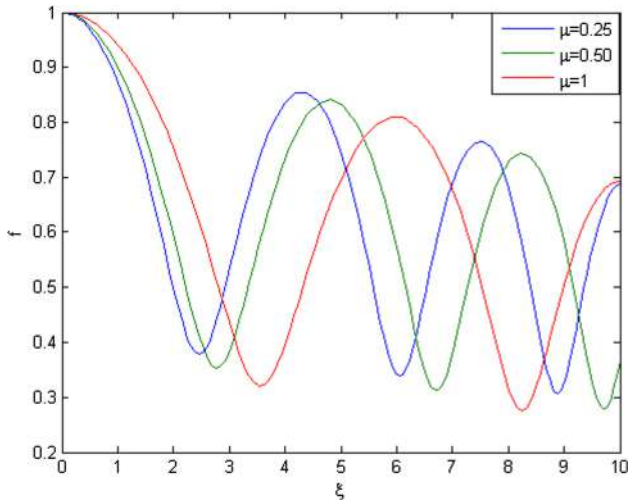


Fig. 6 Evolution of beam widths of first-order Bessel–Gauss laser beams with distance of propagation through plasma for different values of μ and at fixed value of d', i.e., $d\prime = 0.025$

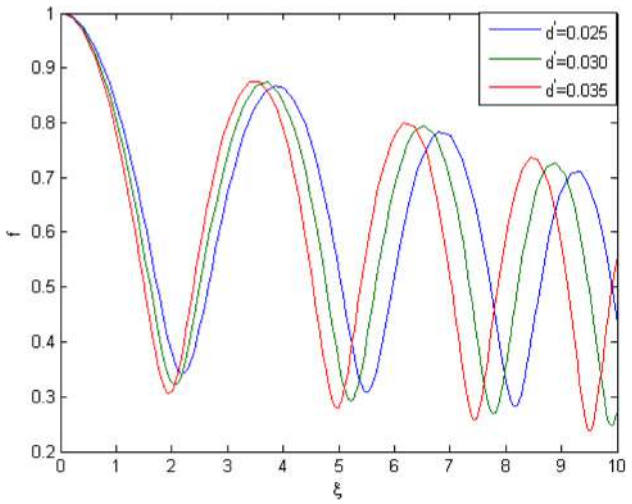


Fig. 7 Evolution of beam widths of zeroth-order Bessel–Gauss laser beams with distance of propagation through plasma for different values of $d\prime$ and at fixed value of μ, i.e., $\mu = 0.50$

comparison to the zeroth-order Bessel–Gauss beam, the first-order Bessel–Gauss beam exhibits a less pronounced focusing characteristic. This is attributed to the fact that the first-order Bessel–Gauss laser beam contains a central dark region, i.e., a region with null intensity. Consequently, the first-order Bessel–Gauss laser beam does not receive any contribution from axial rays toward the nonlinear refraction. Hence, the first-order Bessel–Gauss laser beam demonstrates a less focused nature compared to the zeroth-order Bessel–Gauss laser beam.

Figure 6 depicts the effect of transverse component of wave vector μ on self-focusing of first-order Bessel–Gauss laser beams. It can be seen that with increase in the value of μ there is increase in the extent of self-focusing of first-order Bessel–Gauss laser beams. This is due to the fact that with increase in the value of μ, there is decrease in the area of central dark region and increase in the intensity of the surrounding bright ring of first-order Bessel–Gauss laser beam. Thus, first-order Bessel–Gauss laser beams with larger values of μ produce more optical nonlinearity and thus possess enhanced self-focusing character.

Figure 7 illustrates the effect of slope of density ramp on self-focusing of the laser beam. It can be seen that with increase in the slope of density ramp the extent of self-focusing of the laser beam increases. This is due to the fact that with increase in slope density of ramp, the number of electrons contributing to the ponderomotive nonlinearity increases along the direction of propagation. This results in enhanced transverse as well as longitudinal gradient in the index of refraction of plasma that in turn increases the extent of self-focusing of the laser beam.

Evolution of power of excited electron plasma waves

Electron plasma waves (EPWs) may emerge in plasmas due to their distinct features of quasi-neutrality and collective behavior. Unlike ordinary states like solids, liquids, and gases, a plasma represents a high-temperature state of matter that causes atoms to lose their individual characteristics. In a plasma, although negatively charged electrons are still attracted to positively charged nuclei, they are no longer bound together, leading to unique properties. The free-moving electrons and ions within a plasma demonstrate a heightened sensitivity to electric and magnetic fields, even though the plasma as a whole maintains quasi-neutrality.

In spite of the overall quasi-neutrality, the separation of electrons and positively charged ions allows disturbances to create regions with a net negative and net positive charge, resembling the plates of a charged parallel plate capacitor. This uneven distribution results in an electric field running from positive to negative regions. The electric field exerts equal forces, pulling electrons and ions toward each other. Due to the greater mass of ions, they remain relatively inert, while electrons move toward the ions. As electrons approach the ions, they accumulate velocity and momentum, akin to a pendulum moving toward its mean position from an extreme. This gain in momentum causes electrons to overshoot their equilibrium positions, initiating a reversal in the direction of the electric field.

The reversed electric field obstructs electron motion, slowing them down before pulling them back once more. This cyclic process establishes an electron oscillator. Intense laser beams can set these electron oscillators into motion. When a laser beam permeates the plasma region, it exerts

Principal
Dyal Singh College
KARNAL

pressure on plasma electrons, causing them to shift aside. As the laser beam departs, leaving a region devoid of electrons, plasma electrons promptly return to restore equilibrium. This motion of plasma electrons initiates oscillations, leading to the formation of plasma waves.

There are several mechanisms by which laser beams can excite EPWs in plasmas. These mechanisms include:

Resonant Absorption: When a laser beam interacts with a plasma, resonant absorption can occur when the laser frequency matches the natural frequency of plasma oscillations. In the case of electron plasma waves, the Langmuir frequency becomes influential. The laser energy is absorbed by electrons, inducing their oscillation at the plasma frequency and generating electron plasma waves. Self-Modulation Instability: In high-intensity laser-plasma interactions, the laser may undergo self-modulation instability, resulting in the formation of plasma density modulations. The associated electric fields can excite electron plasma waves. Parametric Instability: Parametric instabilities involve nonlinear coupling between the incident laser beam and plasma waves, where stimulated raman scattering (SRS) and stimulated brillouin scattering (SBS) processes can lead to the excitation of electron plasma waves. In SRS, incident photons transfer energy to a plasma wave, creating electron plasma waves. In SBS, the incident laser beam interacts with ion acoustic waves, generating electron plasma waves. Beat-Wave Excitation: Beat-wave excitation results from the interference between two laser beams with slightly different frequencies. The resulting beat frequency may match the plasma frequency, leading to the excitation of electron plasma waves. Inverse Bremsstrahlung: Inverse bremsstrahlung involves electrons gaining energy by absorbing photons from the laser beam. As electrons gain energy, they can drive plasma waves. Relativistic Self-Focusing: At high laser intensities, relativistic effects come into play, causing self-focusing due to the ponderomotive force. This concentration of laser energy can excite electron plasma waves. Nonlinear Wave Mixing: Nonlinear processes, including four-wave mixing, can lead to the excitation of plasma waves. In this process, three waves interact, and their frequencies satisfy conditions for resonant excitation of a fourth wave, often an electron plasma wave. Frequency Doubling and Harmonic Generation: Harmonic generation involves producing higher harmonics of the incident laser frequency. If one of these harmonics matches the plasma frequency, it can resonantly excite electron plasma waves. Raman Amplification: Raman amplification transfers energy from a pump laser to a counter-propagating seed laser through the excitation of plasma waves. The seed laser can be at the plasma frequency or its harmonics. Two-Plasmon Decay: In high-intensity laser interactions, two-plasmon decay occurs, involving the decay of an incident laser beam into an electron plasma wave and an ion acoustic wave. Nonlinear Landau Damping: Nonlinear Landau damping refers to the absorption of energy from a laser beam by resonant electrons, leading to the excitation of plasma waves. Chirped Pulse Amplification: Chirped pulse amplification involves stretching and compressing a laser pulse. During the compression stage, the intensity can become high enough to drive plasma waves. Relativistic Oscillation: At relativistic intensities, the laser field can push electrons to relativistic speeds, generating plasma waves through the relativistic oscillation of electrons.

The propagation of excited EPW is governed by the wave equation:

$$2\imath k_{\mathrm{ep}}\frac{\partial n_{\mathrm{ep}}}{\partial z}=\nabla_{\perp}^{2}\mathrm{n}_{\mathrm{ep}}+\frac{\omega_{\mathrm{ep}}^{2}}{v_{\mathrm{th}}^{2}}(1+\tan(\mathrm{d}z))\left\{1-e^{-\beta A_{0}A_{0}^{\star}}\right\}n_{\mathrm{ep}} \tag{11}$$

where $v_{\mathrm{th}}=\sqrt{\frac{2KT_0}{m}}$ is the thermal velocity of plasma electrons. This equation can be obtained by linearizing equation of continuity, Poisson's equation and equation of motion of electron fluid. Considering the Gaussian ansatz for the EPW as

$$n_{\mathrm{ep}}=\frac{n_{00}}{f_{\mathrm{ep}}}e^{-\frac{r}{2r_0^2f_{\mathrm{ep}}^2}} \tag{12}$$

and using the procedure of Sect. 4, we get the equations for the evolution of beam widths of the EPW as

$$\begin{aligned}
&\frac{\mathrm{d}^2f_{\mathrm{ep}}}{\mathrm{d}\xi^2}=\frac{1}{f_{\mathrm{ep}}^3}+\left(\frac{\omega_{p0}^2r_0^2}{v_{\mathrm{th}}^2}\right)\left(\frac{n_{00}}{n_0^0}\right)^2\left(1+\tan(\mathrm{d}'\xi)\right)\frac{\beta E_{00}^2}{f_{\mathrm{ep}}^3}\left(\mu I_5-(n+1)I_6\right)\\
&I_5=\int_0^\infty te^{-\frac{f^2}{f_{\mathrm{ep}}^2}t}e^{-t}e^{-\frac{\beta E_{00}^2}{f^3}e^{-t}\left[j_n\left(\mu\sqrt{t}\right)\right]^2}\left[j_n\left(\mu\sqrt{t}\right)\right]^3j_{n-1}\left(\mu\sqrt{t}\right)\mathrm{d}t\\
&I_6=\int_0^\infty te^{-\frac{f^2}{f_{\mathrm{ep}}^2}t}e^{-t}e^{-\frac{\beta E_{00}^2}{f^3}e^{-t}\left[j_n\left(\mu\sqrt{t}\right)\right]^2}\left[j_n\left(\mu\sqrt{t}\right)\right]^4\mathrm{d}t
\end{aligned} \tag{13}$$

Principal
Dyal Singh College
KARNAL

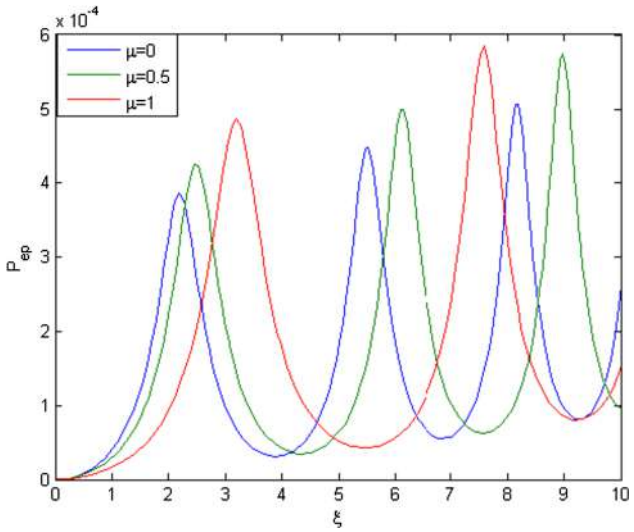


Fig. 8 Evolution of power of EPW with distance of propagation through plasma excited by zeroth-order Bessel–Gauss laser beams for different values of μ and at fixed value of d$\prime$, i.e., d$\prime = 0.025$

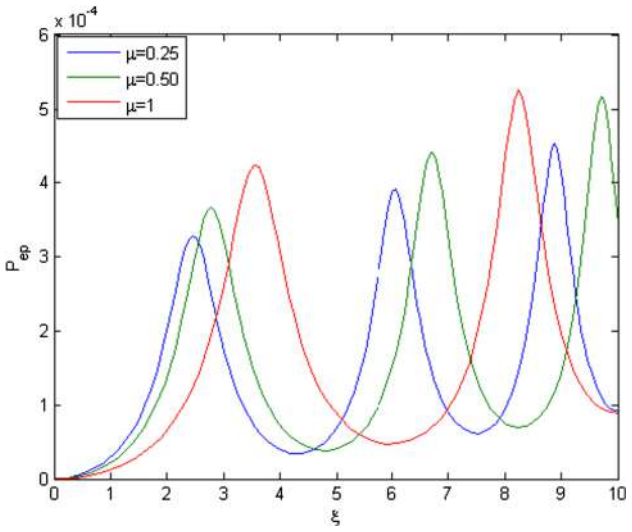


Fig. 10 Evolution of power of EPW with distance of propagation through plasma excited by first-order Bessel–Gauss laser beams for different values of μ and at fixed value of d$\prime$, i.e., d$\prime = 0.025$

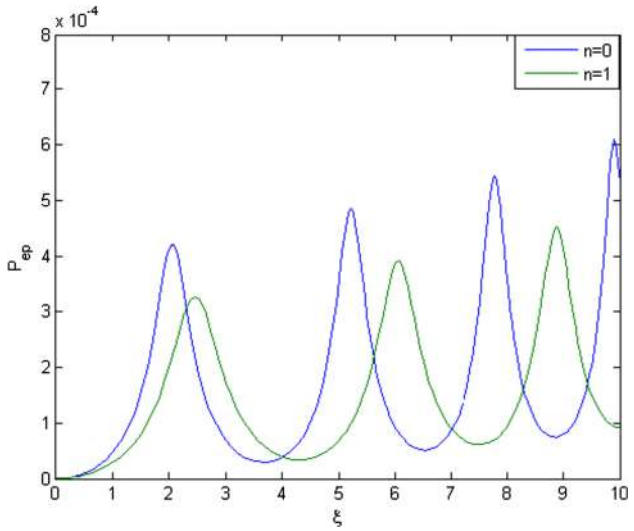


Fig. 9 Comparison between the powers of EPWs with distance of propagation through plasma excited by zeroth-order and first-order Bessel–Gauss laser beams for $\mu = 0.25$ and d$\prime = 0.025$

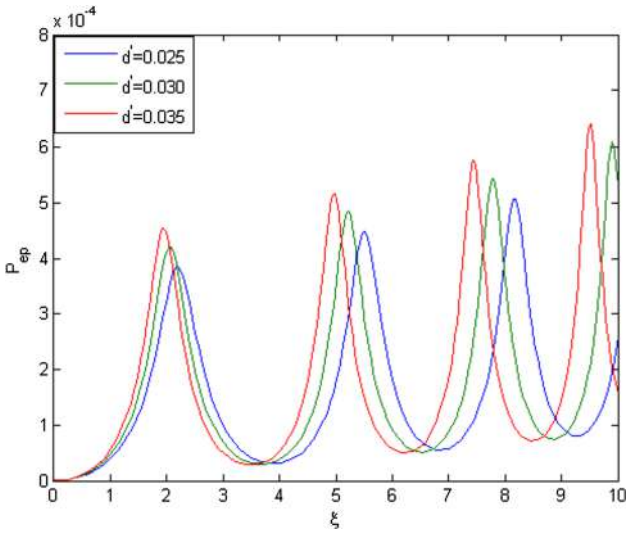


Fig. 11 Evolution of power of EPW with distance of propagation through plasma excited by zeroth-order Bessel–Gauss laser beams for different values of d$\prime$ and at fixed value of μ , i.e., $\mu = 0.50$

Equation (13) shows the coupling of EPW with pump beam, i.e., Bessel–Gauss laser beam. It can be seen that the density perturbation associated with EPW is very sensitive to the self-focusing of the laser beam. Using Poisson's equation, the electric field of the excited EPW can be obtained as

$$\boldsymbol{E_{ep}} = E_{ep} e^{\imath(k_{ep}z - \omega_{ep}t)}$$
$$E_{ep} = \frac{\imath m\omega_{ep}^2}{ck_{ep}f_{ep}} e^{-\frac{r}{2r_0^2 f_{ep}^2}} \tag{14}$$

The normalized power of excited EPW can be defined as

$$P_{ep} = \frac{\int_{ep}^{E} E_{ep}^{\star} \mathrm{d}^2 r}{\int_0^A A_0^{\star} \mathrm{d}^2 r} \tag{15}$$

In present investigation Eq. (15) has been solved in association with Eqs. (10) and (13) for $\frac{n_{00}}{n_0^0} = 0.0001$ and $T_0 = 10^6 K$. The corresponding evolution of power of excited EPW has been shown in Figs. 8, 9, 10 and 11. Importantly, the intensity of the electric field associated

Principal
Dyal Singh College
KARNAL

with the generated electron plasma wave (EPW) displays an oscillatory pattern during propagation, reaching its maximum magnitude precisely at the focal spots of the laser beam. This occurrence stems from the EPW's amplitude being highly responsive to the self-focusing degree of the laser beam. As the pump beam undergoes self-focusing, its intensity increases, consequently escalating the oscillation amplitude of the plasma electrons. Consequently, this amplification in amplitude enhances the strength of the EPW. The oscillatory evolution of the pump beam's width mirrors this behavior, and correspondingly, the strength of the generated EPW follows a similar trend. The maximum electric field strength aligns with the point of minimum beam width in the pump beam due to the direct correlation between self-focusing and EPW amplitude.

The plots in Fig. 8 depict that with increase in the value of transverse component of wave parameter μ, the power of EPW excited by zeroth-order Bessel–Gauss laser beam increases considerably. This is due to the enhancement of extent of self-focusing of the zeroth-order Bessel–Gauss beam with increase in the value of transverse component of wave parameter μ.

Figure 9 gives the comparison between the power of EPWs excited by zeroth- and first-order Bessel–Gauss beam. It can be seen that for given set of plasma parameters the power of EPW excited by zeroth-order beam is higher compared to that excited by first-order Bessel–Gauss beam. This is due to deeper focusing of zeroth-order Bessel–Gauss beam compared to first-order Bessel–Gauss beam.

The plots in Fig. 10 depict that with increase in the value of transverse component of wave parameter μ, the power of EPW excited by first-order Bessel–Gauss laser beam increases considerably. This is due to the enhancement of extent of self-focusing of the first-order Bessel–Gauss beam with increase in the value of transverse component of wave parameter μ.

Figure 11 depicts the effect of slope of the density ramp on power of EPW excited by zeroth-order Bessel–Gauss beam. It can be seen that with increase in the value of slope of density ramp there is increase in the power of excited EPW. This is again due to the enhancement of self-focusing of the pump beam with increase in the value of slope of density ramp.

References

1. V.N. Tsytovich, G.E. Morfill, H. Thomas, Complex plasmas: I. complex plasmas as unusual state of matter. Plasma Phys. Rep. **28**, 623 (2002)
2. I. Bishop, S. Xian, S. Feller, Robert A. Millikan and the oil drop experiment. The Phys. Teacher **57**, 442 (2019)
3. M. Tabak, J. Hammer, M.E. Glinsky, W.L. Kruer, S.C. Wilks, J. Woodworth, E.M. Campbell, M.D. Perry, Ignition and high gain with ultrapowerful lasers. Phys. Plasmas **1**, 1626 (1994)
4. H. Hora, New aspects for fusion energy using inertial confinement. Laser Part. Beams **25**, 37 (2007)
5. K.A. Brueckner, S. Jorna, Laser-driven fusion. Rev. Modern Phys. **46**, 325 (1974)
6. M. Moyer, Fusion's false dawn. Sci. Am. **302**, 50 (2010)
7. A.R. Kantrowitz, T.R. Brogan, R.J. Rosa, J.F. Louis, The magnetohydro dynamic power generator-basic principles, state of the art, and areas of application. IRE Trans. on Military Electron. **6**, 78 (1962)
8. A. Singh, N. Gupta, Beat wave excitation of electron plasma wave by relativistic cross focusing of cosh-Gaussian laser beams in plasma. Phys. Plasmas **22**, 062115 (2015)
9. N. Gupta, A. Singh, Effect of cross-focusing of two q-Gaussian laser beams on excitation of electron plasma wave in collisional plasma. Optik **127**, 8542 (2016)
10. L. Friedlandl, A.G. Shagalov, Extreme driven ion acoustic waves featured. Phys. Plasmas **24**, 082106 (2017)
11. B. Song, N.D. Angelo, R.L. Merlino, Ion-acoustic waves in a plasma with negative ions. Phys. Fluids B **3**, 284 (1991)
12. M. Smid, O. Renner, A. Colaitis, V.T. Tikhonchuk, T. Schlegel, F.B. Rosme, Characterization o super thermal electrons inside a laser accelerated plasma via highly-resolved Kα-emission. Nat. Commun. **10**, 4212 (2019)
13. R.E. Olson, R.J. Leeper, A. Nobile, J.A. Oertel, G.A. Chandler, K. Cochrane, S.C. Dropinski, S. Evans, S.W. Haan, J.L. Kaae, J.P. Knauer, K. Lash, L.P. Mix, A. Nikroo, G.A. Rochau, G. Rivera, C. Russell, D. Schroen, R.J. Sebring, D.L. Tanner, R.E. Turner, R.J. Wallace, Shock propagation, preheat, and x-ray burnthrough in indirect-drive inertial confinement fusion ablator materials. Phys. Plasmas **11**, 2778 (2004)
14. N.V. Kabadi, R. Simpson, P.J. Adrian, A. Bose, J.A. Frenje, M.G. Johnson, B. Lahmann, C.K. Li, C.E. Parker, F.H. Seguin, G.D. Sutcliffe, R.D. Petrasso, S. Atzeni, J. Eriksson, C. Forrest, S. Fess, V.Y. Glebov, R. Janezic, O.M. Mannion, H.G. Rinderknecht, M.J. Rosenberg, C. Stoeckl, G. Kagan, M. Hoppe, R. Luo, M. Schoff, C. Shuldberg, H.W. Sio, J. Sanchez, L. Hopkins, D. Schlossberg, K. Hahnand, C. Yeamans, Thermal decoupling of deuterium and tritium during the inertial confinement fusion shock-convergence phase. Phys. Rev. E **104**, 013201 (2021)
15. N. Gupta, S. Kumar, Linear and nonlinear propagation characteristics of multi-Gaussian laser beams. Chinese Phys. B **29**, 114210 (2020)
16. A. Sharma, I. Kourakis, Spatial evolution of a q-Gaussian laser beam in relativistic plasma. Laser and Part. Beams **28**, 479 (2010)
17. N. Gupta, S. Kumar, Generation of second harmonics of q -Gaussian laser beams in collisional plasma with upward density ramp. Laser Phys. **30**, 066003 (2020)
18. N. Gupta, S. Kumar, A. Gnaneshwaran, S. Kumar, S. Choudhry, Self-focusing of cosh-Gaussian laser beam in collisional plasma: effect of nonlinear absorption. J. Optics **50**, 701 (2021)
19. P. Johannisson, D. Anderson, M. Lisak, M. Marklund, Nonlinear Bessel beams. Opt. Commun. **222**, 107 (2003)
20. D. Anderson, M. Bonnedal, M. Lisak, Nonlinear propagation of elliptically shaped Gaussian laser beams. J. Plasma Phys. **23**, 115 (1980)
21. D. Anderson, M. Bonnedal, Variational approach to nonlinear self-focusing of Gaussian laser beams. Phys. Fluids **22**, 105 (1979)
22. N. Gupta, S.B. Bhardwaj, Nonlinear interaction of Bessel-Gauss laser beams with plasmas with axial temperature ramp. J. Opt. **51**, 950 (2022)

Principal
Dyal Singh College
KARNAL

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

Principal
Dyal Singh College
KARNAL

Thin–Walled Structures 196 (2024) 111448

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Full length article

Generalized Rayleigh waves in a multi-layered structure of porous piezoelectric materials overlying a functionally graded porous piezoelectric base

Anil K. Vashishth [a], Vishakha Gupta [b], Umang Bareja [c,*]

[a] Department of Mathematics, Kurukshetra University, Kurukshetra 136119, Haryana, India
[b] Department of Mathematics, Dyal Singh College, Karnal 132001, Haryana, India
[c] Department of Mathematics, Mukand Lal National College, Yamunanagar 135001, Haryana, India

ARTICLE INFO

Keywords:
Rayleigh wave
Piezoelectric
Functionally graded material
Porous
Phase velocity
Transfer matrix

ABSTRACT

Functionally graded materials (FGM) are materials in which there is a gradual variation in functional properties of the material so as to make it useful for different purposes. The life span and efficiency of Surface Acoustic Waves (SAW) devices can be increased by taking FGM into consideration. Further, FGM as a substrate can help to improve the structural integrity of a component or device. FGM substrates offer flexibility in design, enabling engineers to tailor the substrate's characteristics for specific functions within a device or system. Rayleigh-type surface waves, known for their numerous advantageous attributes, find extensive applications in various functional devices, and Rayleigh waves in functionally graded porous piezoelectric medium have not been studied so far and for more accurate simulation of field conditions, porous layers should be taken into account when determining the excitation and propagation processes of Rayleigh surface waves. Taking these considerations into account, this paper introduces a new model of composites of 'n' porous piezoelectric layers over functionally graded porous piezoelectric half-space (FGPPHS) and different characteristics of generalized Rayleigh waves in this model are studied. The material properties of the FGPPHS are taken to vary along the vertical direction (thickness). Closed form frequency equations are obtained for electrically short and open boundaries. Computing the model numerically, the impacts of gradation and wavenumber on the phase velocity and group velocity of generalized Rayleigh waves are examined. Also, lateral and vertical fluctuations of the electric potentials, stresses, mechanical displacements and electrical displacements are depicted by plotting 3D surface and contour graphs. In acoustic devices, a crucial measure that reflects the impact of piezoelectricity on wave phase velocity is the electromechanical coupling factor, therefore, the numerical analysis in terms of the electromechanical coupling factor is done and it is observed that the gradation coefficient can be adjusted to produce fairly high electromechanical coupling factor for the structure at a particular wave number. Numerical results are presented for alternating layers of Barium Titanate Crystal, PZT-5H, and PZT-7H and it is found that phase velocity decreases as the number of porous piezoelectric layers above FGPPHS increases for a particular wavenumber. The particle motion, in the layers and the half-space, is also determined and is found to be elliptic, in general, but its eccentricity changes with layer to FGPPHS and with depth. The outcome of the study provides a deeper understanding of the nature of generalized Rayleigh wave propagation in non-homogeneous functionally graded porous materials and may find applications in designing high performance SAW devices and also in the optimization of Rayleigh wave based devices for engineering applications.

1. Introduction

A form of mechanical wave called a surface acoustic wave travels along the surface of a solid substance. Because of their outstanding ability to move along the boundary between the surface and the bulk of the material, these waves have a wide variety of applications in many different sectors. The two main types of SAWs are Love waves and Rayleigh waves. In addition to these, hybrid SAW types also exist, such as Stoneley waves and Sezawa waves. Love waves are purely horizontal shear waves. Love waves have a completely horizontal particle motion that is perpendicular

* Corresponding author.
E-mail addresses: akvashishth@kuk.ac.in (A.K. Vashishth), vi_shu85@yahoo.co.in (V. Gupta), umangbareja.maths@kuk.ac.in (U. Bareja).

https://doi.org/10.1016/j.tws.2023.111448
Received 3 July 2023; Received in revised form 30 November 2023; Accepted 1 December 2023
Available online 10 December 2023
0263-8231/© 2023 Elsevier Ltd. All rights reserved.

Principal
Dyal Singh College
KARNAL

to the direction of wave propagation. Particle motion produced by Rayleigh-type waves is elliptical because it includes both longitudinal and transverse motion. Rayleigh-type surface waves provide various advantages over Love waves. A number of problems have been studied for the propagation and dispersion of waves in different media [1–6].

Rayleigh-type surface waves are extensively used in a variety of functional devices including transducers, filters, oscillators, sensors, delay lines, actuators, and amplifiers, which are widely employed in power electronics, mechatronics, telecommunications, diagnostic equipment, and other contemporary industrial domains because of their many favourable characteristics [7–9]. Rayleigh-type SAW devices can easily be coupled with electrical components like interdigitated transducers (IDTs) and microfluidic channels to create compact and reliable sensor systems. The low power consumption of Rayleigh-type SAWs makes them ideal for battery-operated and portable applications. A high signal-to-noise ratio is another characteristic of Rayleigh-type SAW devices that is essential for reliable and accurate sensing applications. Due to its widespread use in several fields of applied science and engineering, the study of Rayleigh surface waves in various types of media under diverse physical conditions is a subject of particular interest to researchers from numerous disciplines.

Piezoelectric materials are used in the design of SAW devices, where the elastodynamic waves originate through an electromechanical coupling. Numerous investigations have been done on Rayleigh wave propagation in piezoelectric material structures. Schmidt and Voltmer [10] examined Rayleigh waves in a hexagonal piezoelectric layer on the top of an isotropic elastic substrate. Collet and Destrade [11] derived secular equations representing Rayleigh modes for piezo-acoustic waves. Sharma et al. [12] investigated Rayleigh wave propagation in piezo-thermo-elastic half-space. Pang et al. [13] demonstrated the propagation behaviour of Rayleigh waves in the layered piezoelectric/piezomagnetic structure. Rayleigh waves in an initially stressed rotating piezoelectric half-space were examined by Singh and Singh [14]. An analytical approach is used to investigate Rayleigh surface waves in a piezoelectric layer overlying elastic half-space [15]. Vashishth and Sukhija [16] studied Rayleigh waves in a piezoelectric layer overlying porous piezo-thermoelastic half-space. Rayleigh waves in piezoelectric semiconductor half-space structures were studied analytically [17–19]. SIGA-PML approach is applied to examine Rayleigh surface waves in piezoelectric layered structure [20]. Tung [21] analytically examined Rayleigh waves in non-local piezoelastic half-space. Sharma [22] studied generalized Rayleigh waves in a piezoelectric medium with arbitrary anisotropy. Othmani et al. [23] presented a review study for wave propagation in elastic, piezoelectric and magneto-electro-elastic composites.

Even though piezoelectric materials have many advantages, it has been discovered that their brittleness may account for impurities, cracks, and ultimately device failure under electrical and/or mechanical loadings. Numerous authors have made attempts to contribute towards acquiring pronounced knowledge on fabricating better wave acoustic devices. Functionally graded piezoelectric material (FGPM), which has been developed with the advancement of material technology, is utilized to increase the effectiveness and endurance of SAW devices. Various studies have been conducted on Rayleigh wave propagation in FGPM. The WKB approach was used to determine the Rayleigh surface wave dispersion relation in FGPM half-space [24]. Rayleigh wave propagation along the piezoelectric material with subsurface damage was studied by Cao et al. [25]. Rayleigh waves in FGPM layered structure by using stiffness matrix and ordinary differential equation methods were examined [26,27]. Li et al. [28] investigated the propagation behaviour of Rayleigh waves in the FGPM layer overlying anisotropic elastic half-space having an imperfect interface. Li et al. [29] examined complex Rayleigh surface waves using the Laguerre polynomial approach in FGPM half space. Rayleigh wave in an initially stressed porous layer over functionally graded half-space was studied [30]. Li et al. [31] investigated Rayleigh surface waves in magneto-electro-elastic half space by modifying the Laguerre orthogonal polynomial. Khaldi and Sanbi [32] used a numerical method to examine the propagation of Rayleigh waves in a functionally graded piezoelectric structure. Hemalatha et al. [33] applied the variable separable method approach to examine Rayleigh waves in a graded piezoelectric layer on the top of an elastic substrate.

Acoustic wave devices with high quality factors and low losses are strongly required for the next generation of SAW devices used in communication systems, filters and sensors. These requirements can be met by multi-layered structures that combine materials with various characteristics into a single stack. These structures can be thought of as a new class of materials for SAW devices. Zinchuk and Podlipenets [34] examined Rayleigh waves in a periodically layered piezoelectric structure using the numerical-analytic method based on the formalism of periodic Hamiltonian systems. Vashishth and Khurana [35] studied generalized Rayleigh waves in a multi-layered poroelastic solid sandwiched between a fluid layer and elastic half-space by using the transfer matrix technique. Rayleigh wave propagation in layered piezoelectric crystals by deriving the transfer matrix was studied [36,37]. The recursive asymptotic method is used to analyse the Rayleigh and Love waves propagation in the multilayered piezoelectric structure by Zhang et al. [38]. Theoretical investigation of SAW propagation in an initially stressed piezoelectric layered structure is done using the differential equation method and stiffness matrix method by Mseddi et al. [39]. Fu et al. [40] investigated Rayleigh and Love waves surface modes in ZnO film based multi-layered structure. Ghorbanpour and Zamani [41] studied the electro-mechanical bending response of porous functionally graded sandwich nanoplate including piezoelectric face sheets. Thermal buckling characteristics of sandwich piezoelectric nanoplates with functionally graded cores using nonlocal second-order shear deformation theory were examined by Karami et al. [42]. Karami and Ghayesh [43] studied the vibration characteristics in porous functionally graded face sheets using the Hamilton principle.

The study of Rayleigh waves in different types of media is a subject of interest due to its wide range of applications in SAW devices. FGM substrates can help to improve the structural integrity of a component or device. In FGMs, gradual changes in material characteristics can lower stress concentrations and lessen the chance of delamination or breakdown at the interface between the substrate and other materials. This can lead to longer-lasting and more reliable structures. Applications where adhesion and interfacial qualities are essential, such as in the industry of semiconductors or for advanced composites, can benefit especially from this [44–46]. The steady shift in material properties reduces abrupt transitions that may interrupt waves, improving wave propagation characteristics [30,47]. FGM substrates offer flexibility in design, enabling engineers to tailor the substrate's characteristics for specific functions within a device or system. This versatility is especially useful when a substrate plays a critical role in determining the overall performance of a device. FGM substrates can be tailored for a variety of uses, such as microelectronics, sensors, and optical devices. Their ability of customization to meet the unique demands of each application makes them a versatile choice [46,48].

Rayleigh wave propagation in functionally graded porous piezoelectric medium has not been studied so far and for more accurate simulation of field conditions, porous layers should be taken into account when determining the excitation and propagation processes of Rayleigh surface waves in layered half-space structures. Therefore, this paper examines Rayleigh waves in 'n' porous piezoelectric layers over functionally graded porous piezoelectric half-space. The material characteristics of the FGPPHS are considered to vary along the thickness direction. Transfer matrix is obtained for the porous piezoelectric layers. Closed form frequency equations are obtained for electrically short and open circuit boundaries. Numerical computations and graphical demonstrations have been done. The impacts of gradation and wavenumber on the phase and group velocities have been examined. Also, variations of the electric potential, stresses, mechanical displacements and electrical displacements along the horizontal and vertical direction in FGPPHS have been studied. Numerical computations of results in terms of the attenuation quality factor and electromechanical coupling factor are done and it is discovered that the gradation coefficient can be adjusted to produce a fairly high electromechanical coupling

Principal
Dyal Singh College
KARNAL

factor at a particular wave number. Numerical results are presented for alternating layers of Barium titanate crystal, PZT-5H, and PZT-7H and it is discovered that phase velocity decreases as the number of porous piezoelectric layers above FGPPHS increases. Also, the behaviour of elliptical particle motion is examined in porous piezoelectric layers and FGPPHS. The findings of this paper may provide a deeper understanding of the nature of Rayleigh waves in non-homogeneous functionally graded materials and find application in designing high-spec surface acoustic wave devices and also in the optimization of Rayleigh wave based devices for engineering applications.

Symbol	Nomenclature
$\boldsymbol{\sigma}/\sigma^*$	Stress tensors corresponding to the solid/fluid phase
$\boldsymbol{D}/\boldsymbol{D}^*$	Electric displacements corresponding to the solid/fluid phase
$\boldsymbol{u}/\ \boldsymbol{u}^*$	Mechanical displacements corresponding to the solid/fluid phase
$\boldsymbol{\rho^{11}}, \boldsymbol{\rho^{12}}, \boldsymbol{\rho^{22}}$	Dynamical coefficients
f	Porosity
ρ	Porous aggregate density
ρ^*	Density of pore fluid
$\boldsymbol{b}$	Dissipation tensor
μ	Viscosity of the fluid
χ	Solid matrix permeability
χ_0	Norm of the permeability matrix
$\bar{\nu}$	Wave frequency
$\boldsymbol{\epsilon}/\epsilon^*$	Strain tensors
$\boldsymbol{E}/\boldsymbol{E}^*$	Electric fields corresponding to solid/fluid phase
$\boldsymbol{c}, \boldsymbol{m}, \boldsymbol{R}$	Elastic constants
$\boldsymbol{e}, \boldsymbol{\zeta}, \tilde{\boldsymbol{\zeta}}, \boldsymbol{e}^*$	Piezoelectric constants
$\boldsymbol{\xi}, \boldsymbol{A}, \boldsymbol{\xi}^*$	Dielectric constants
$\boldsymbol{\epsilon}/\epsilon^*$	Strain tensors corresponding to solid/fluid phase
$\boldsymbol{E}/\boldsymbol{E}^*$	Electric fields corresponding to solid/fluid phase
ϕ/ϕ^*	Electric potentials for the solid/fluid phase
c	Phase velocity
ω	Angular frequency
α	Grade coefficient
Q^{-1}	Attenuation quality factor
K^2	Electromechanical coupling factor
h	Thickness of layered structure

2. Formulation of the problem

A structure consisting of 'n' porous piezoelectric layers stacked on the top of FGPPHS, depicted in Fig. 1, is considered for the study. The electrical and mechanical properties of FGPPHS are subjected to exponential grading with depth x_3. The piezoelectric material's poling direction is considered to be perpendicular to the $x_1 - x_3$ plane. Both materials are bonded at the interface $x_3 = h$ and possess symmetry of 6 mm type. The layers occupy the region $0 \le x_3 \le h$ i.e., h is the total thickness of porous piezoelectric layers and $h_j, (j = 1, 2, 3, \ldots, n)$ denotes the thickness of j^{th} layer. The FGPPHS occupies the region $x_3 \ge h$ and the region above the porous piezoelectric layers is considered as vacuum.

3. Governing equations and solutions

3.1. For porous piezoelectric layers

The equations of motion for the porous piezoelectric medium in the absence of body forces and surface charge density are [49]

$$\begin{aligned} \nabla \cdot \boldsymbol{\sigma} &= \boldsymbol{\rho^{11}} \cdot \ddot{\boldsymbol{u}} + \boldsymbol{\rho^{12}} \cdot \ddot{\boldsymbol{u}}^* + \boldsymbol{b} \cdot (\dot{\boldsymbol{u}} - \dot{\boldsymbol{u}}^*), \\ \nabla \sigma^* &= \boldsymbol{\rho^{12}} \cdot \ddot{\boldsymbol{u}} + \boldsymbol{\rho^{22}} \cdot \ddot{\boldsymbol{u}}^* - \boldsymbol{b} \cdot (\dot{\boldsymbol{u}} - \dot{\boldsymbol{u}}^*), \\ \nabla \cdot \boldsymbol{D} &= \boldsymbol{0}, \\ \nabla \cdot \boldsymbol{D}^* &= \boldsymbol{0}, \end{aligned} \tag{3.1}$$

where $\boldsymbol{\sigma}/\sigma^*$ are the stress tensors, $\boldsymbol{D}/\boldsymbol{D}^*$ are the electric displacements, $\boldsymbol{u}/\ \boldsymbol{u}^*$ are the mechanical displacements corresponding to the solid/fluid phase. $\boldsymbol{\rho^{11}}, \boldsymbol{\rho^{12}}$ and $\boldsymbol{\rho^{22}}$ are the dynamical coefficients depends upon the porosity(f), porous aggregate density(ρ), density of pore fluid(ρ^*) and the inertial coupling parameters.

The dissipation tensor $\boldsymbol{b}$ [49] in the low frequency range is given by

$$\boldsymbol{b} = \frac{\mu f^2}{\chi}, \tag{3.2}$$

where μ is the viscosity of the fluid and χ represents the solid matrix permeability.

If the frequency range is high, μ is substituted by $\mu F(K)$, where $F(K)$ is given by

$$F(K) = \frac{\sqrt{\imath K}\tanh(\sqrt{\imath K})}{3(1 - \tanh(\sqrt{\imath K})/\sqrt{\imath K})},$$

Principal
Dyal Singh College
KARNAL

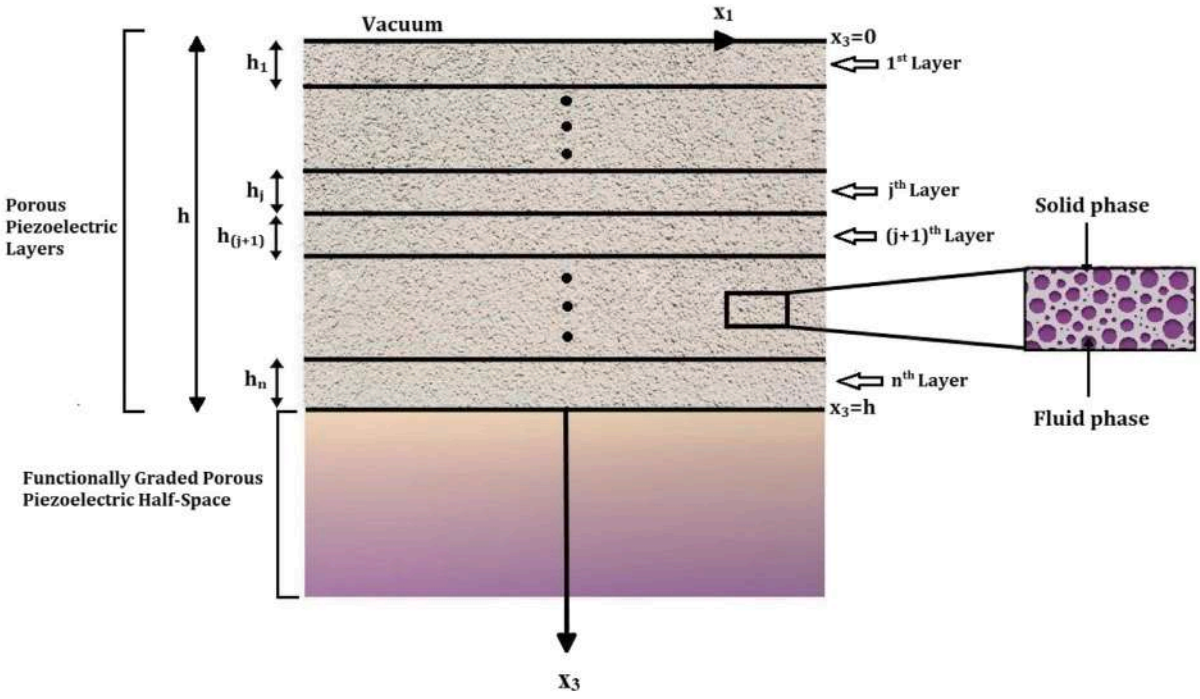


Fig. 1. Geometry of the proposed structure.

and

$$K = \sqrt{6\pi}\sqrt{\chi_0 \bar{\nu}\rho^*/\mu f},$$

where χ_0 is the norm of the permeability matrix and $\bar{\nu}$ is the wave frequency.

The constitutive equations for the porous piezoelectric material can be written as [49]

$$\begin{aligned}
\boldsymbol{\sigma} &= \boldsymbol{c} : \boldsymbol{\varepsilon} + \boldsymbol{m}\varepsilon^* - \boldsymbol{e}\cdot\boldsymbol{E} - \boldsymbol{\zeta}\cdot\boldsymbol{E}^*,\\
\sigma^* &= \boldsymbol{m} : \boldsymbol{\varepsilon} + R\varepsilon^* - \tilde{\boldsymbol{\zeta}}\cdot\boldsymbol{E} - \boldsymbol{e}^*\cdot\boldsymbol{E}^*,\\
\boldsymbol{D} &= \boldsymbol{e} : \boldsymbol{\varepsilon} + \tilde{\boldsymbol{\zeta}}\varepsilon^* + \boldsymbol{\xi}\cdot\boldsymbol{E} + \boldsymbol{A}\cdot\boldsymbol{E}^*,\\
\boldsymbol{D}^* &= \boldsymbol{\zeta} : \boldsymbol{\varepsilon} + \boldsymbol{e}^*\varepsilon^* + \boldsymbol{A}\cdot\boldsymbol{E} + \boldsymbol{\xi}^*\cdot\boldsymbol{E}^*,
\end{aligned} \tag{3.3}$$

where $\boldsymbol{\varepsilon}/\varepsilon^*$ are the strain tensors and $\boldsymbol{E}/\boldsymbol{E}^*$ are the electric fields corresponding to solid/fluid phase and $\boldsymbol{c}, \boldsymbol{m}, R$ are the elastic constants, $\boldsymbol{e}, \boldsymbol{\zeta}, \tilde{\boldsymbol{\zeta}}, \boldsymbol{e}^*$ are the piezoelectric constants and $\boldsymbol{\xi}, \boldsymbol{A}, \boldsymbol{\xi}^*$ are the dielectric constants.

The strain tensors $\boldsymbol{\varepsilon}/\varepsilon^*$ and the electric fields $\boldsymbol{E}/\boldsymbol{E}^*$ corresponding to solid/fluid phase are given by [50]

$$\begin{aligned}
\boldsymbol{\varepsilon} &= \frac{1}{2}(\nabla\boldsymbol{u} + \nabla\boldsymbol{u}^T), \qquad \varepsilon^* = \nabla\cdot\boldsymbol{u}^*,\\
\boldsymbol{E} &= -\nabla\phi, \qquad \boldsymbol{E}^* = -\nabla\phi^*,
\end{aligned} \tag{3.4}$$

where ϕ/ϕ^* are the electric potentials for the solid/fluid phase.

For Rayleigh waves propagating in the $x_1 - x_3$ plane, plane harmonic waves solutions are assumed in the form as [51,52]

$$\begin{bmatrix} u_1\\ u_3\\ u_1^*\\ u_3^*\\ \phi\\ \phi^* \end{bmatrix} = \begin{bmatrix} U_1\\ U_3\\ U_1^*\\ U_3^*\\ \boldsymbol{\Phi}\\ \boldsymbol{\Phi}^* \end{bmatrix} \exp(i\omega(\frac{x_1}{c} + qx_3 - t)), \tag{3.5}$$

where c is the phase velocity, ω is the angular frequency of Rayleigh waves, q is the unknown wave vector component along x_3 axis and $U_1, U_3, U_1^*, U_3^*, \boldsymbol{\Phi}, \boldsymbol{\Phi}^*$ are the associated wave amplitudes.

Using Eqs. (3.1)–(3.5), the following system is obtained.

$$\boldsymbol{\Gamma}\boldsymbol{G} = \boldsymbol{0}, \tag{3.6}$$

where $\boldsymbol{\Gamma}$ is a symmetric matrix given in Appendix A and $\boldsymbol{G} = [U_1, U_3, U_1^*, U_3^*, \boldsymbol{\Phi}, \boldsymbol{\Phi}^*]^T$.

The condition of the existence of the non-trivial solution of the homogeneous system (3.6) gives

$$k_1 q^{10} + k_2 q^8 + k_3 q^6 + k_4 q^4 + k_5 q^2 + k_6 = 0, \tag{3.7}$$

where the coefficients $k_1, k_2, \ldots, k_6$ are listed in Appendix A.

Principal
Dyal Singh College
KARNAL

The Eq. (3.7) gives ten complex values of q. For each $q_i (i = 1, 2, 3, \ldots, 10)$, the corresponding amplitude ratios are determined as

$$U'_{3i} = \frac{A(\Gamma_{62})_{q_i}}{A(\Gamma_{61})_{q_i}}, \quad U^{*\prime}_{1i} = \frac{A(\Gamma_{63})_{q_i}}{A(\Gamma_{61})_{q_i}}, \quad U^{*\prime}_{3i} = \frac{A(\Gamma_{64})_{q_i}}{A(\Gamma_{61})_{q_i}}, \quad \Phi'_i = \frac{A(\Gamma_{65})_{q_i}}{A(\Gamma_{61})_{q_i}}, \quad \Phi^{*\prime}_i = \frac{A(\Gamma_{66})_{q_i}}{A(\Gamma_{61})_{q_i}}, \tag{3.8}$$

where $A(\Gamma_{mn})_{q_i}$ refers to the cofactor of Γ_{mn} corresponding to q_i and

$$U'_{3i} = \frac{U_{3i}}{U_{1i}}, \; U^{*\prime}_{1i} = \frac{U^*_{1i}}{U_{1i}}, \; U^{*\prime}_{3i} = \frac{U^*_{3i}}{U_{1i}}, \; \Phi'_i = \frac{\Phi_i}{U_{1i}}, \; \Phi^{*\prime}_i = \frac{\Phi^*_i}{U_{1i}}. \tag{3.9}$$

The mechanical displacements and electrical potentials can then be written in the form

$$\begin{bmatrix} u_1 \\ u_3 \\ u^*_1 \\ u^*_3 \\ \phi \\ \phi^* \end{bmatrix} = \sum_{i=1}^{10} \begin{bmatrix} 1 \\ U'_{3i} \\ U^{*\prime}_{1i} \\ U^{*\prime}_{3i} \\ \Phi'_i \\ \Phi^{*\prime}_i \end{bmatrix} U_{1i} \; \exp(i\omega(\frac{x_1}{c} + q_i x_3 - t)). \tag{3.10}$$

The mechanical stresses and electric displacements can be expressed as

$$\begin{bmatrix} \sigma_{13} \\ \sigma_{33} \\ \sigma^* \\ D_3 \\ D^*_3 \end{bmatrix} = \sum_{i=1}^{10} \begin{bmatrix} \wp_{1i} \\ \wp_{2i} \\ \wp_{3i} \\ \wp_{4i} \\ \wp_{5i} \end{bmatrix} U_{1i} \; \exp(i\omega(\frac{x_1}{c} + q_i x_3 - t)), \tag{3.11}$$

where $\wp_{1i}, \wp_{2i}, \wp_{3i}, \wp_{4i}, \wp_{5i}$ are given in Eq. (A.2) in Appendix A.

3.1.1. Transfer matrix

The formal solutions for the field variables in the j^{th} porous piezoelectric layer can be written as

$$\boldsymbol{Y}^{(j)} = \boldsymbol{V}^{(j)} \boldsymbol{W}^{(j)} \boldsymbol{S}^{(j)}, \tag{3.12}$$

where $\boldsymbol{Y}^{(j)}, \boldsymbol{V}^{(j)}, \boldsymbol{W}^{(j)}$ and $\boldsymbol{S}^{(j)}$ are given in Appendix B.

The relation between the field vectors at the top of Ist layer and bottom of nth layer is given by

$$\boldsymbol{Y}^{(1)^-} = \boldsymbol{T}^* \boldsymbol{Y}^{(n)^+}, \tag{3.13}$$

where

$$\boldsymbol{T}^* = \boldsymbol{T}_1 \boldsymbol{T}_2 \ldots \boldsymbol{T}_n. \tag{3.14}$$

$\boldsymbol{T}^*$ is the global transfer matrix relating the field variables at the top and the bottom of the layered structure and

$$\boldsymbol{T}_j = \boldsymbol{V}^{(j)} \boldsymbol{W}^{(j)^-} (\boldsymbol{W}^{(j)^+})^{-1} (\boldsymbol{V}^{(j)})^{-1}. \tag{3.15}$$

$\boldsymbol{T}_j$ is the transfer matrix relating the field vectors at the top of the j^{th} layer to the bottom of the j^{th} layer. The matrix $(\boldsymbol{V}^{(j)})^{-1}$ is given in Appendix B.

3.2. For FGPPHS

The constitutive equations for the functionally graded porous piezoelectric medium are given by

$$\begin{aligned} \boldsymbol{\sigma}^f &= \boldsymbol{c}^f : \boldsymbol{\varepsilon}^f + \boldsymbol{m}^f \varepsilon^{*f} - \boldsymbol{e}^f \cdot \boldsymbol{E}^f - \boldsymbol{\zeta}^f \cdot \boldsymbol{E}^{*f}, \\ \sigma^{*f} &= \boldsymbol{m}^f : \boldsymbol{\varepsilon}^f + R^f \varepsilon^{*f} - \tilde{\boldsymbol{\zeta}}^f \cdot \boldsymbol{E}^f - \boldsymbol{e}^{*f} \cdot \boldsymbol{E}^{*f}, \\ \boldsymbol{D}^f &= \boldsymbol{e}^f : \boldsymbol{\varepsilon}^f + \tilde{\boldsymbol{\zeta}}^f \varepsilon^{*f} + \boldsymbol{\xi}^f \cdot \boldsymbol{E}^f + \boldsymbol{A}^f \cdot \boldsymbol{E}^{*f}, \\ \boldsymbol{D}^{*f} &= \boldsymbol{\zeta}^f : \boldsymbol{\varepsilon}^f + \boldsymbol{e}^{*f} \varepsilon^{*f} + \boldsymbol{A}^f \cdot \boldsymbol{E}^f + \boldsymbol{\xi}^{*f} \cdot \boldsymbol{E}^{*f}, \end{aligned} \tag{3.16}$$

Superscript f is used to differentiate the field variables and material parameters of FGPPHS from porous piezoelectric layers and here, elastic coefficients, piezoelectric coefficients and dielectric coefficients depend on x_3.

The equations of motion for the FGPPHS, in the absence of body forces and surface charge density, are given by

$$\begin{aligned} \nabla \cdot \boldsymbol{\sigma}^f &= \boldsymbol{\rho}^{11f} \cdot \ddot{\boldsymbol{u}}^f + \boldsymbol{\rho}^{12f} \cdot \ddot{\boldsymbol{u}}^{*f} + \boldsymbol{b}^f \cdot (\dot{\boldsymbol{u}}^f - \dot{\boldsymbol{u}}^{*f}), \\ \nabla \sigma^{*f} &= \boldsymbol{\rho}^{12f} \cdot \ddot{\boldsymbol{u}}^f + \boldsymbol{\rho}^{22f} \cdot \ddot{\boldsymbol{u}}^{*f} - \boldsymbol{b}^f \cdot (\dot{\boldsymbol{u}}^f - \dot{\boldsymbol{u}}^{*f}), \\ \nabla \cdot \boldsymbol{D}^f &= \boldsymbol{0}, \\ \nabla \cdot \boldsymbol{D}^{*f} &= \boldsymbol{0}. \end{aligned} \tag{3.17}$$

Let us assume that the material characteristics vary exponentially along the thickness direction.

$$\begin{aligned} \boldsymbol{c}^f &= \boldsymbol{c}^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{m}^f = \boldsymbol{m}^{\boldsymbol{0}} e^{\alpha x_3}, \quad R^f = R^0 e^{\alpha x_3}, \\ \boldsymbol{e}^f &= \boldsymbol{e}^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{e}^{*f} = \boldsymbol{e}^{*\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{\zeta}^f = \boldsymbol{\zeta}^{\boldsymbol{0}} e^{\alpha x_3}, \quad \tilde{\boldsymbol{\zeta}}^f = \tilde{\boldsymbol{\zeta}}^{\boldsymbol{0}} e^{\alpha x_3}, \\ \boldsymbol{\xi}^f &= \boldsymbol{\xi}^{\boldsymbol{0}} e^{\alpha x_3}, \boldsymbol{A}^f = \boldsymbol{A}^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{\xi}^{*f} = \boldsymbol{\xi}^{*\boldsymbol{0}} e^{\alpha x_3}, \\ \boldsymbol{\rho}^{11f} &= (\boldsymbol{\rho}^{11f})^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{\rho}^{12f} = (\boldsymbol{\rho}^{12f})^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{\rho}^{22f} = (\boldsymbol{\rho}^{22f})^{\boldsymbol{0}} e^{\alpha x_3}, \quad \boldsymbol{b}^f = \boldsymbol{b}^{\boldsymbol{0}} e^{\alpha x_3}, \end{aligned} \tag{3.18}$$

Principal
Dyal Singh College
KARNAL

where α is the grading coefficient.

Let the solutions of equations of motion in the FGPPHS be expressed as

$$\begin{bmatrix} u_1^f \\ u_3^f \\ u_1^{*f} \\ u_3^{*f} \\ \phi^f \\ \phi^{*f} \end{bmatrix} = \begin{bmatrix} U_1^f \\ U_3^f \\ U_1^{*f} \\ U_3^{*f} \\ \Phi^f \\ \Phi^{*f} \end{bmatrix} \exp(i\omega(\frac{x_1}{c} + q^f x_3 - t)), \tag{3.19}$$

where q^f is the unknown wave vector component along x_3 axis and $U_1^f, U_3^f, U_1^{*f}, U_3^{*f}, \Phi^f, \Phi^{*f}$ are the associated wave amplitudes.

Using Eqs. (3.16)–(3.19), we get a homogeneous system

$$\boldsymbol{\Gamma}^f \boldsymbol{G}^f = \boldsymbol{0}, \tag{3.20}$$

where the elements of $\boldsymbol{\Gamma}^f$ are given in Eq. (C.1) in Appendix C and $\boldsymbol{G}^f = [U_1^f, U_3^f, U_1^{*f}, U_3^{*f}, \Phi^f, \Phi^{*f}]^T$.

The determinant of coefficient matrix $\boldsymbol{\Gamma}^f$ vanishes for the non-trivial solution, resulting in

$$t_1(q^f)^{10} + t_2(q^f)^9 + t_3(q^f)^8 + t_4(q^f)^7 + t_5(q^f)^6 + t_6(q^f)^5 + t_7(q^f)^4 + t_8(q^f)^3 + t_9(q^f)^2 + t_{10}(q^f) + t_{11} = 0, \tag{3.21}$$

where the coefficients $t_i (i = 1, 2, 3, \ldots, 11)$ are written in Appendix C.

The Eq. (3.21) gives ten complex values of wave vector q^f. In the half-space $x_3 \geq h$, those five roots $q_i^f (i = 1, 2, 3, \ldots, 5)$ are retained that causing the displacement amplitude to decay with increasing depth.

For each $q_i^f (i = 1, 2, 3, \ldots, 5)$, the associated eigenvectors $U_{1i}^f, U_{3i}^f, U_{1i}^{*f}, U_{3i}^{*f}, \Phi_i{}^f, \Phi_i^{*f}$ can be obtained as

$$U_{3i}^{f\prime} = \frac{A(\Gamma_{62}^f)_{q_i}}{A(\Gamma_{61}^f)_{q_i}}, \quad U_{1i}^{*f\prime} = \frac{A(\Gamma_{63}^f)_{q_i}}{A(\Gamma_{61}^f)_{q_i}}, \quad U_{3i}^{*f\prime} = \frac{A(\Gamma_{64}^f)_{q_i}}{A(\Gamma_{61}^f)_{q_i}}, \Phi_i{}^{f\prime} = \frac{A(\Gamma_{65}^f)_{q_i}}{A(\Gamma_{61}^f)_{q_i}}, \Phi_i^{*f\prime} = \frac{A(\Gamma_{66}^f)_{q_i}}{A(\Gamma_{61}^f)_{q_i}}, \tag{3.22}$$

where

$$U_{3i}^{f\prime} = \frac{U_{3i}^f}{U_{1i}^f}, \; U_{1i}^{*f\prime} = \frac{U_{1i}^{*f}}{U_{1i}^f}, \; U_{3i}^{*f\prime} = \frac{U_{3i}^{*f}}{U_{1i}^f}, \; \Phi_i^{f\prime} = \frac{\Phi_i^f}{U_{1i}^f}, \; \Phi_i^{*f\prime} = \frac{\Phi_i^{*f}}{U_{1i}^f}, \tag{3.23}$$

and $A(\Gamma_{ij}^f)_{q_i}$ signifies the cofactor of Γ_{ij}^f corresponding to the eigen value q_i.

Thus, the mechanical displacements and electrical potentials in the FGPPHS can be written as

$$\begin{bmatrix} u_1^f \\ u_3^f \\ u_1^{*f} \\ u_3^{*f} \\ \phi^f \\ \phi^{*f} \end{bmatrix} = \sum_{i=1}^{5} \begin{bmatrix} 1 \\ U_{3i}^{f\prime} \\ U_{1i}^{*f\prime} \\ U_{3i}^{*f\prime} \\ \Phi_i{}^{f\prime} \\ \Phi_i^{*f\prime} \end{bmatrix} U_{1i}^f \; \exp(i\omega(\frac{x_1}{c} + q^f x_3 - t)). \tag{3.24}$$

Stresses and electric displacements in the FGPPHS can be expressed as

$$\begin{bmatrix} \sigma_{31}^f \\ \sigma_{33}^f \\ \sigma^{*f} \\ D_3^f \\ D_3^{*f} \end{bmatrix} = \sum_{i=1}^{5} \begin{bmatrix} \wp_{1i}^f \\ \wp_{2i}^f \\ \wp_{3i}^f \\ \wp_{4i}^f \\ \wp_{5i}^f \end{bmatrix} U_{1i}^f \; \exp(i\omega(\frac{x_1}{c} + q^f x_3 - t)), \tag{3.25}$$

where $\wp_{1i}^f, \ldots, \wp_{5i}^f$ are given in Eq. (D.1) in Appendix D.

The relation between the mechanical displacements, electrical potentials, electric displacements, and mechanical stresses in the FGPPHS and the wave amplitudes corresponding to FGPPHS can be written as

$$\boldsymbol{Y}^f = \boldsymbol{T}^f \boldsymbol{S}^f, \tag{3.26}$$

Principal
Dyal Singh College
KARNAL

where

$$\boldsymbol{Y}^f=\begin{bmatrix} u_1^f \\ u_3^f \\ u_3^{*f} \\ \sigma_{33}^f \\ \phi^f \\ D_3^f \\ \sigma^{*f} \\ \sigma_{13}^f \\ \phi^{*f} \\ D_3^{*f} \end{bmatrix}, \boldsymbol{T}^f=\begin{bmatrix} \Xi_1^f & \Xi_2^f & \Xi_3^f & \Xi_4^f & \Xi_5^f \\ U_{31}^{f'}\Xi_1^f & U_{32}^{f'}\Xi_2^f & U_{33}^{f'}\Xi_3^f & U_{34}^{f'}\Xi_4^f & U_{35}^{f'}\Xi_5^f \\ U_{31}^{*f'}\Xi_1^f & U_{32}^{*f'}\Xi_2^f & U_{33}^{*f'}\Xi_3^f & U_{34}^{*f'}\Xi_4^f & U_{35}^{*f'}\Xi_5^f \\ \wp_{21}^f\Xi_1^f & \wp_{22}^f\Xi_2^f & \wp_{23}^f\Xi_3^f & \wp_{24}^f\Xi_4^f & \wp_{25}^f\Xi_5^f \\ \boldsymbol{\Phi}_1^{f'}\Xi_1^f & \boldsymbol{\Phi}_2^{f'}\Xi_2^f & \boldsymbol{\Phi}_3^{f'}\Xi_3^f & \boldsymbol{\Phi}_4^{f'}\Xi_4^f & \boldsymbol{\Phi}_5^{f'}\Xi_5^f \\ \wp_{41}^f\Xi_1^f & \wp_{42}^f\Xi_2^f & \wp_{43}^f\Xi_3^f & \wp_{44}^f\Xi_4^f & \wp_{45}^f\Xi_5^f \\ \wp_{31}^f\Xi_1^f & \wp_{32}^f\Xi_2^f & \wp_{33}^f\Xi_3^f & \wp_{34}^f\Xi_4^f & \wp_{35}^f\Xi_5^f \\ \wp_{11}^f\Xi_1^f & \wp_{12}^f\Xi_2^f & \wp_{13}^f\Xi_3^f & \wp_{14}^f\Xi_4^f & \wp_{15}^f\Xi_5^f \\ \boldsymbol{\Phi}_1^{*f'}\Xi_1^f & \boldsymbol{\Phi}_2^{*f'}\Xi_2^f & \boldsymbol{\Phi}_3^{*f'}\Xi_3^f & \boldsymbol{\Phi}_4^{*f'}\Xi_4^f & \boldsymbol{\Phi}_5^{*f'}\Xi_5^f \\ \wp_{51}^f\Xi_1^f & \wp_{52}^f\Xi_2^f & \wp_{53}^f\Xi_3^f & \wp_{54}^f\Xi_4^f & \wp_{55}^f\Xi_5^f \end{bmatrix}, \boldsymbol{S}^f=\begin{bmatrix} U_{11}^f \\ U_{12}^f \\ U_{13}^f \\ U_{14}^f \\ U_{15}^f \end{bmatrix}, \tag{3.27}$$

$$\Xi_i^f = exp(i\omega q_i^f h), (i=1,2,\ldots,5).$$

By invoking the conditions of continuity of mechanical displacements, electric potentials, electric displacements, and mechanical stresses at the interface of the n^{th} layer and the FGPPHS and also using the Eqs. (3.13) and (3.26), we have

$$\boldsymbol{Y}^{(1)^-}=\mathfrak{T}\boldsymbol{S}^f, \tag{3.28}$$

where $\mathfrak{T}=\boldsymbol{T}^*\boldsymbol{T}^f$.

4. Boundary conditions and frequency equations

Mechanical Boundary Conditions

The mechanical boundary conditions at $x_3=0$ can be expressed as

$$\begin{aligned} &(i)\ \sigma_{13}=0, \\ &(ii)\ \sigma_{33}=0, \\ &(iii)\ \sigma^*=0. \end{aligned} \tag{4.1}$$

Electrical Boundary Conditions

(a) The electrical boundary conditions used for the open surface case is an approximate. The normal component of the electric displacement is assumed to be zero rather than continuous, in other words, the electric displacement in vacuum is neglected which leads to the boundary conditions at $x_3=0$, as [53]

$$\begin{aligned} &(i)\ D_3=0, \\ &(ii)\ D_3^*=0. \end{aligned} \tag{4.2}$$

(b) The electrical boundary conditions at $x_3=0$, when boundary is electrically shorted can be written as

$$\begin{aligned} &(i)\ \phi=0, \\ &(ii)\ \phi^*=0. \end{aligned} \tag{4.3}$$

In case of electrically open boundary at $x_3=0$, Eqs. (3.28), (4.1) and (4.2) yield the frequency equation of Rayleigh wave as

$$\begin{vmatrix} \mathfrak{T}(4,1) & \mathfrak{T}(4,2) & \mathfrak{T}(4,3) & \mathfrak{T}(4,4) & \mathfrak{T}(4,5) \\ \mathfrak{T}(7,1) & \mathfrak{T}(7,2) & \mathfrak{T}(7,3) & \mathfrak{T}(7,4) & \mathfrak{T}(7,5) \\ \mathfrak{T}(8,1) & \mathfrak{T}(8,2) & \mathfrak{T}(8,3) & \mathfrak{T}(8,4) & \mathfrak{T}(8,5) \\ \mathfrak{T}(6,1) & \mathfrak{T}(6,2) & \mathfrak{T}(6,3) & \mathfrak{T}(6,4) & \mathfrak{T}(6,5) \\ \mathfrak{T}(10,1) & \mathfrak{T}(10,2) & \mathfrak{T}(10,3) & \mathfrak{T}(10,4) & \mathfrak{T}(10,5) \end{vmatrix}=0, \tag{4.4}$$

where $\mathfrak{T}(r,s)$ represents the element in the r^{th} row and s^{th} column of $\mathfrak{T}$.

The following frequency equation of the Rayleigh wave is given by Eqs. (3.28), (4.1) and (4.3) when the boundary $x_3=0$ is electrically shorted.

$$\begin{vmatrix} \mathfrak{T}(4,1) & \mathfrak{T}(4,2) & \mathfrak{T}(4,3) & \mathfrak{T}(4,4) & \mathfrak{T}(4,5) \\ \mathfrak{T}(7,1) & \mathfrak{T}(7,2) & \mathfrak{T}(7,3) & \mathfrak{T}(7,4) & \mathfrak{T}(7,5) \\ \mathfrak{T}(8,1) & \mathfrak{T}(8,2) & \mathfrak{T}(8,3) & \mathfrak{T}(8,4) & \mathfrak{T}(8,5) \\ \mathfrak{T}(5,1) & \mathfrak{T}(5,2) & \mathfrak{T}(5,3) & \mathfrak{T}(5,4) & \mathfrak{T}(5,5) \\ \mathfrak{T}(9,1) & \mathfrak{T}(9,2) & \mathfrak{T}(9,3) & \mathfrak{T}(9,4) & \mathfrak{T}(9,5) \end{vmatrix}=0. \tag{4.5}$$

5. Validation of methodology and numerical computation

To validate the methodology and numerical results of the present problem, comparisons are made with the available results. The considered model has been reduced to the following cases for the sake of methodology and code validation:

Principal
Dyal Singh College
KARNAL

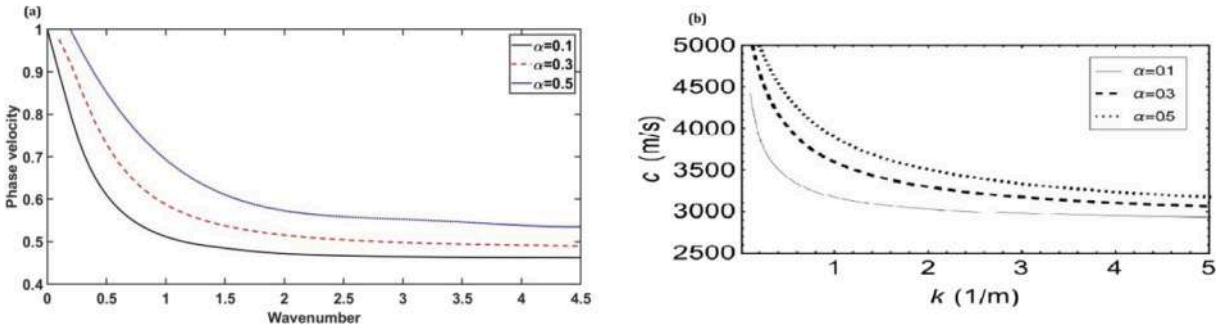


Fig. 2. Comparison of dispersion curves (a) results from present method; (b) results from [55].

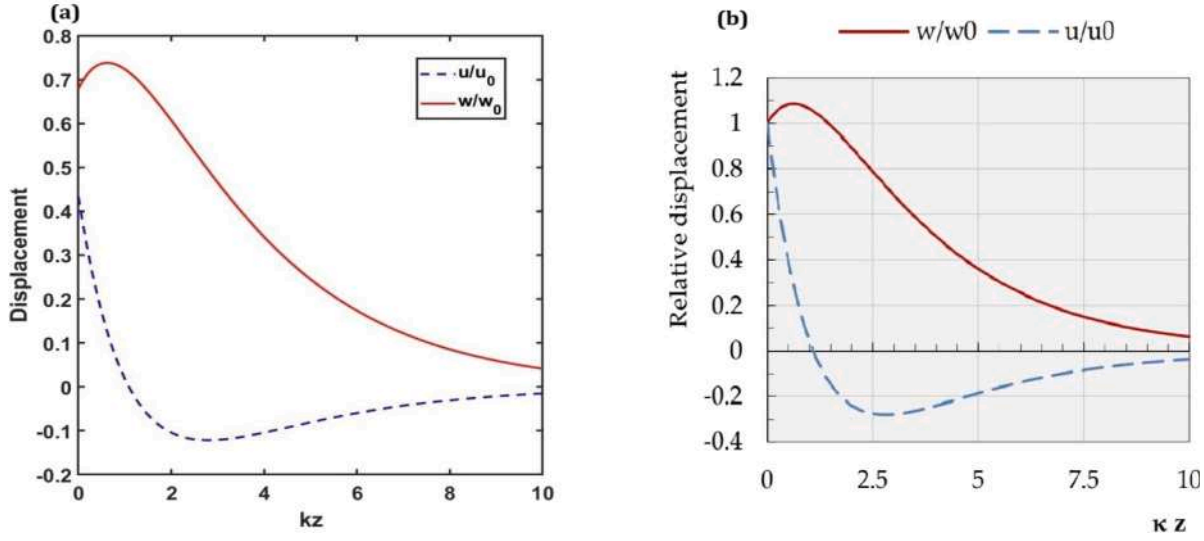


Fig. 3. Variation of displacement with depth (a) author's result; (b) result from [56].

(i) If porous piezoelectric layers are removed and we take $\boldsymbol{m}^f = \boldsymbol{0}, R^f = 0, \boldsymbol{\zeta}^f = \boldsymbol{0}, \boldsymbol{e}^{*f} = \boldsymbol{0}, \tilde{\boldsymbol{\zeta}}^f = \boldsymbol{0}, \boldsymbol{\xi}^{*f} = \boldsymbol{0}, \boldsymbol{A}^f = \boldsymbol{0}$, then the present model reduces to FGPM half-space and constitutive equations corresponding to FGPPHS reduce to those for FGPM half-space. The outcomes in this instance are consistent with [54].

(ii) If in addition to (i), we take $\boldsymbol{e}^f = \boldsymbol{0}$, $\boldsymbol{\xi}^f = \boldsymbol{0}$, then the FGPM half-space reduces to functionally graded half-space. Plots of dispersion curves of Rayleigh waves in FGM half-space using the present approach are plotted (Fig. 2(a)) and a comparison is made with available results (Fig. 2(b)). The results from the method proposed in this paper are in qualitative agreement, analytically and numerically, with the results of [55] which validates the accuracy of the present method.

(iii) Further, the model obtained in (ii) reduces to non-graded elastic half-space by taking $\alpha = 0$ and displacement curves are plotted with depth and a comparison between the obtained results and the published results [56] is provided in Fig. 3. The graphs obtained closely aligns with the graph presented in the [56]. Furthermore, results obtained also exhibit strong agreement with the results provided in the study by Rose [57].

(iv) To verify the correctness of obtained results, displacement and dispersion curves are plotted for structure having elastic layer above elastic half-space by reducing the proposed model and the graphs obtained are compared with the available results. In Fig. 4, we present the variations of displacement curves with depth, and in Fig. 5, we illustrate dispersion curves. The findings of the study are in accordance with the displacement and dispersion curves reported by [58]. Specifically, the displacement curves derived by reducing our model (Fig. 4(a)) align well with those obtained by [59].

6. Results and discussions

The three porous piezoelectric layers are made of Barium Titanate Crystal(BTC), PZT-5H, and PZT-7H and the material BTC is considered as the FGPPHS for numerical computation. The material parameters are presented in Tables 1–4 [60,61].

Rayleigh wave dispersion curves for electrically short and open boundaries are depicted in Fig. 6. The phase velocity of Rayleigh waves is seen to decrease with wavenumber. For small values of the wave number, the wave is highly dispersive, but its dispersion decreases with the increase of the wave number. It is further observed that the phase velocity of Rayleigh waves in the electrically short case is lower than that of the electrically open case. This is due to the fact that in an electrically short case, a metal film deposited on the surface eliminates the tangential electric field, and thus partially suppresses the piezoelectricity of the materials [62]. In the case of electrically open boundary conditions, the electric field that accompanies the wave remains active, involves a rigidity of the material, and hence increases the velocity of Rayleigh wave [63]. The circular frequency is related to the phase velocity of the Rayleigh wave by the relation c=ω/k. For a particular value of wavenumber (k), phase velocity is

Principal
Dyal Singh College
KARNAL

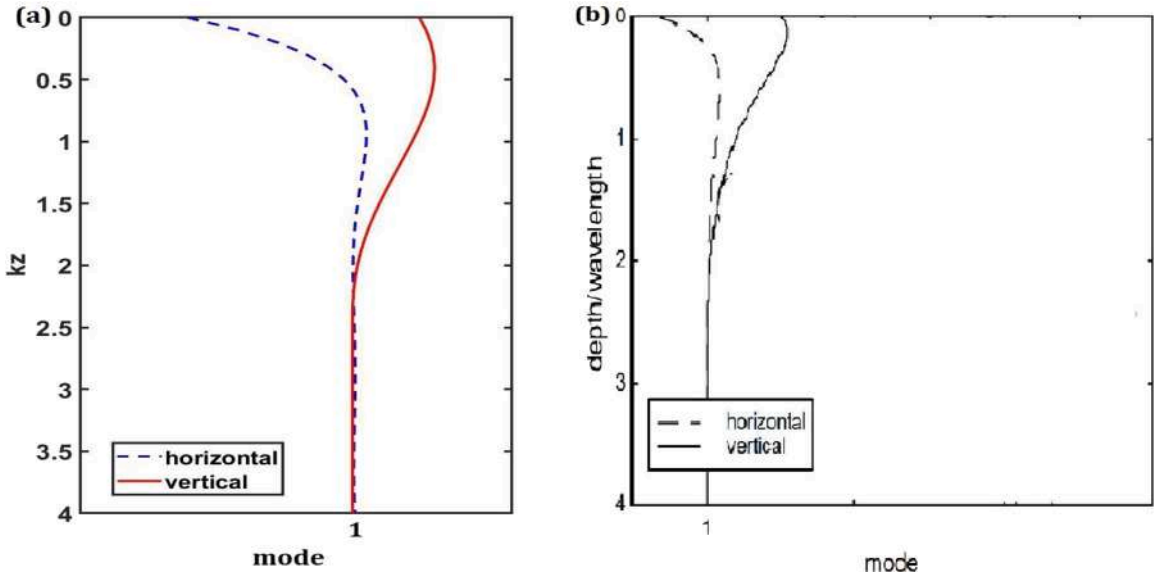


Fig. 4. Variation of displacement with depth (a) author's result; (b) result from [58].

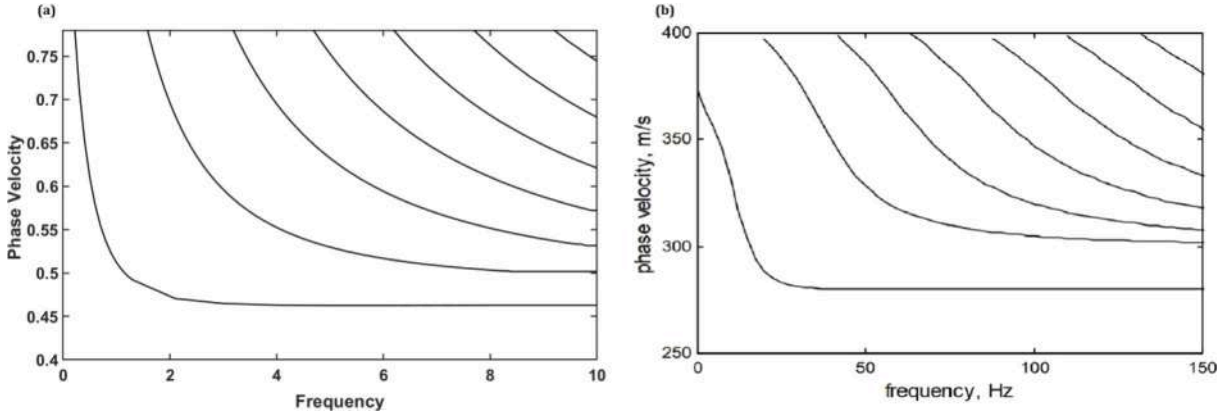


Fig. 5. Comparison of dispersion curves (a) results from present method; (b) results from [58].

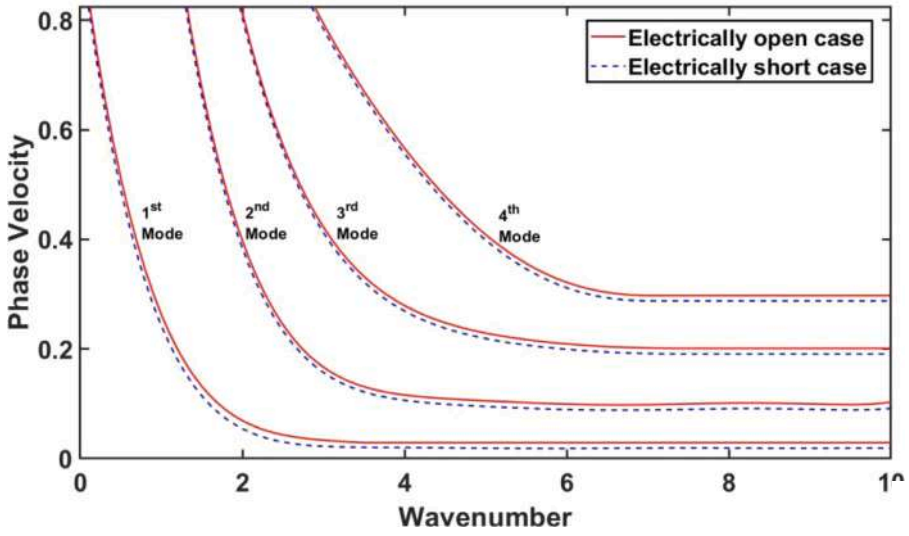


Fig. 6. Variation of phase velocity with wavenumber when $\alpha = 100$.

Principal
Dyal Singh College
KARNAL

Table 1
Material parameters of Barium Titanate Crystal.

Elastic parameters 10^9 N/m^2	c_{11}	c_{12}	c_{13}	c_{33}	c_{44}	m_{11}	m_{33}	R
	150.4	65.63	65.94	145.5	43.86	8.8	5.2	20
Piezoelectric parameters C/m^2	e_{15}	e_{31}	e_{33}	ζ_{15}	ζ_{31}	ζ_{33}	e_3^*	$\tilde{\zeta}_3$
	11.4	−4.32	17.4	4.56	−1.728	6.96	−3.6	−7.5
Dielectric parameters 10^{-9} F/m	ξ_{11}	ξ_{33}	ξ_{11}^*	ξ_{33}^*	A_{11}	A_{33}		
	10.8	13.1	11.8	13.9	12.8	15.1		

Table 2
Material parameters of PZT-5H crystal.

Elastic parameters 10^9 N/m^2	c_{11}	c_{12}	c_{13}	c_{33}	c_{44}	m_{11}	m_{33}	R
	127.2	80.21	84.67	117.4	22.99	8.8	5.2	20
Piezoelectric parameters C/m^2	e_{15}	e_{31}	e_{33}	ζ_{15}	ζ_{31}	ζ_{33}	e_3^*	$\tilde{\zeta}_3$
	17	−6.62	23.2	3.36	−0.8	5.76	−3.6	−7.5
Dielectric parameters 10^{-9} F/m	ξ_{11}	ξ_{33}	ξ_{11}^*	ξ_{33}^*	A_{11}	A_{33}		
	27.71	30.1	11.8	13.9	12.8	15.1		

Table 3
Material parameters of PZT-7H crystal.

Elastic parameters 10^9 N/m^2	c_{11}	c_{12}	c_{13}	c_{33}	c_{44}	m_{11}	m_{33}	R
	148	76.2	74.2	131	25.3	8.8	5.2	20
Piezoelectric parameters C/m^2	e_{15}	e_{31}	e_{33}	ζ_{15}	ζ_{31}	ζ_{33}	e_3^*	$\tilde{\zeta}_3$
	9.3	−2.324	10.99	2.72	−0.48	5.32	−3.6	−7.5
Dielectric parameters 10^{-9} F/m	ξ_{11}	ξ_{33}	ξ_{11}^*	ξ_{33}^*	A_{11}	A_{33}		
	3.984	2.081	11.8	13.9	12.8	15.1		

Table 4
Mass density coefficients, permeability tensors and remaining parameters for porous piezoelectric layers and FGPPHS.

Dynamical coefficients kg/m^3	ρ_{11}^{11}/ρ	ρ_{33}^{11}/ρ	ρ_{11}^{12}/ρ	ρ_{33}^{12}/ρ	ρ_{11}^{22}/ρ	ρ_{33}^{22}/ρ
	0.66	0.64	−0.15	−0.13	0.66	0.64
Permeability tensors m^2	χ_{11}	χ_{33}				
	2.5×10^{-10}	4.5×10^{-10}				
Density kg/m^3	$\rho(BTC)$	$\rho(PZT-5H)$	$\rho(PZT-7H)$	ρ_f	ρ^*	
	5700	7500	7700	1000	1000	
Remaining parameters	μ(Ns/m^2)	f	c_f(m/s)	$\bar{\nu}$(MHz)		
	1×10^{-3}	0.2	1500	1		

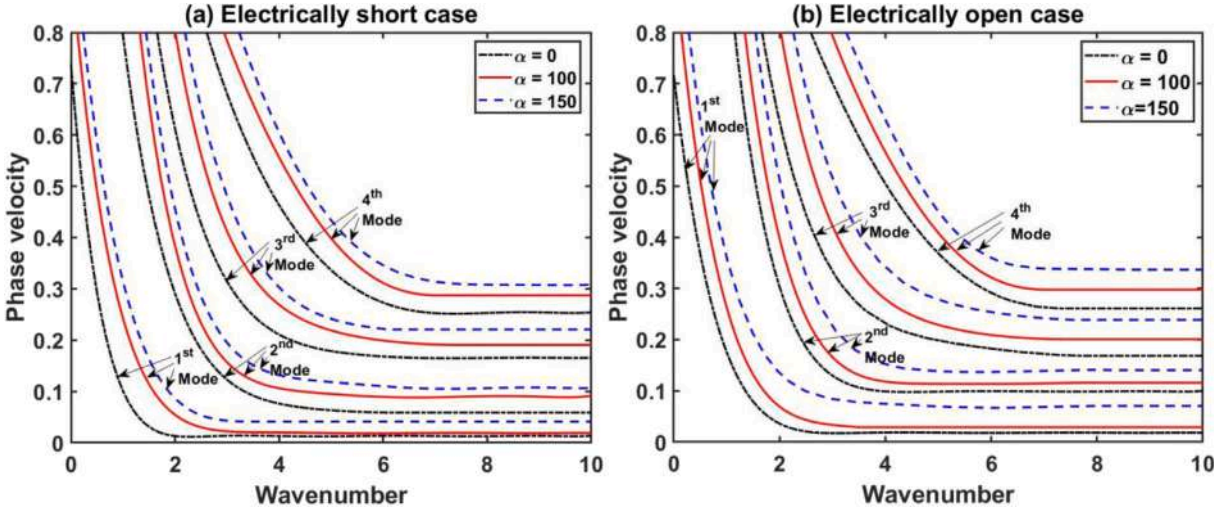


Fig. 7. Effect of gradation on phase velocity curves (a) electrically short case; (b) electrically open case.

Principal
Dyal Singh College
KARNAL

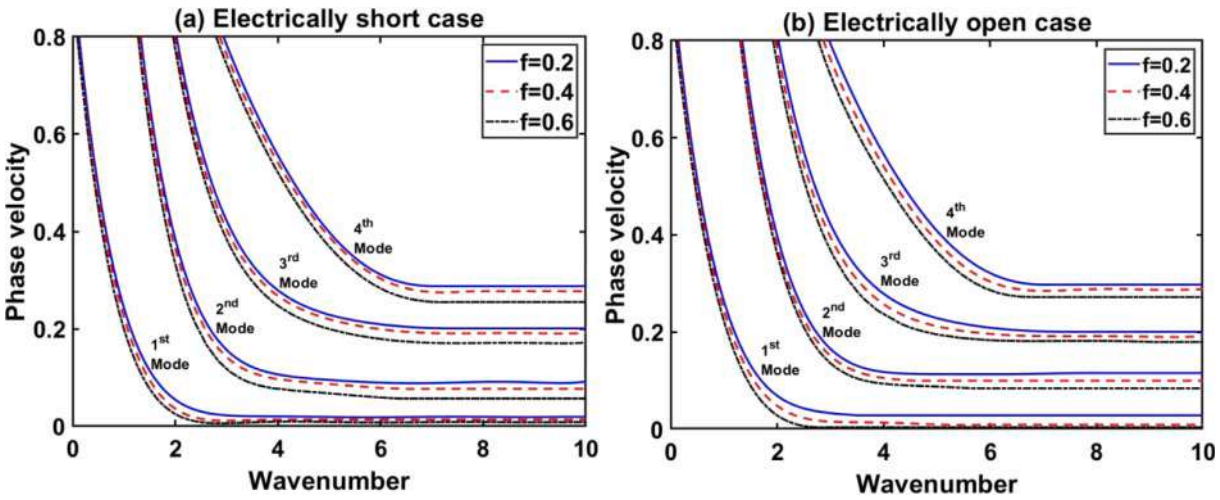


Fig. 8. Effect of porosity on phase velocity curves (a) electrically short case; (b) electrically open case.

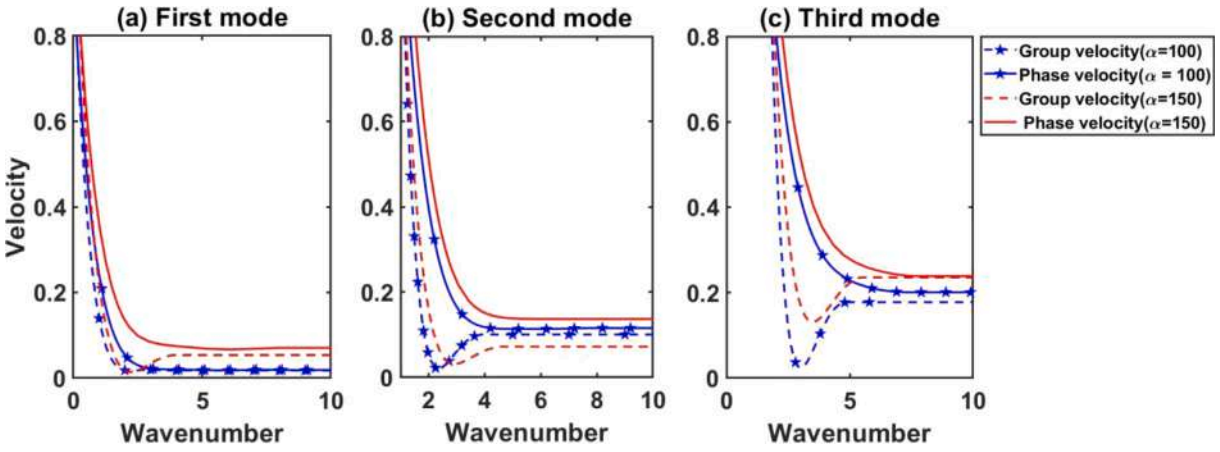


Fig. 9. Variation of phase velocity and group velocity with wavenumber for different grade coefficients in an electrically open case.

directly proportional to circular frequency. Therefore, the circular frequency of the Rayleigh waves in the electrically short case is lower than that of the electrically open case.

Fig. 7 illustrates the impact of the grade coefficient on the dispersion curves in electrically short and open boundaries. It is found that as grade coefficient α increases, phase velocity increases. In the absence of gradation in the half-space, denoted by $\alpha = 0$, the functionally graded porous piezoelectric half-space reverts to a porous piezoelectric half-space. In this scenario, it is observed that the phase velocity of Rayleigh waves in the non-graded half-space is lower than that in the functionally graded half-space. The increase in grade coefficient involves a change in material properties which increases the rigidity of the material and leads to an increase in phase velocity. Therefore, the dispersive characteristics of the Rayleigh wave can be modified by changing the grade coefficient. This result is crucial for the advancement of surface acoustic wave devices. It is remarked that the influence of gradation on dispersion curves is more noticeable in the case of the electrically open boundary as α increases from 100 to 150.

The effect of porosity on dispersion curves of Rayleigh waves for electrically short boundary and open boundary is depicted in Fig. 8. It can be seen that as porosity increases, the phase velocity of Rayleigh waves decreases for a fixed wavenumber. The decrease in the phase velocity with increasing porosity can be explained by the change in the effective mechanical properties of the material. Porosity introduces voids or air pockets within the material so that the increase in the porosity of a medium decreases the shear modulus of the medium and in turn, decreases the phase speed of the Rayleigh wave [64].

Fig. 9 shows the variation of phase velocity and group velocity with wavenumber for different values of α in an electrically open case corresponding to different modes of propagation. Fig. 9(a), 9(b), and 9(c) represent the phase and group velocities curves for the first, second, and third modes respectively. The graphic shows that, as the wavenumber increases group velocity decreases. The group velocity of Rayleigh waves is less than the phase velocity. The phase velocity and group velocity of each mode of Rayleigh waves tend to coincide for higher wavenumbers. This is expected from the relation between the group velocity and phase velocity also. It is also revealed that as grade coefficient α increases, phase velocity and group velocity increase. The effect of the grading coefficient is more prominent in the case of the electrically open boundary. Plots for electrically shorted boundary are therefore not presented.

The effect of the number of porous piezoelectric layers overlying FGGPHS on the dispersion curves in the electrically short case is demonstrated in Fig. 10. Dispersion curves for a single porous piezoelectric layer, three porous piezoelectric layers, six porous piezoelectric layers and nine porous piezoelectric layers above FGPPHS are plotted. It is observed that as the count of porous piezoelectric layers above FGPPHS increases from 1 to 3

Principal
Dyal Singh College
KARNAL

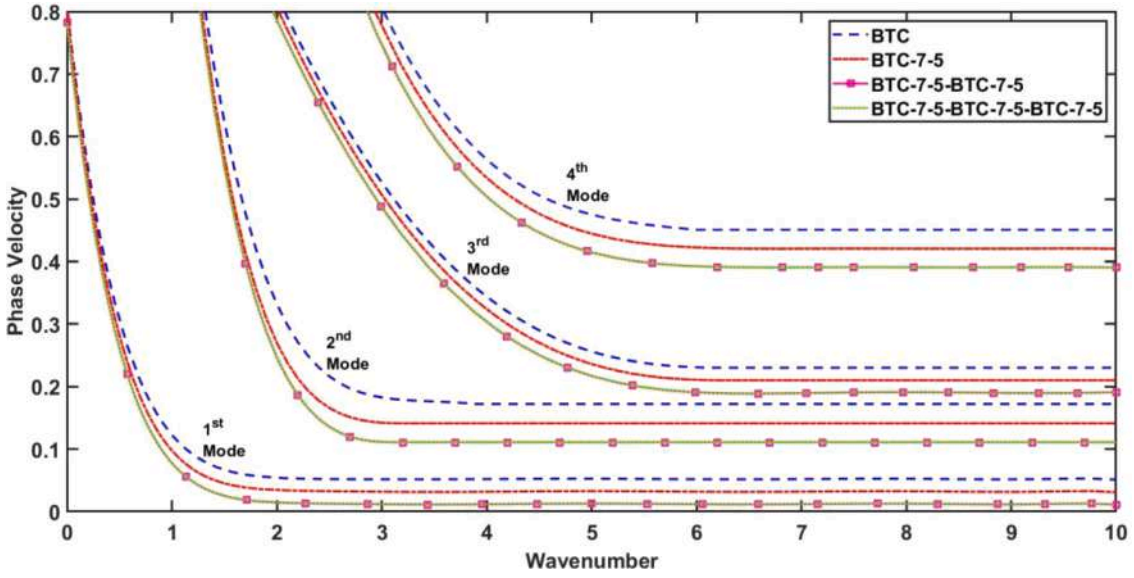


Fig. 10. Effect of layering on phase velocity curves in electrically short case.

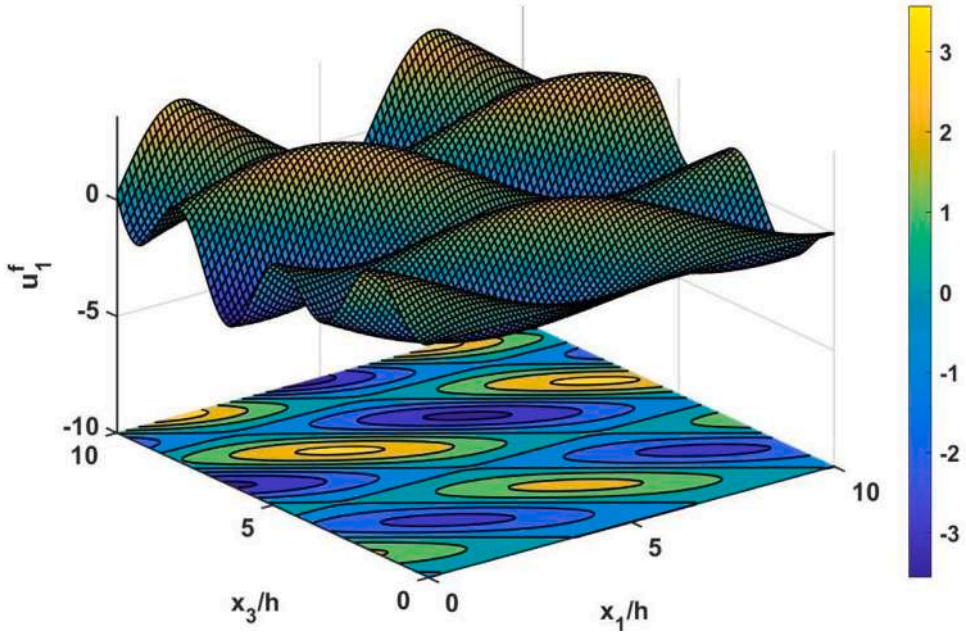


Fig. 11. Three dimensional surface and contour plot of variation of u_1^f in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and from 3 to 6, phase velocity decreases. When a wave travels through a layered structure with a large number of layers, more energy is trapped in the stack which results in a decrease in phase velocity. An increase in the number of layers increases the thickness of porous piezoelectric material above FGPPHS. This observation is in agreement with a similar result [65] where a decrease in phase velocity with the increase in thickness of the layer is reported. An additional increase in layers from 6 to 9 does not affect the phase velocity curves. Thus, the initial rise in the layer stack is more significant. A similar effect of the number of porous piezoelectric layers on phase velocity curves is observed in the electrically open case, therefore, not depicted here.

The 3D and contour plot of displacement field u_1^f in the lateral and along the vertical direction is exhibited in Fig. 11 for the electrically short boundary. The yellow-coloured area in the figure represents large values, and the blue area represents small values. The figure shows that the displacement is zero when $x_3 = 0$ and as x_3 increases displacement exhibits sinusoidal behaviour along the wave propagation direction. The maximum value of displacement is observed at $x_1 = 2.8, x_3 = 6.6$. From the contour plot, elliptical motion in the vertical plane along the direction of travel is noted. It is found that the behaviour of displacement field u_1^f in the electrically open case is identical to that of the short case but the magnitude of displacement increases in the electrically open case implying that waves in the case of electrically open boundary carry more energy in comparison to the shorted one. In electrical open boundary, there are minimal constraints on the movement of charge which implies that the piezoelectric material can deform more easily, resulting in greater mechanical displacement.

Principal
Dyal Singh College
KARNAL

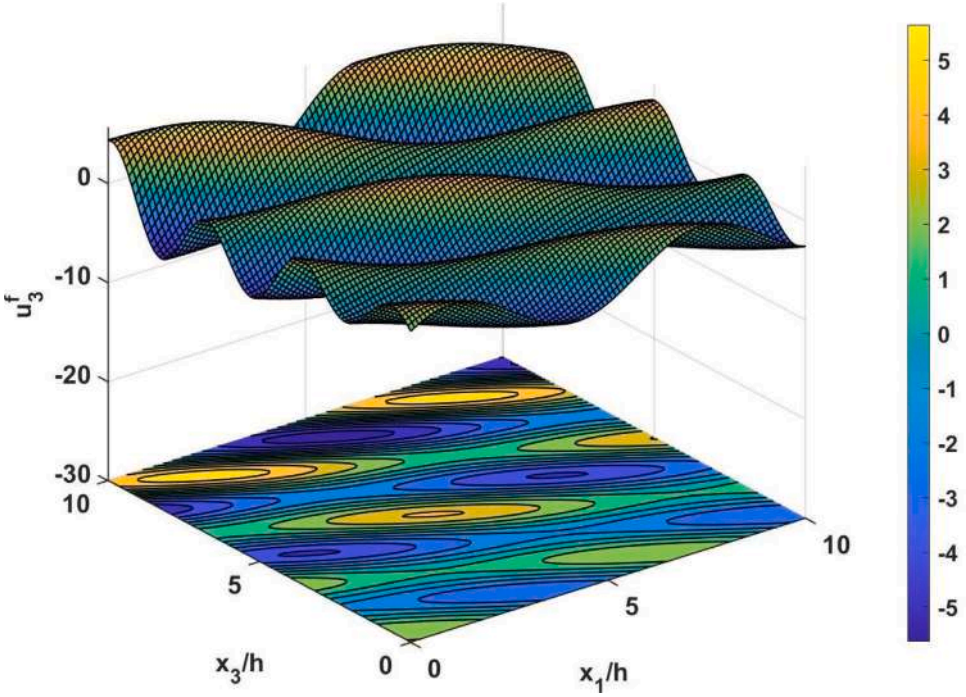


Fig. 12. Three-dimensional surface and contour plot of variation of u_3^f in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 12 delineates the variation of mechanical displacement u_3^f in the horizontal and vertical direction for the electrically open boundary. When examined in the x_3 direction, mechanical displacement is seen to behave sinusoidally. It was found that the magnitude of displacement increases significantly in the electrically open case as compared to the short case and this difference is primarily due to the boundary. In the electrically open case, there is no closed electrical circuit or a high-impedance termination, so the electric field that accompanies the wave remains active. This electric field leads to a significant voltage gradient across the material thickness which further exerts a significant vertical (up and down) force on the material's surface, leading to pronounced mechanical displacement in the upward and downward directions whereas in the electrically short case, the electric field is dissipated by the closed circuit. As a result, the associated vertical component of motion is weaker compared to the electrically open case. Therefore, the plot for an electrically open boundary is shown here. The contour plot reveals elliptical motion along the path of travel in the vertical plane. On making the comparison with the contour plot of the electrically shorted boundary, it was observed that the wave is more elliptically polarized in the case of the electrically open boundary as compared to the electrically shorted boundary.

Variation of mechanical displacement u_1^{*f} in the direction of propagation of wave and direction perpendicular to the propagation direction is sketched in Fig. 13 for the electrically short boundary. The behaviour of u_1^{*f} is found to be sinusoidal when viewed along x_3 direction and when examined from x_1 direction, it is noted that u_1^{*f} first increases and then decreases. An increase in magnitude was observed in electrically open boundary but wave packets are found to be more elliptic in shape in electrically short case.

The fluctuation of mechanical displacement u_3^{*f} in the longitudinal and transverse directions for an electrically open case is shown in Fig. 14. Waves are more elliptically polarized in electrically short case while in electrically open case that tends to be more linear. A significant increase in magnitude is observed in the electrically open boundary as compared to the electrically short case. On comparing Figs. 12 and 14, it is observed that the vertical component of mechanical displacement is more elliptically polarized in the solid phase as compared to the fluid phase of porous aggregate. A significant difference in the magnitude of displacement in the solid phase and fluid phase of porous aggregate is observed. The fundamental cause of the observed variance in elliptical polarization between the vertical components of mechanical displacement in the solid and fluid phases of a porous aggregate is the transversely isotropic nature of the solid phase. An elliptical polarization pattern develops as Rayleigh waves pass through the solid phase is due to the anisotropy which causes intricate interactions. The fluid phase properties in contrast to the solid phase simplify the behaviour and result in more linear polarization in the fluid phase.

Figs. 15 and 16 show the variation of electrical potential ϕ^f along the wave propagation direction and in a direction perpendicular to the propagation direction in the electrically short case and electrically open case respectively. The polarizations are shown in the corresponding contour plots. It is observed that electrical potential in the electrically open case shows sinusoidal behaviour. It can be seen from contour plots that the electrical potential in an electrically short case is more elliptically polarized as compared to an electrically open case. The reason behind the difference in electric potential in the different boundaries is due to the difference in electrical properties. For optimizing the efficiency of devices like sensors, transducers, and actuators, understanding the polarization state of Rayleigh waves is crucial. An increase in the magnitude of electric potential is found in the electrically open case. Similar behaviour is observed for electrical potential ϕ^{*f} (Figs. 17 and 18). A comparison of the electric potential of the solid and fluid phases of a porous aggregate in an electrically open boundary, as shown in Figs. 16 and 18, reveals that the amplitude of the electric potential wave is significantly higher in the electrically open boundary condition compared to the short boundary. Upon analysing the accompanying contour plots, it is evident that the electric potential curve predominantly showcases linear polarization rather than elliptical polarization. Figs. 19 and 20 present the variation of shear stress σ_{31}^f in the lateral and vertical direction for electrically short and open boundaries respectively. It is observed that variation of shear stress is more dominant in the shorted boundary. The amplitude of wave is greater in short boundary. Wave with higher amplitude can lead to a more significant response to the external stimulus being measured, making the sensor

Principal
Dyal Singh College
KARNAL

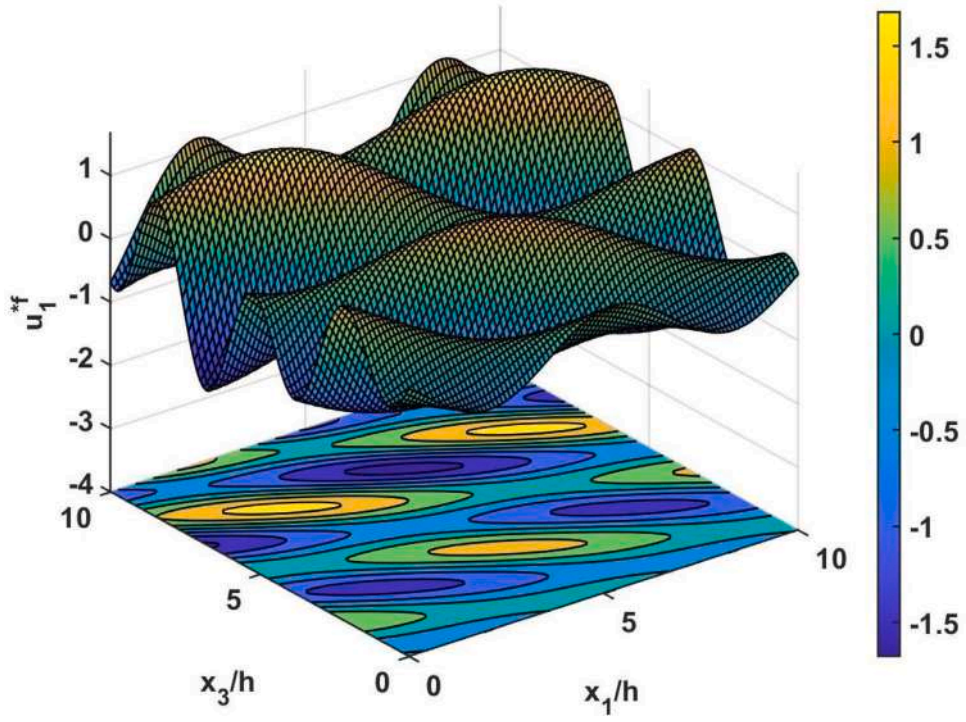


Fig. 13. Three dimensional surface and contour plot of variation of u_1^{*f} in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

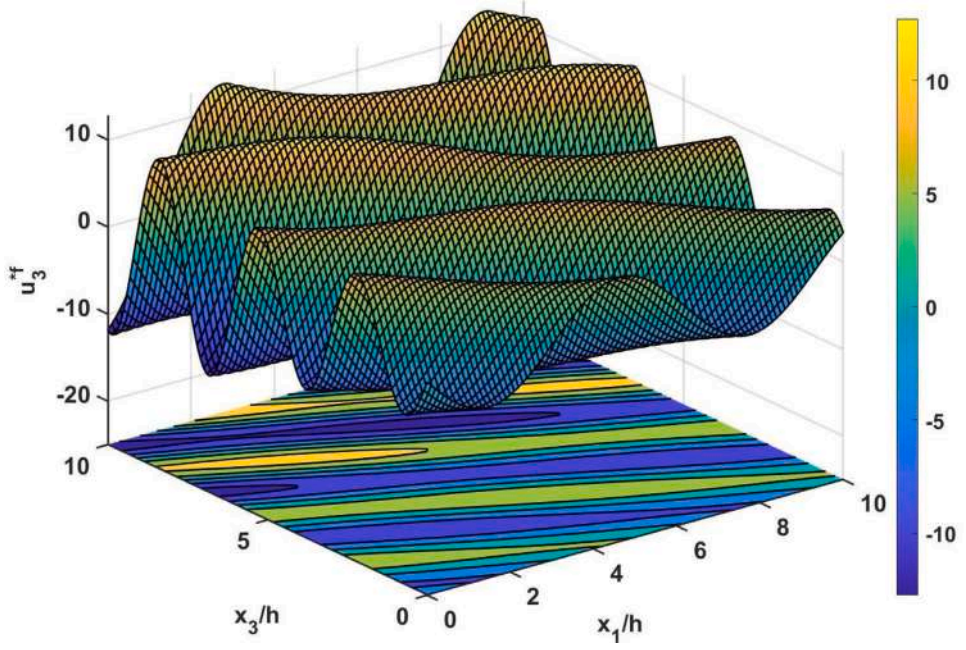


Fig. 14. Three dimensional surface and contour plot of variation of u_3^{*f} in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

more sensitive. Also, in the field of communication, such as TV, radio, and wireless signals, the amplitude of waves is crucial. The strength of the signal depends on the amplitude. A stronger signal results in better reception and a clearer image or sound. From the projection of the surface plot, it is found that ellipses with higher eccentricity are observed in Fig. 19. The observed contour plots are the result of the interaction between Rayleigh waves and the boundary's electrical properties. Figs. 21 and 22 depict the variation of normal stress σ_{33}^f along the wave propagation direction and the direction perpendicular to the propagation direction for short and open boundaries respectively. It is noted that σ_{33}^f in the electrically short case shows sinusoidal behaviour. It is reported from contour plots that the wave in the electrically open case is more elliptically polarized as compared to the short case which is polarized more linear. An increase in the magnitude of normal stress is observed in the electrically open case. The rise in normal stress leads to more accurate and exact measurements of acceleration, pressure, or sound in applications like accelerometers, pressure

Principal
Dyal Singh College
KARNAL

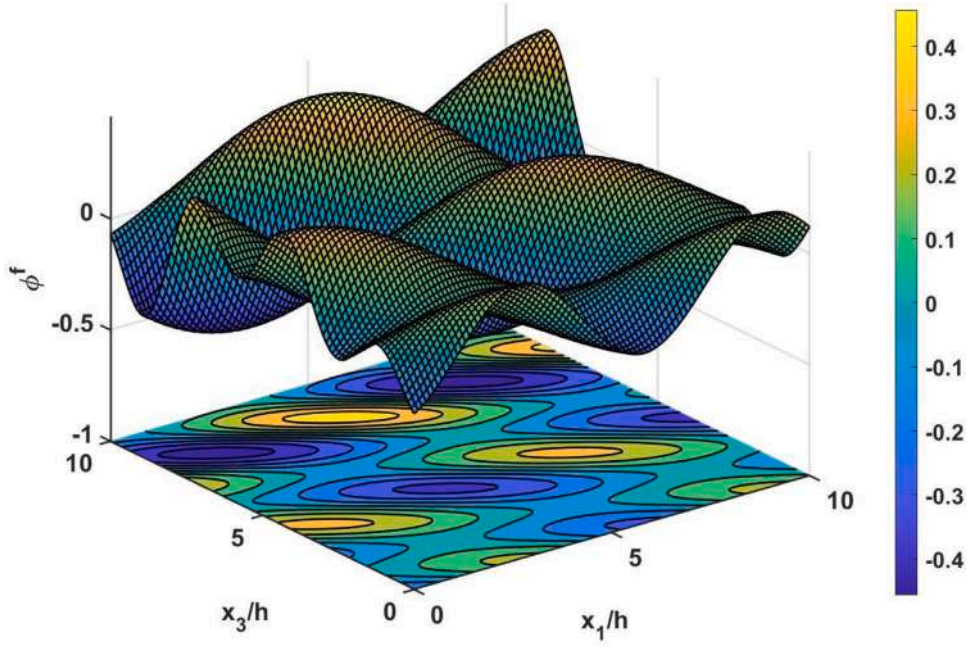


Fig. 15. Three dimensional surface and contour plot of variation of ϕ^f in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

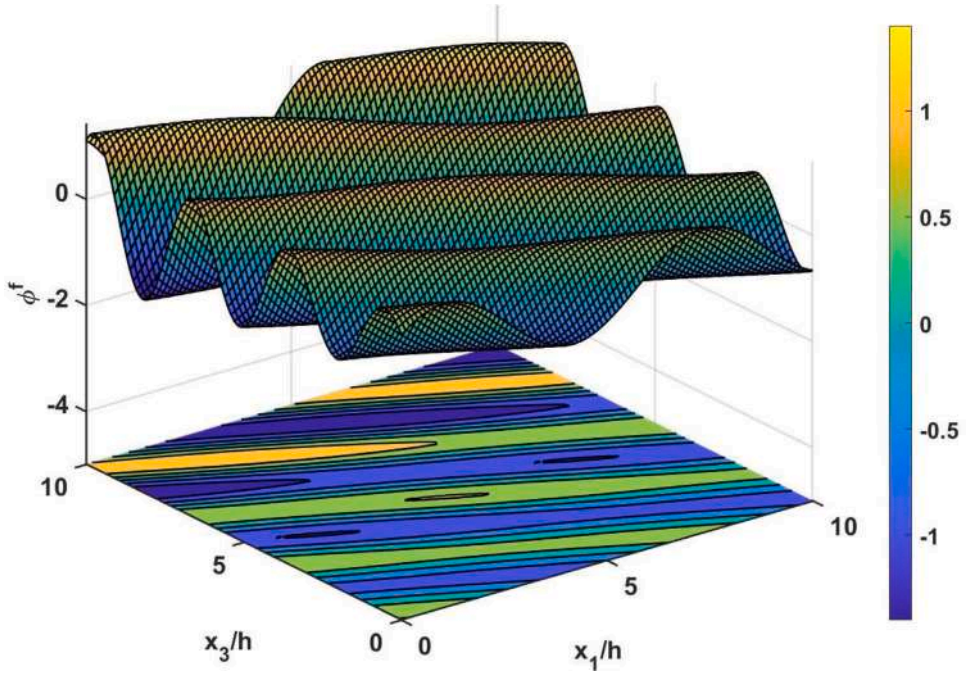


Fig. 16. Three dimensional surface and contour plot of variation of ϕ^f in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

sensors, and acoustic instruments. Open boundary gives way for more lateral variation of normal stress. Additionally, it has been discovered that normal stress predominates over shear stress.

The difference in the plots of stress σ^{*f} for the electrically short and open boundary with x_1/h and x_3/h can be seen from Figs. 23 and 24. It is observed that σ^{*f} exhibits sinusoidal behaviour when examined from x_3 direction in both boundaries and when viewed from x_1 direction σ^{*f} first increases and then decreases in electrically short boundary and in open boundary, it first decreases and then increases. The stress plot is found to be more elliptic in the electrically short case and linear in the electrically open case. However, the magnitude of normal stress is the same in both the boundaries. Normal stresses in the fluid phase, consequently the pore pressure, are dominant in shorted boundary, unlike normal stress in the solid phase. Comparisons between stress plots, for σ_{31}, σ_{33}, and σ^*, in both boundary conditions revealed distinct characteristics. The magnitude of the normal stress σ_{33} was observed to exceed that of the shear stresses σ_{31} and σ^* in both boundaries. Furthermore, the stress waves exhibited

Principal
Dyal Singh College
KARNAL

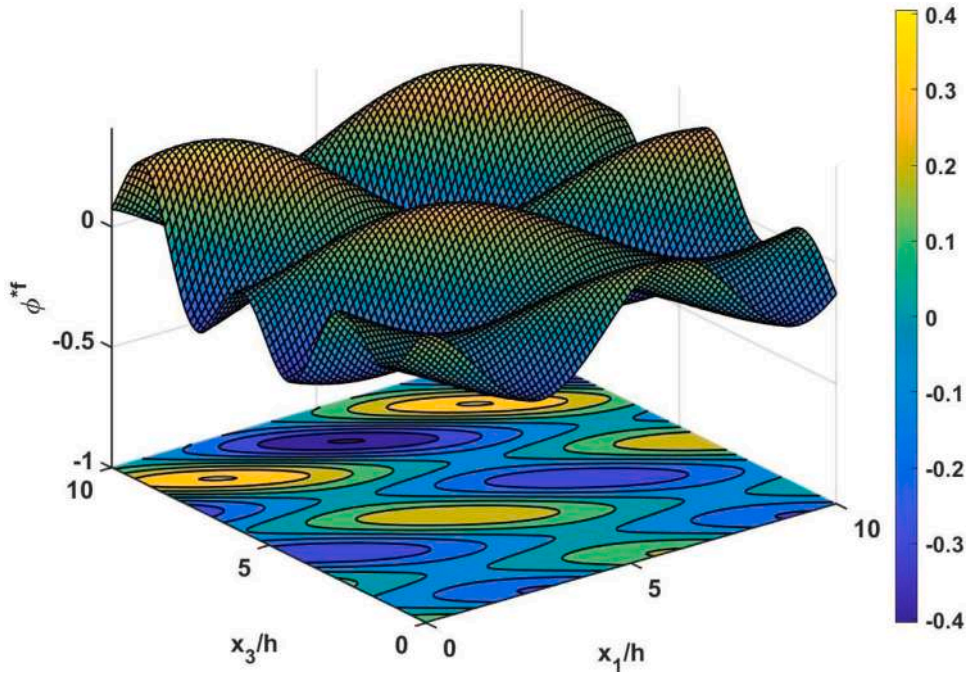


Fig. 17. Three dimensional surface and contour plot of variation of ϕ^{*f} in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

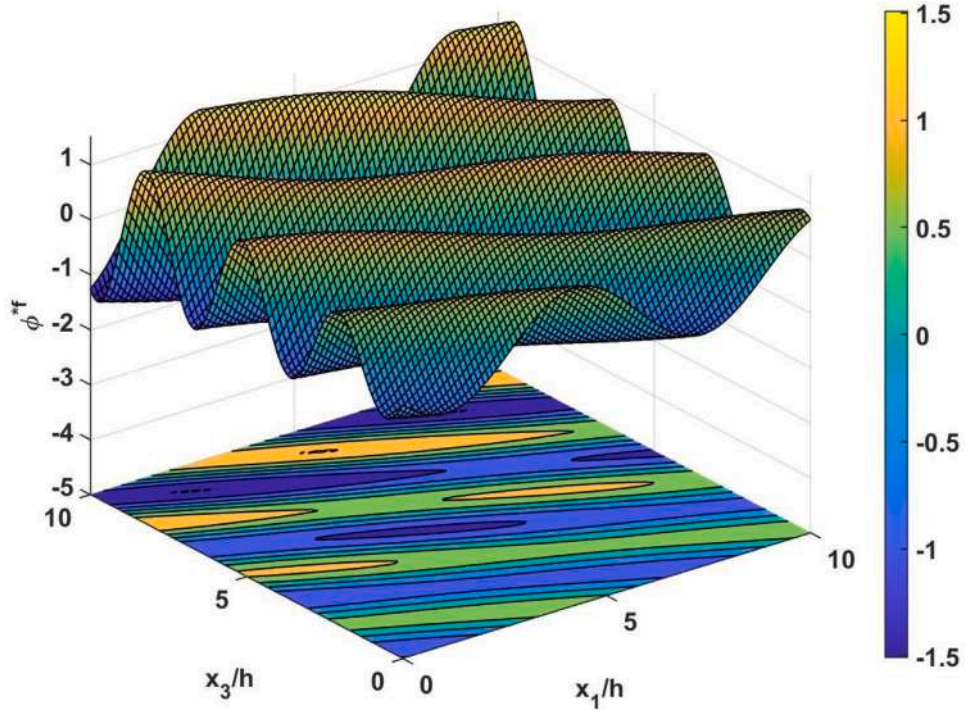


Fig. 18. Three dimensional surface and contour plot of variation of ϕ^{*f} in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

a more pronounced elliptical polarization for σ_{31} and σ_{33} in the electrically open case. On the other hand, for the stress σ^*, the polarization was more prominent in the shorted boundary.

Fig. 25 shows the variation of electrical displacement D_z^f in the horizontal and vertical directions for electrically short case. It is found that the magnitude of electrical displacement is more in the electrically short case as compared to the electrically open case while the behaviour of electrical displacement is reported same in both boundaries. Therefore, the plot for the electrically short boundary is illustrated here. The performance of piezoelectric devices and sensors may be affected by this difference in electrical displacement as the magnitude of the electrical displacement has an impact on their sensitivity and efficiency.

Principal
Dyal Singh College
KARNAL

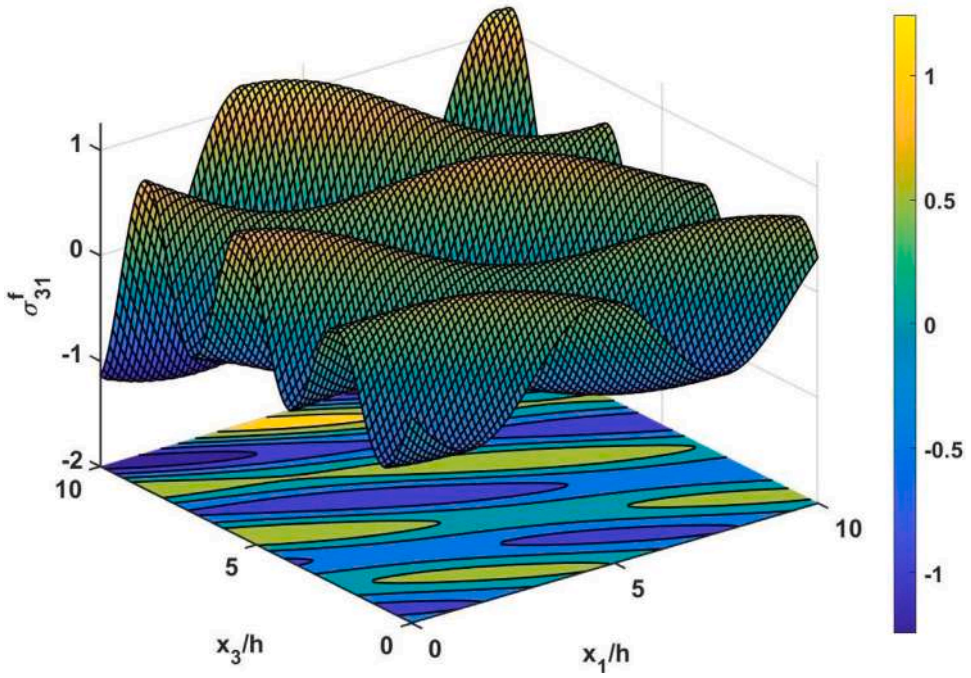


Fig. 19. Three dimensional surface and contour plot of variation of σ_{31}^f in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

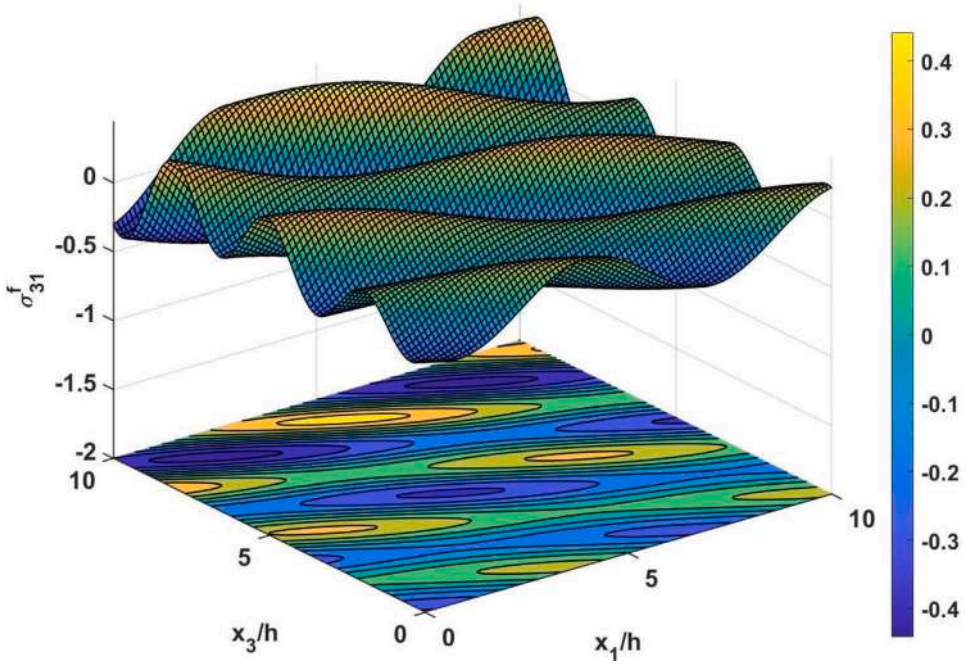


Fig. 20. Three dimensional surface and contour plot of variation of σ_{31}^f in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Variation of electrical displacement corresponding to fluid phase in the longitudinal and transverse direction is depicted in Figs. 26 and 27 for electrically shorted and open boundary respectively. It is seen that electrical displacements show sinusoidal behaviour when observed along the x_3 direction. Polarization ellipses with higher eccentricity are found in the case of the electrically open boundary. The frequency response of SAW devices is influenced by how eccentric the polarization ellipse is. It has an impact on the bandwidth and centre frequency of SAW filters and resonators, which may be useful in making SAW devices more efficient. In contrast to the solid phase, electric displacement is more prevalent in the fluid phase. Particle motion is another important aspect in the propagation of Rayleigh waves. Fig. 28 shows the particle motion with depth along the wave propagation direction in the electrically short and electrical open boundary for $\alpha = 0$. When $x_3/h = 0$ i.e. at the top surface of

Principal
Dyal Singh College
KARNAL

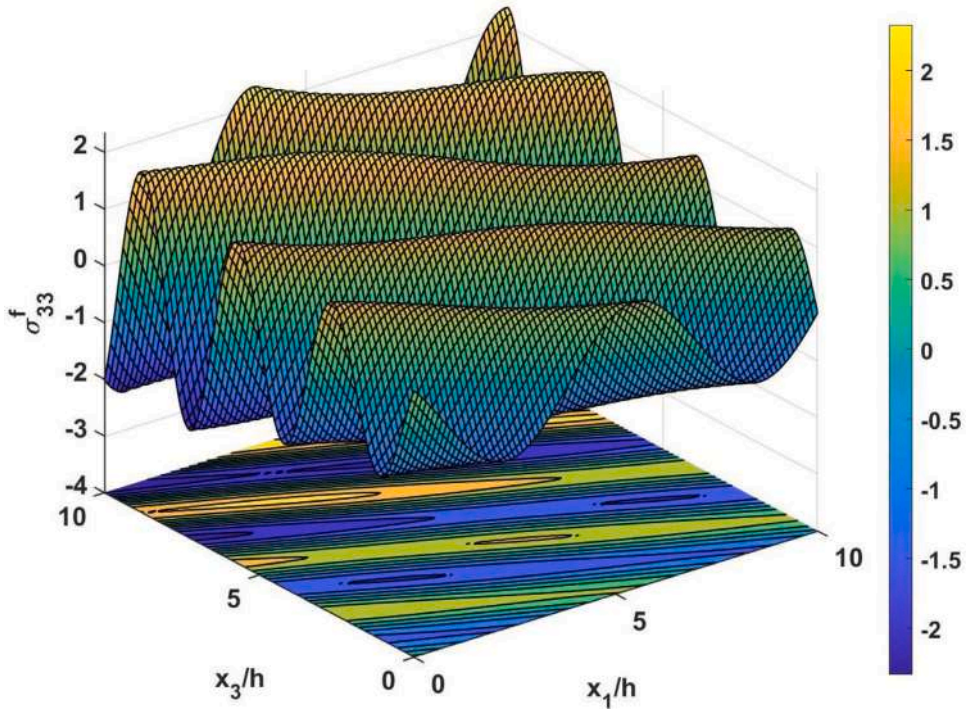


Fig. 21. Three dimensional surface and contour plot of variation of σ^f_{33} in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

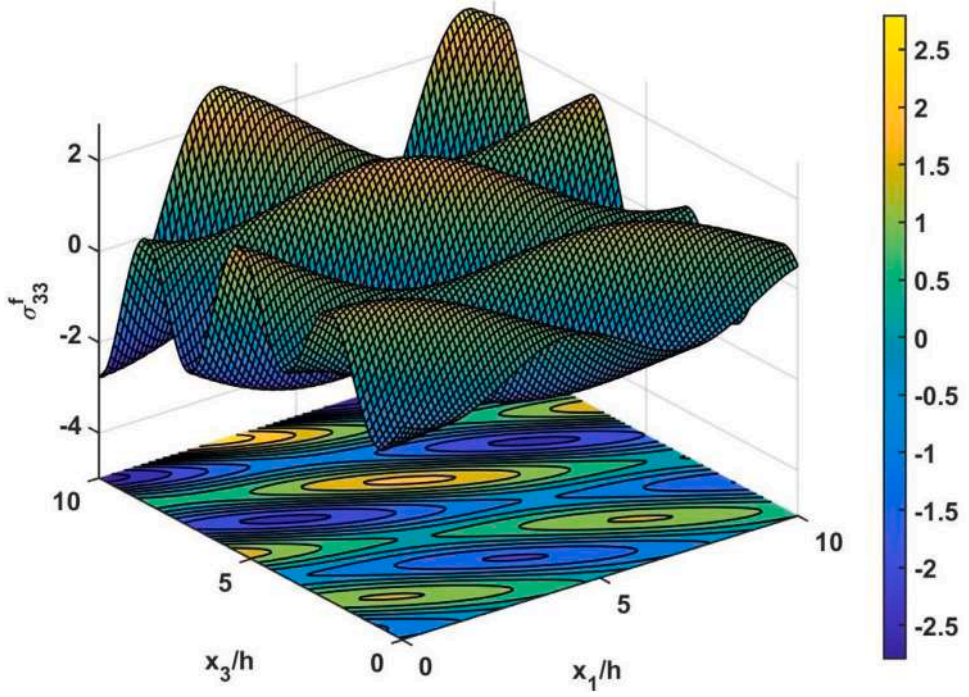


Fig. 22. Three dimensional surface and contour plot of variation of σ^f_{33} in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the porous piezoelectric layer and at $x_3/h = 0.5$, Rayleigh waves show retrograde particle motion and as depth increases i.e. at $x_3/h = 1$, (the boundary between porous piezoelectric layers and FGPPHS) particle motion is vertical and as depth further increases, the orientation of particle motion changes and prograde Rayleigh wave particle motion is observed in FGPPHS. Decaying of particle motion in the interior and change in ellipticity is observed for both boundaries. However, it is observed that the amplitude of Rayleigh waves increases in electrically open case. When we increase the grade parameter α (Fig. 29), particle motion increases and the change in ellipticity is observed with the change in gradation and again with the depth amplitude of Rayleigh waves decreases. Prograde wave motion in FGPPHS is observed.

Principal
Dyal Singh College
KARNAL

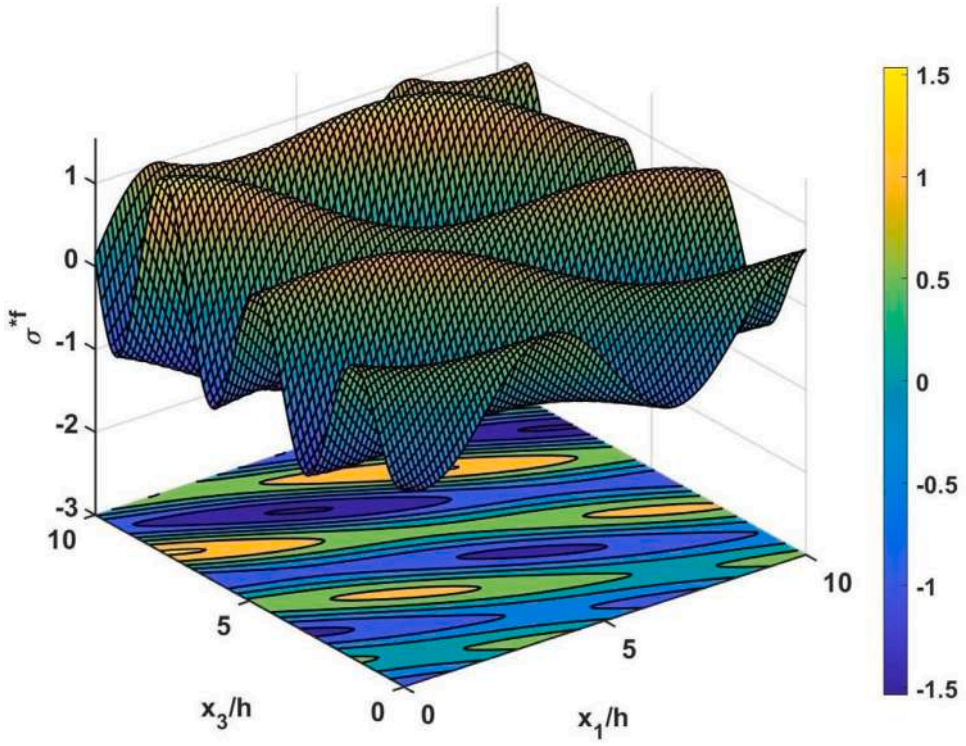


Fig. 23. Three dimensional surface and contour plot of variation of σ^{*f} in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

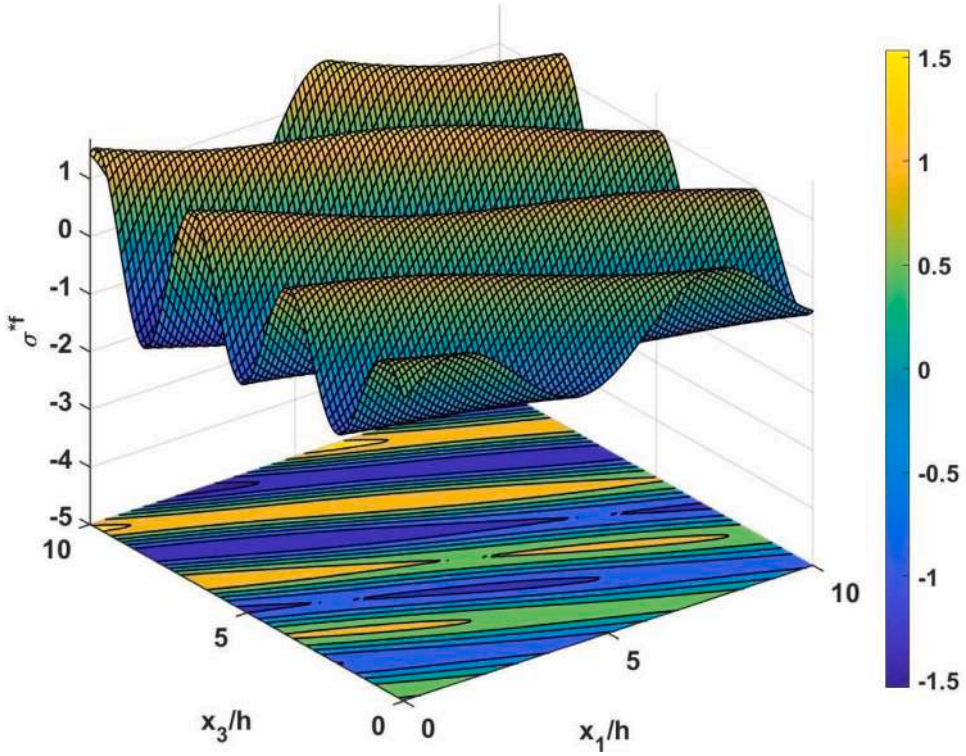


Fig. 24. Three dimensional surface and contour plot of variation of σ^{*f} in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Principal
Dyal Singh College
KARNAL

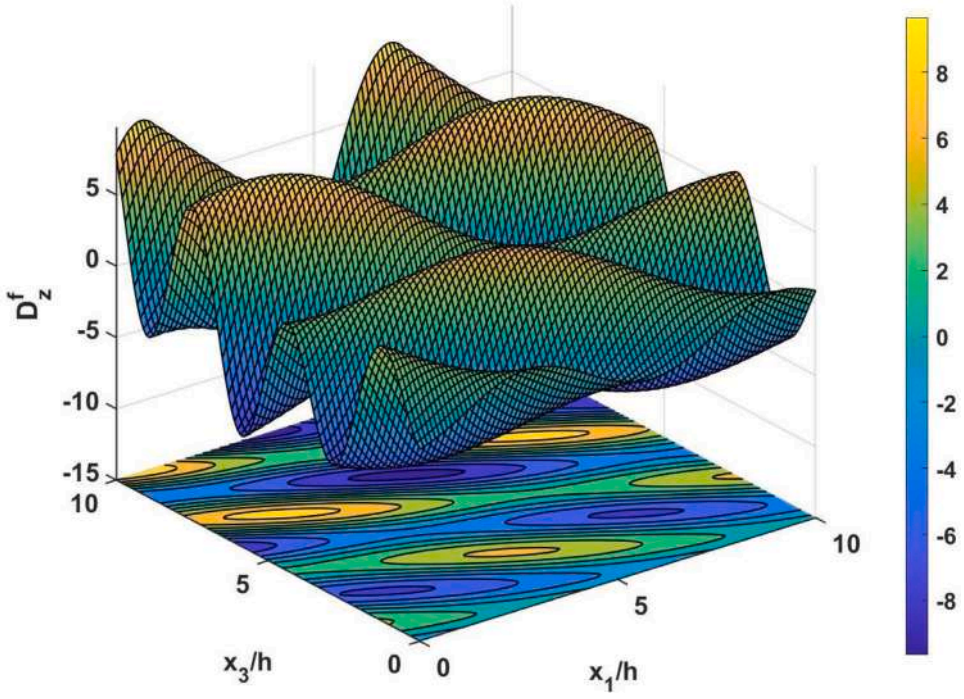


Fig. 25. Three dimensional surface and contour plot of variation of D_z^f in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

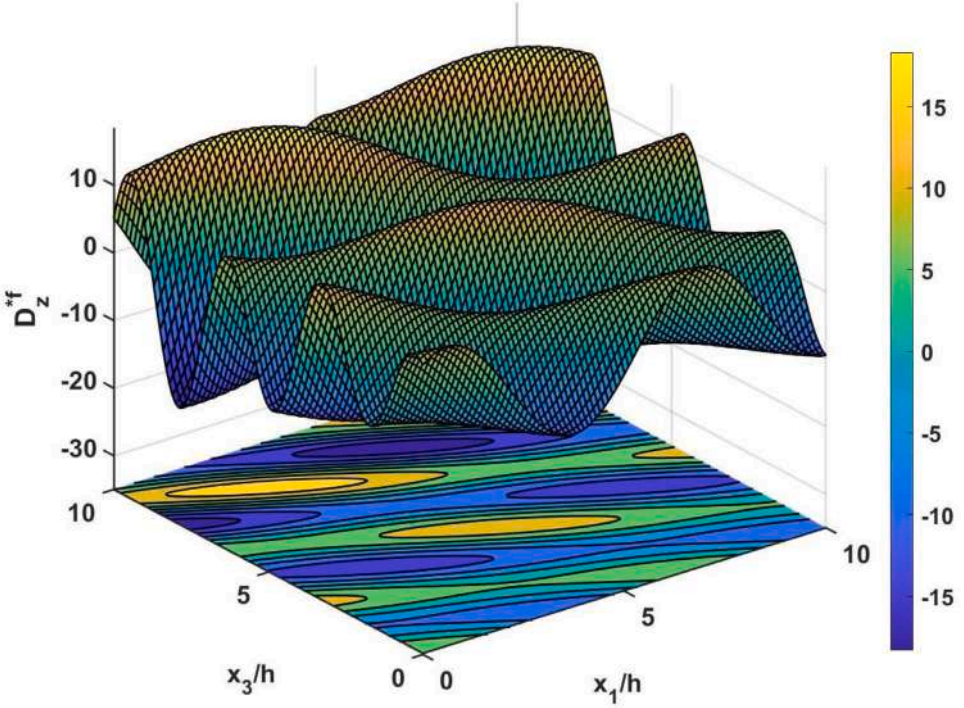


Fig. 26. Three dimensional surface and contour plot of variation of D_z^{*f} in the lateral and vertical direction for electrically short case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Attenuation quality factor Q^{-1} is often described as $Q^{-1} = -\Im(C^2)/\Re(C^2)$, where C is the complex Rayleigh wave velocity.

The variation of attenuation quality factor with wavenumber for different values of grade coefficient α is shown in Fig. 30. It is observed that attenuation decreases with wavenumber and increases as grade coefficient α increases. This is because of the fact that gradation influences the distribution of void spaces within a material. These voids or pores lead to an increase in attenuation by trapping and dissipating wave energy.

An essential parameter of an efficient acoustic sensor design is the electromechanical coupling factor, which may be described as [66] $K^2 = \frac{2(c_0 - c_f)}{c_0}$, where c_0 and c_f are the wave velocities for the electrically open and shorted boundaries respectively.

Principal
Dyal Singh College
KARNAL

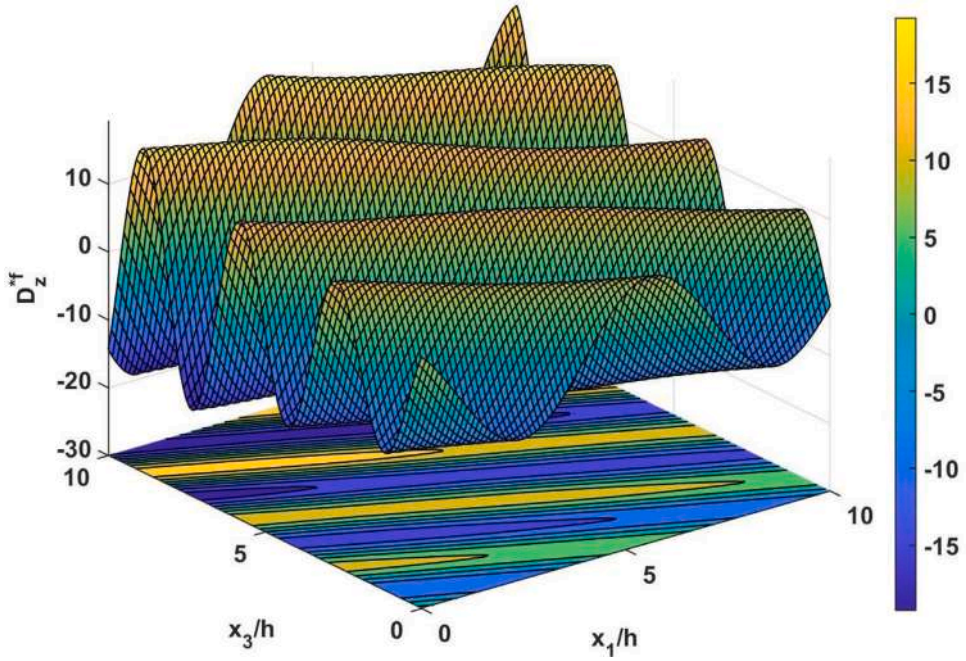


Fig. 27. Three dimensional surface and contour plot of variation of D_z^{*f} in the lateral and vertical direction for electrically open case. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

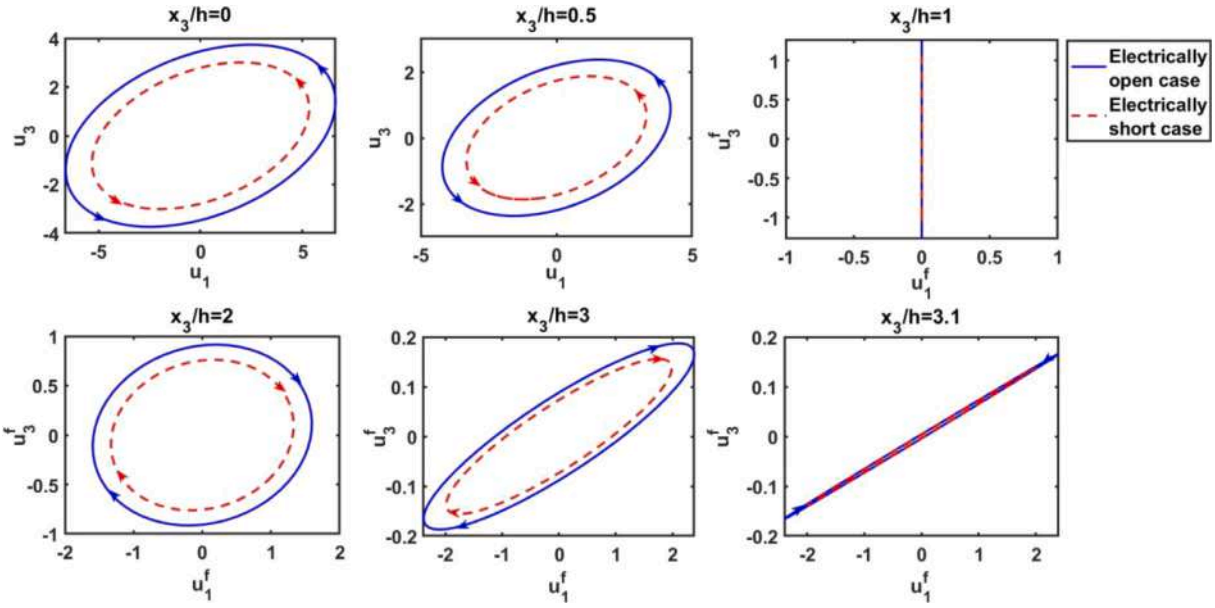


Fig. 28. Particle motion with depth in electrically open case and electrically short case when α=0.

Fig. 31 depicts the variation of electromechanical coupling factor with wavenumber for different grade coefficient α. Electromechanical coupling factor corresponding to the first Rayleigh mode, second Rayleigh mode, third Rayleigh mode, and fourth Rayleigh mode of propagation are plotted and shown in Fig. 31(a), 31(b), 31(c), and 31(d) respectively. It is apparent that the coupling factor first increases as the wavenumber increases and then slightly decreases asymptotically to a certain value. At low wavenumber, the difference in phase velocity for electrically short boundary and open boundary is very less, and for higher wavenumber, this difference increases. Furthermore, the phase velocities become almost constant. By definition, the coupling factor depends upon the difference of phase velocity between open and closed boundaries. The graph of K^2 as a function of wavenumber for Rayleigh waves in piezoelectric materials shows peaks or dips at specific wavenumbers corresponding to resonance or anti-resonance conditions. These peaks or dips in the graph indicate the frequencies or wavenumbers at which the conversion between electrical and mechanical energy is most efficient or least efficient for Rayleigh waves.

Also, the influence of the grade coefficient on the electromechanical coupling factor can be seen from the figure. The electromechanical coupling factor curves for different grade parameters show a similar trend. However, it is observed that there is a gradual increase in the value of the coupling factor when $\alpha = 100$ as compared to when $\alpha = 150$. This is because of difference of phase velocity in the electrically short case and open case is

Principal
Dyal Singh College
KARNAL

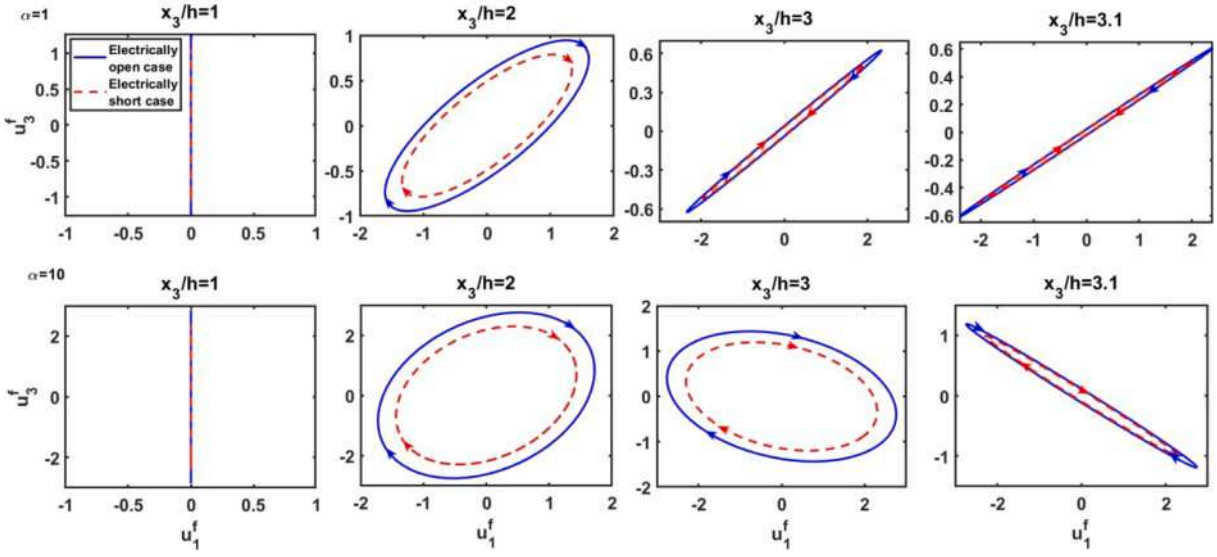


Fig. 29. Effect of gradation on particle motion with depth in FGPPHS for electrically open case and electrically short case.

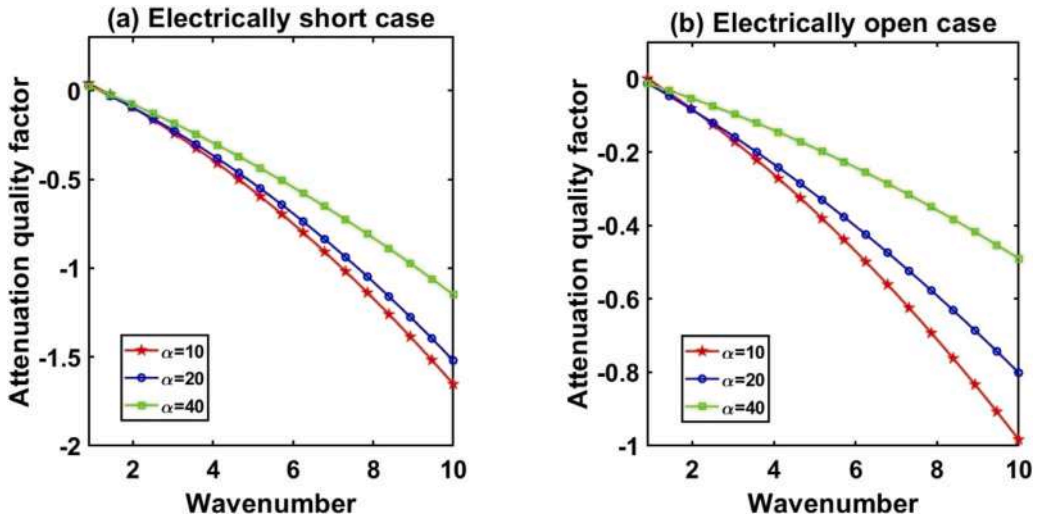


Fig. 30. Variation of attenuation quality factor with wavenumber for different values of α.

very small when $\alpha = 100$ as compared to when $\alpha = 150$. Thus, the gradation coefficient can be adjusted to produce a fairly high electromechanical coupling factor at a particular wave number.

The influence of wavenumber on mechanical displacements in the electrically short and open boundaries is shown in Table 5. It is observed that displacements u_1^f, u_3^f and u_1^{*f} first decrease and then increase with wavenumber. The magnitude of displacements is more in electrically open boundary as compared to electrically short boundary. Table 6 shows the variation of electrical potentials (ϕ^f, ϕ^{*f}) and electrical displacements (D_z^f, D_z^{*f}) with wavenumber for both the boundaries. It is noted that electrical potentials and electrical displacements first decrease and then increase with wavenumber in both the boundaries. The effect of wavenumber is more observed in electrical potential ϕ^{*f} as compared to electrical potential ϕ^f. Table 7 shows the variation of stresses $\sigma_{31}^f, \sigma_{33}^f$ and σ^{*f} with wavenumber for both the boundaries. It is found that as the wavenumber increases, σ_{31}^f and σ^{*f} increase after a little decrease and attain their maximum value and then decrease. Similar behaviour is observed for both boundaries. However, the magnitude of stress is more in the case of open boundary. On the other hand, stress σ_{33}^f first decreases and then increases.

Principal
Dyal Singh College
KARNAL

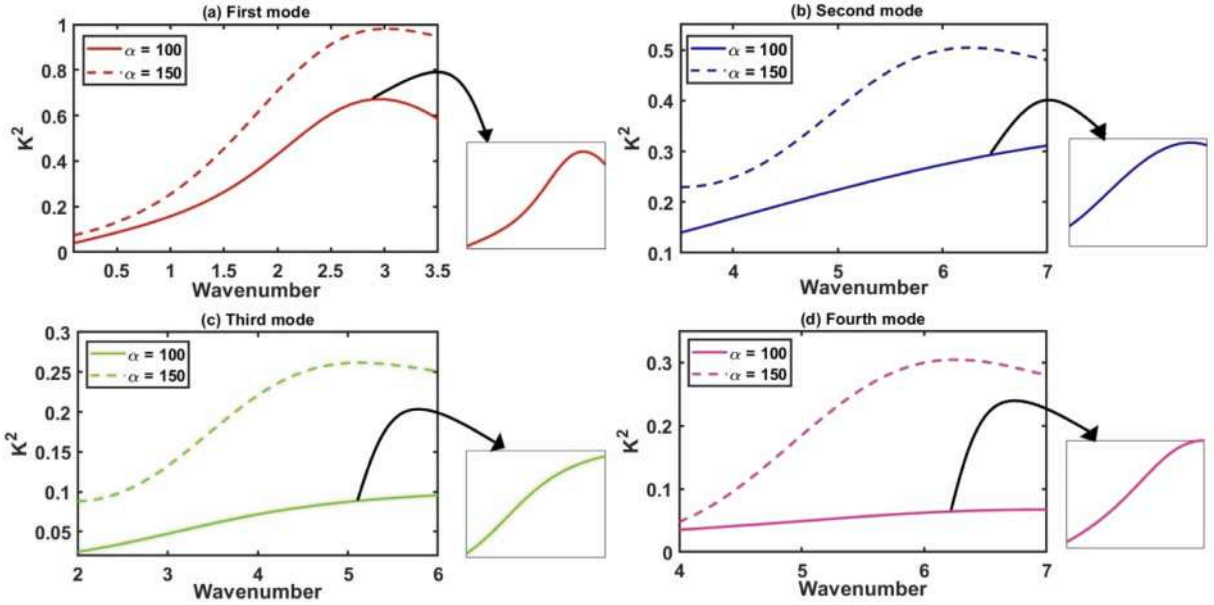


Fig. 31. Variation of electromechanical coupling factor with wavenumber for different values of α corresponding to different modes.

Table 5
Variation of mechanical displacements with wavenumber.

Wavenumber	u_1^f		u_3^f		u_1^{*f}		u_3^{*f}	
	Short case	Open case	Short case	Open case	Short case	Open case	Short case	Open case
1	−0.121267048	−0.145520457	0.486022517	0.54416275	1.336302168	1.603562601	0.855492775	1.02659133
2	−0.297362392	−0.35683487	−0.262201479	−0.297385708	0.784593452	0.941512142	1.40026087	1.680313043
3	−0.326072969	−0.391287563	−0.815743033	−0.949533835	0.066649334	0.079979201	1.561762695	1.874115234
4	−0.140173723	−0.168208467	−1.225226117	−1.471923426	−0.997021133	−1.19642536	1.36191465	1.63429758
5	0.280750116	0.336900139	−1.231584638	−1.504995106	−1.725824298	−2.070989157	0.867389049	1.040866859
6	0.907953438	1.089544125	−0.729974829	−0.883675584	−2.194320516	−2.63318462	0.124806818	0.149768181
7	1.314226757	1.577072108	−0.042446201	−0.029039323	−2.10842959	−2.530115508	−1.006133263	−1.207359916
8	1.46295126	1.755541511	0.797815469	0.97889475	−1.496769001	−1.796122802	−1.906443309	−2.287731971
9	1.130781145	1.356937374	1.676387832	1.980823373	−0.174366961	−0.209240354	−2.611636723	−3.133964068
10	0.248870723	0.298644868	1.934206512	2.328448429	1.109937898	1.331925478	−2.690617393	−3.228740871

Table 6
Variation of electrical potentials and electrical displacements with wavenumber.

Wavenumber	ϕ^f		ϕ^{*f}		D_z^f		D_z^{*f}	
	Short case	Open case	Short case	Open case	Short case	Open case	Short case	Open case
1	0.034438508	0.04132621	−1.391673501	−1.670008202	−0.086630474	−0.103956569	−0.079813543	−0.095776252
2	−0.015775867	−0.01893104	−2.993963944	−3.592756732	−0.390946685	−0.469136022	−0.36012589	−0.432151068
3	−0.053411022	−0.064093227	−3.692852329	−4.431422795	−0.709462863	−0.851355436	−0.653217844	−0.783861412
4	−0.081729999	−0.098075998	−3.580866437	−4.297039724	−0.98658038	−1.183896456	−0.907695939	−1.089235127
5	−0.083022426	−0.099626911	−2.576564411	−3.091877293	−0.878706874	−1.054448249	−0.807706952	−0.969248342
6	−0.06000304	−0.072003648	−0.844280143	−1.013136171	−0.34747922	−0.416975064	−0.318208017	−0.381849621
7	−0.004467232	−0.005360678	1.995320351	2.394384421	0.925748558	1.11089827	0.853490489	1.024188587
8	0.064393789	0.077272546	4.373717295	5.248460755	2.287029955	2.744435946	2.105091269	2.526109523
9	0.110749663	0.132899596	6.476167797	7.771401357	3.840624254	4.608749106	3.531987867	4.238385441
10	0.128298938	0.153958726	6.718908484	8.062690181	4.463586521	5.356303826	4.10259698	4.923116375

7. Conclusions

Dispersion equations for Rayleigh waves propagating in a structure consisting of 'n' porous piezoelectric layers overlying FGPPHS are obtained in closed form for both boundaries. The following conclusions are made based on numerical study.

- For small values of the wavenumber, the wave is highly dispersive, but its dispersion decreases with the increase of the wavenumber.
- The boundary has a discernible impact on the dispersion curves. For a given wavenumber, the electrically open boundary has a higher circular frequency of Rayleigh waves than the shorted boundary.
- Grade coefficient affects the dispersion curves significantly. Phase velocity increases as the gradation parameter increases.
- Phase velocity of Rayleigh waves in the porous piezoelectric layers overlying a non-graded half-space is less than that in the porous piezoelectric layers atop a functionally graded half-space.

Principal
Dyal Singh College
KARNAL

Table 7
Variation of stresses with wavenumber.

Wavenumber	σ_{31}^{f}		σ_{33}^{f}		σ^{*f}	
	Short case	Open case	Short case	Open case	Short case	Open case
1	−0.268056203	−0.321667444	−0.095981195	−0.115177435	0.133104708	0.159725649
2	−0.332787207	−0.399344647	−0.436971738	−0.524366086	0.597875063	0.717450076
3	0.00254052	0.003048624	−0.814930408	−0.97791649	1.069109729	1.282931675
4	1.00683359	1.208200308	−1.180195993	−1.416235192	1.45275726	1.743308712
5	2.107187412	2.528624894	−1.103076451	−1.323691741	1.256370403	1.507644484
6	3.165962972	3.799155566	−0.519943254	−0.623931904	0.43627995	0.52353594
7	3.81243679	4.574924148	0.98393017	1.180716204	−1.452476264	−1.742971517
8	3.26278729	3.915344749	2.671029168	3.205235002	−3.414582742	−4.09749929
9	0.843740148	1.012488177	4.703204925	5.64384591	−5.576721007	−6.692065209
10	−2.450580074	−2.940696089	5.626734686	6.752081623	−6.365139387	−7.628855166

- An increase in the porosity of a medium leads to a reduction in the medium's shear modulus, consequently causing a decrease in the phase speed of the Rayleigh wave.
- The effect of porosity is more pronounced in the electrically open boundary and in higher modes.
- As a wave propagates through a multi-layered structure containing numerous layers, the presence of layering leads to the confinement of more energy within the layered stack. This confinement of energy results in a decrease in the phase velocity of the wave. Further, an initial increase in the stack of layers is significant.
- The Rayleigh wave's group velocity is lower than its phase velocity, and it tends to approach the phase velocity for high wavenumber.
- Significant impact of gradation is observed on group velocity. Group velocity has been found to increase as gradation does.
- Coupled electromechanical factor first increases as wavenumber increases and then decreases. With the increase in grade coefficient, the coupling factor increases.
- The graph of electromechanical coupling factor as a function of wavenumber for Rayleigh waves shows peaks or dips at specific wavenumbers corresponding to resonance or anti-resonance conditions. These peaks or dips in the graph indicate the frequencies or wavenumbers at which the conversion between electrical and mechanical energy is most efficient or least efficient for Rayleigh waves.
- Attenuation quality factor decreases with wavenumber and increases with gradation.
- The effect of boundary is examined in the variation of physical quantities (mechanical displacements, electric displacements, electrical potentials, and stresses) with wavenumber.
- Lateral and transverse variations of displacements, electrical potentials, and stresses are depicted through the 3D surface and contour plots for different boundaries.
- Observation of lateral and vertical changes reveals that mechanical displacements have a larger magnitude in an electrically open boundary. This is because of minimal constraints on the movement of charge in the electrically open boundary. Due to this, the piezoelectric material can deform more easily, resulting in greater mechanical displacement.
- Comparing the electrically open case to the electrically short case, the electrical potential in the latter is more elliptically polarized. For optimizing the efficiency of devices like sensors, transducers, and actuators, understanding the polarization state of Rayleigh waves is crucial.
- The prevalence of normal stresses over shear stresses has been identified and normal stresses in the fluid phase, consequently the pore pressure, is dominant in shorted boundary, unlike normal stress in the solid phase.
- The magnitude of the normal stress σ_{33} was observed to exceed that of the shear stresses σ_{31} and σ^{*} in both boundaries. Furthermore, the stress waves exhibited a more pronounced elliptical polarization for σ_{31} and σ_{33} in the electrically open case. On the other hand, for the stress σ^{*}, the polarization was more prominent in the shorted boundary.
- The magnitude of electric displacement is greater in the fluid phase compared to the solid phase. The performance of piezoelectric devices and sensors may be affected by this difference in electrical displacement as the magnitude of the electrical displacement has an impact on their sensitivity and efficiency.
- Retrograde particle motion in porous piezoelectric layers and prograde in FGPPHS is observed and also it is found that Rayleigh wave particle motion increases with gradation and decays with depth.
- Boundary affects the particle motion remarkably.
- The outcome of the research could assist to boost the functionality of SAW devices.

CRediT authorship contribution statement

Anil K. Vashishth: Validation, Supervision, Project administration, Methodology, Conceptualization. **Vishakha Gupta:** Software, Methodology, Conceptualization. **Umang Bareja:** Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Principal
Dyal Singh College
KARNAL

Appendix A

$$\boldsymbol{\Gamma}=\begin{bmatrix} c_{11}/c^2+c_{44}\,q^2-\bar{\rho}_{11}^{11} & (c_{13}+c_{44})\,q/c & m_{11}/c^2-\bar{\rho}_{11}^{12} & m_{11}\,q/c & (e_{15}+e_{31})\,q/c & (\zeta_{15}+\zeta_{31})\,q/c \\ & c_{44}/c^2+c_{33}\,q^2-\bar{\rho}_{33}^{11} & m_{33}\,q/c & m_{33}\,q^2-\bar{\rho}_{33}^{12} & e_{15}/c^2+e_{33}\,q^2 & \zeta_{15}/c^2+\zeta_{33}\,q^2 \\ & & R/c^2-\bar{\rho}_{11}^{22} & R\,q/c & \tilde{\zeta}_3\,q/c & e_3^*\,q/c \\ & \text{Sym.} & & R\,q^2-\bar{\rho}_{33}^{22} & \tilde{\zeta}_3\,q^2 & e_3^*q^2 \\ & & & & -\xi_{11}/c^2-\xi_{33}\,q^2 & -A_{11}/c^2-A_{33}\,q^2 \\ & & & & & -\xi_{11}^*/c^2-\xi_{33}^*\,q^2 \end{bmatrix}, \text{ where}$$

$$\bar{\boldsymbol{\rho}}^{\mathbf{11}}=\boldsymbol{\rho}^{\mathbf{11}}+\frac{i}{\omega}\boldsymbol{b},\quad \bar{\boldsymbol{\rho}}^{\mathbf{12}}=\boldsymbol{\rho}^{\mathbf{12}}-\frac{i}{\omega}\boldsymbol{b},\quad \bar{\boldsymbol{\rho}}^{\mathbf{22}}=\boldsymbol{\rho}^{\mathbf{22}}+\frac{i}{\omega}\boldsymbol{b}, \tag{A.1}$$

$$k_1=\beta_1\gamma_1-\beta_5\gamma_{10}+\beta_9\gamma_{17}-\beta_{13}\gamma_{26},\ k_2=\beta_2\gamma_1+\beta_1\gamma_2-\beta_6\gamma_{10}-\beta_5\gamma_{11}+\beta_{10}\gamma_{17}+\beta_9\gamma_{18}-\beta_{14}\gamma_{26}-\beta_{13}\gamma_{27},$$

$$k_3=\beta_3\gamma_1+\beta_2\gamma_2+\beta_1\gamma_3-\beta_7\gamma_{10}-\beta_6\gamma_{11}+\beta_{11}\gamma_{17}+\beta_{10}\gamma_{18}+\beta_9\gamma_{19}-\beta_{15}\gamma_{26}-\beta_{14}\gamma_{27}-\beta_{13}\gamma_{28},$$

$$k_4=\beta_4\gamma_1+\beta_3\gamma_2+\beta_2\gamma_3-\beta_8\gamma_{10}-\beta_7\gamma_{11}+\beta_{12}\gamma_{17}+\beta_{11}\gamma_{18}+\beta_{10}\gamma_{19}-\beta_{16}\gamma_{26}-\beta_{15}\gamma_{27}-\beta_{14}\gamma_{28},$$

$$k_5=\beta_4\gamma_2+\beta_3\gamma_3+\beta_{12}\gamma_{18}+\beta_{11}\gamma_{19}-\beta_8\gamma_{11}-\beta_{16}\gamma_{27}-\beta_{15}\gamma_{28},k_6=\beta_4\gamma_3+\beta_{12}\gamma_{19}-\beta_{16}\gamma_{28},$$

where

$$\beta_1=\delta_1\gamma_{12}-\delta_4\gamma_{14}+\delta_7\gamma_{15},\beta_2=\delta_2\gamma_{12}+\delta_1\gamma_{13}-\delta_5\gamma_{14}+\delta_8\gamma_{15}+\delta_7\gamma_{16},\beta_3=\delta_3\gamma_{12}+\delta_2\gamma_{13}-\delta_6\gamma_{14}+\delta_9\gamma_{15}+\delta_8\gamma_{16},$$

$$\beta_4=\delta_3\gamma_{13}+\delta_9\gamma_{16},\beta_5=\delta_1\gamma_4-\delta_4\gamma_6+\delta_7\gamma_8,\beta_6=\delta_2\gamma_4+\delta_1\gamma_5-\delta_5\gamma_6-\delta_4\gamma_7+\delta_8\gamma_8+\delta_7\gamma_9,$$

$$\beta_7=\delta_3\gamma_4+\delta_2\gamma_5-\delta_6\gamma_6-\delta_5\gamma_7+\delta_9\gamma_8+\delta_8\gamma_9,\beta_8=\delta_3\gamma_5-\delta_6\gamma_7+\delta_9\gamma_9,\beta_9=\eta_1\gamma_4-\eta_4\gamma_6+\eta_7\gamma_8,$$

$$\beta_{10}=\eta_2\gamma_4+\eta_1\gamma_5-\eta_5\gamma_6-\eta_4\gamma_7+\eta_8\gamma_8+\eta_7\gamma_9,\beta_{11}=\eta_3\gamma_4+\eta_2\gamma_5-\eta_6\gamma_6-\eta_5\gamma_7+\eta_9\gamma_8+\eta_8\gamma_9,$$

$$\beta_{12}=\eta_3\gamma_5-\eta_6\gamma_7+\eta_9\gamma_9,\beta_{13}=\nu_1\gamma_4-\nu_4\gamma_6+\nu_7\gamma_8,\beta_{14}=\nu_2\gamma_4+\nu_1\gamma_5-\nu_5\gamma_6-\nu_4\gamma_7+\nu_8\gamma_8+\nu_7\gamma_9,$$

$$\beta_{15}=\nu_3\gamma_4+\nu_2\gamma_5-\nu_6\gamma_6-\nu_5\gamma_7+\nu_9\gamma_8+\nu_8\gamma_9,\beta_{16}=\nu_3\gamma_5-\nu_6\gamma_7+\nu_9\gamma_9,$$

$$\delta_1=\gamma_{22}\gamma_{33}-\gamma_{24}\gamma_{31},\delta_2=\gamma_{22}\gamma_{34}+\gamma_{23}\gamma_{33}-\gamma_{25}\gamma_{31}-\gamma_{24}\gamma_{32},\delta_3=\gamma_{23}\gamma_{34}-\gamma_{25}\gamma_{32},\delta_4=\gamma_{20}\gamma_{33}-\gamma_{24}\gamma_{29},$$

$$\delta_5=\gamma_{20}\gamma_{34}+\gamma_{21}\gamma_{33}-\gamma_{24}\gamma_{30}-\gamma_{25}\gamma_{29},\delta_6=\gamma_{21}\gamma_{34}-\gamma_{25}\gamma_{30},\delta_7=\gamma_{20}\gamma_{31}-\gamma_{22}\gamma_{29},$$

$$\delta_8=\gamma_{20}\gamma_{32}+\gamma_{21}\gamma_{31}-\gamma_{23}\gamma_{29}-\gamma_{22}\gamma_{30},\delta_9=\gamma_{21}\gamma_{32}-\gamma_{23}\gamma_{30},$$

$$\eta_1=\gamma_{14}\gamma_{33}-\gamma_{15}\gamma_{31},\eta_2=\gamma_{14}\gamma_{34}-\gamma_{16}\gamma_{31}-\gamma_{15}\gamma_{32},\eta_3=-\gamma_{16}\gamma_{32},\eta_4=\gamma_{12}\gamma_{33}-\gamma_{15}\gamma_{29},$$

$$\eta_5=\gamma_{12}\gamma_{34}+\gamma_{13}\gamma_{33}-\gamma_{16}\gamma_{29}-\gamma_{15}\gamma_{30},\eta_6=\gamma_{13}\gamma_{34}-\gamma_{16}\gamma_{30},\eta_7=\gamma_{12}\gamma_{31}-\gamma_{14}\gamma_{29},$$

$$\eta_8=\gamma_{12}\gamma_{32}-\gamma_{14}\gamma_{30}+\gamma_{13}\gamma_{31},\eta_9=\gamma_{13}\gamma_{32},$$

$$\nu_1=\gamma_{14}\gamma_{24}-\gamma_{15}\gamma_{22},\nu_2=\gamma_{14}\gamma_{25}-\gamma_{16}\gamma_{22}-\gamma_{15}\gamma_{23},\nu_3=-\gamma_{16}\gamma_{23},\nu_4=\gamma_{12}\gamma_{24}-\gamma_{15}\gamma_{20}$$

$$,\nu_5=\gamma_{12}\gamma_{25}+\gamma_{13}\gamma_{24}-\gamma_{16}\gamma_{20}-\gamma_{15}\gamma_{21},\nu_6=\gamma_{13}\gamma_{25}-\gamma_{16}\gamma_{21},\nu_7=\gamma_{12}\gamma_{22}-\gamma_{14}\gamma_{20},$$

$$\nu_8=\gamma_{12}\gamma_{23}-\gamma_{14}\gamma_{21}+\gamma_{13}\gamma_{22},\nu_9=\gamma_{13}\gamma_{23},$$

$$\gamma_1=e_{33}\kappa_1+\zeta_{33}\kappa_6,\gamma_2=(e_{15}\kappa_1+\zeta_{15}\kappa_6)/c^2+(c_{44}+c_{13})/c+e_{33}\kappa_2+\zeta_{33}\kappa_7,\gamma_3=(e_{15}\kappa_2+\zeta_{15}\kappa_7)/c^2,$$

$$\gamma_4=e_{33}\kappa_3+\zeta_{33}\kappa_8+c_{33},\gamma_5=(e_{15}\kappa_3+\zeta_{15}\kappa_8+c_{44})/c^2-\bar{\rho}_{33}^{11},\gamma_6=e_{33}\kappa_4+\zeta_{33}\kappa_9+m_{33}/c,$$

$$\gamma_7=(e_{15}\kappa_4+\zeta_{15}\kappa_9)/c^2,\gamma_8=e_{33}\kappa_5+\zeta_{33}\kappa_{10}+m_{33},\gamma_9=(e_{15}\kappa_5+\zeta_{15}\kappa_{10})/c^2-\bar{\rho}_{33}^{12},\gamma_{10}=\tilde{\zeta}_3\kappa_1+e_3^*\kappa_6,$$

$$\gamma_{11}=m_{11}/c+\tilde{\zeta}_3\kappa_2+e_3^*\kappa_7,\gamma_{12}=m_{33}+\tilde{\zeta}_3\kappa_3+e_3^*\kappa_8,\gamma_{13}=-\bar{\rho}_{33}^{12},$$

$$\gamma_{14}=R/c+\tilde{\zeta}_3\kappa_4+e_3^*\kappa_9,\gamma_{15}=R+\tilde{\zeta}_3\kappa_5+e_3^*\kappa_{10},\gamma_{16}=-\bar{\rho}_{33}^{22},\gamma_{17}=-\kappa_1\xi_{33}-\kappa_6A_{33},$$

$$\gamma_{18}=(-\kappa_1\xi_{11}-\kappa_6A_{11})/c^2+(e_{15}+e_{31})/c-\xi_{33}\kappa_2-A_{33}\kappa_7,\gamma_{19}=-(\kappa_2\xi_{11}+\kappa_7A_{11})/c^2,$$

$$\gamma_{20}=e_{33}-\kappa_3\xi_{33}-\kappa_8A_{33},\gamma_{21}=(e_{15}-\kappa_3\xi_{11}-\kappa_8A_{11})/c^2,\gamma_{22}=\tilde{\zeta}_3/c-A_{33}\kappa_9-\xi_{33}\kappa_4,$$

$$\gamma_{23}=-(\kappa_4\xi_{11}+\kappa_9A_{11})/c^2,\gamma_{24}=-\kappa_{10}A_{33}-\kappa_5\xi_{33}+\tilde{\zeta}_3,\gamma_{25}=-(\kappa_5\xi_{11}+\kappa_{10}A_{11})/c^2,\gamma_{26}=-\kappa_1A_{33}-\kappa_6\xi_{33}^*,$$

$$\gamma_{27}=(-\kappa_1A_{11}-\kappa_6\xi_{11}^*)/c^2+(\zeta_{15}+\zeta_{31})/c-\kappa_2A_{33}-\kappa_7\xi_{33}^*,\gamma_{28}=-(\kappa_2A_{11}+\kappa_7\xi_{11}^*)/c^2,$$

Principal
Dyal Singh College
KARNAL

$$\gamma_{29} = \zeta_{33} - \kappa_3 A_{33} - \kappa_8 \xi^*_{33}, \gamma_{30} = (\zeta_{15} - \kappa_3 A_{11} - \kappa_8 \xi^*_{11})/c^2, \gamma_{31} = e^*_3/c - \xi^*_{33}\kappa_9 - A_{33}\kappa_4,$$

$$\gamma_{32} = -(\kappa_4 A_{11} + \kappa_9 \xi^*_{11})/c^2, \gamma_{33} = -\kappa_{10}\xi^*_{33} - \kappa_5 A_{33} + e^*_3, \gamma_{34} = -(\kappa_5 A_{11} + \kappa_{10}\xi^*_{11})/c^2,$$

$$\kappa_1 = -c_{44}\, d\, c, \quad \kappa_2 = -(c_{11}/c^2 - \bar{\rho}^{11}_{11})\, dc - (m_{11}/c^2 - \bar{\rho}^{12}_{11})\, c/\tilde{\zeta}_3 + (m_{11}/c^2 - \bar{\rho}^{12}_{11})(e_{15} + e_{31})\, cd/\tilde{\zeta}_3,$$

$$\kappa_3 = (m_{33}(e_{15} + e_{31})\, d - m_{33})/\tilde{\zeta}_3 - (c_{13} + c_{44})\, d,$$

$$\kappa_4 = -(m_{11}/c^2 - \bar{\rho}^{12}_{11})\, dc - (R/c^2 - \bar{\rho}^{22}_{11})\, c/\tilde{\zeta}_3 + (R p_1^2 - \bar{\rho}^{22}_{11})(e_{15} + e_{31})\, d\, c/\tilde{\zeta}_3,$$

$$\kappa_5 = (R(e_{15} + e_{31})\, d - R)/\tilde{\zeta}_3 - m_{11}\, d, \kappa_6 = c_{44}\,\tilde{\zeta}_3\, cd/e^*_3,$$

$$\kappa_7 = (c_{11}/c^2 - \bar{\rho}^{11}_{11})\, d\ \tilde{\zeta}_3 c/e^*_3 - (m_{11}/c^2 - \bar{\rho}^{12}_{11})(e_{15} + e_{31})\, d\, c/e^*_3,$$

$$\kappa_8 = (c_{13} + c_{44})\, d\,\tilde{\zeta}_3/e^*_3 - m_{33}(e_{15} + e_{31})\, d/e^*_3, \kappa_9 = (m_{11}/c^2 - \bar{\rho}^{12}_{11})\, cd\ \tilde{\zeta}_3/e^*_3 - (R/c^2 - \bar{\rho}^{22}_{11})(e_{15} + e_{31})\, cd/e^*_3,$$

$$\kappa_{10} = m_{11}\, d\,\tilde{\zeta}_3/e^*_3 - R(e_{15} + e_{31})\, d/e^*_3, d = e^*_3/(e^*_3(e_{15} + e_{31}) - \tilde{\zeta}_3(\zeta_{15} + \zeta_{31})).$$

$$\wp_{1i} = i\omega(c_{44}\, q_i + (c_{44}\, U'_{3i} + e_{15}\, \boldsymbol{\Phi}'_i + \zeta_{15}\, \boldsymbol{\Phi}^{*'}_i))/c,$$

$$\wp_{2i} = i\omega((c_{33}\, U'_{3i} + m_{33}\, U^{*'}_{3i} + e_{33}\, \boldsymbol{\Phi}'_i + \zeta_{33}\, \boldsymbol{\Phi}^{*'}_i)\, q_i + (c_{31} + m_{33}\, U^{*'}_{1i}))/c,$$

$$\wp_{3i} = i\omega((m_{33}\, U'_{3i} + R\, U^{*'}_{3i} + \tilde{\zeta}_3\, \boldsymbol{\Phi}'_i + e^*_3\, \boldsymbol{\Phi}^{*'}_i)\, q_i + (m_{11} + R\, U^{*'}_{1i}))/c,$$

$$\wp_{4i} = i\omega((e_{33}\, U'_{3i} + \tilde{\zeta}_3\, U^{*'}_{3i} - \xi_{33}\, \boldsymbol{\Phi}'_i - A_{33}\, \boldsymbol{\Phi}^{*'}_i)\, q_i + (e_{31} + \tilde{\zeta}_3\, U^{*'}_{1i}))/c,$$

$$\wp_{5i} = i\omega((\zeta_{33}\, U'_{3i} + e^*_3\, U^{*'}_{3i} - A_{33}\, \boldsymbol{\Phi}'_i - \xi^*_{33}\, \boldsymbol{\Phi}^{*'}_i)\, q_i + (\zeta_{31} + e^*_3\, U^{*'}_{1i}))/c. \tag{A.2}$$

Appendix B

$$\boldsymbol{Y}^{(j)} = \left[u_1^{(j)} \quad u_3^{(j)} \quad u_3^{*(j)} \quad \sigma_{33}^{(j)} \quad \phi^{(j)} \quad D_3^{(j)} \quad \sigma^{*(j)} \quad \sigma_{13}^{(j)} \quad \phi^{*(j)} \quad D_3^{*(j)}\right]^T, \tag{B.1}$$

$$\boldsymbol{S}^{(j)} = \left[U_{11}^{(j)} \quad U_{110}^{(j)} \quad U_{12}^{(j)} \quad U_{19}^{(j)} \quad U_{13}^{(j)} \quad U_{18}^{(j)} \quad U_{14}^{(j)} \quad U_{17}^{(j)} \quad U_{15}^{(j)} \quad U_{16}^{(j)}\right]^T, \tag{B.2}$$

$$\boldsymbol{W}^{(j)} = diag(\Xi_1^{(j)}, \Xi_{10}^{(j)}, \Xi_2^{(j)}, \Xi_9^{(j)}, \Xi_3^{(j)}, \Xi_8^{(j)}, \Xi_4^{(j)}, \Xi_7^{(j)}, \Xi_5^{(j)}, \Xi_6^{(j)}), \tag{B.3}$$

$$\Xi_i^{(j)} = \exp(\iota\omega q_i^{(j)} x_3), \quad (i = 1, 2, \ldots, 10), \tag{B.4}$$

$$\boldsymbol{V}^{(j)} = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
U_{31}^{\prime(j)} & -U_{31}^{\prime(j)} & U_{32}^{\prime(j)} & -U_{32}^{\prime(j)} & U_{33}^{\prime(j)} & -U_{33}^{\prime(j)} & U_{34}^{\prime(j)} & -U_{34}^{\prime(j)} & U_{35}^{\prime(j)} & -U_{35}^{\prime(j)} \\
U_{31}^{*\prime(j)} & -U_{31}^{*\prime(j)} & U_{32}^{*\prime(j)} & -U_{32}^{*\prime(j)} & U_{33}^{*\prime(j)} & -U_{33}^{*\prime(j)} & U_{34}^{*\prime(j)} & -U_{34}^{*\prime(j)} & U_{35}^{*\prime(j)} & -U_{35}^{*\prime(j)} \\
\wp_{21}^{(j)} & \wp_{21}^{(j)} & \wp_{22}^{(j)} & \wp_{22}^{(j)} & \wp_{23}^{(j)} & \wp_{23}^{(j)} & \wp_{24}^{(j)} & \wp_{24}^{(j)} & \wp_{25}^{(j)} & \wp_{25}^{(j)} \\
\boldsymbol{\Phi}_1^{\prime(j)} & -\boldsymbol{\Phi}_1^{\prime(j)} & \boldsymbol{\Phi}_2^{\prime(j)} & -\boldsymbol{\Phi}_2^{\prime(j)} & \boldsymbol{\Phi}_3^{\prime(j)} & -\boldsymbol{\Phi}_3^{\prime(j)} & \boldsymbol{\Phi}_4^{\prime(j)} & -\boldsymbol{\Phi}_4^{\prime(j)} & \boldsymbol{\Phi}_5^{\prime(j)} & -\boldsymbol{\Phi}_5^{\prime(j)} \\
\wp_{41}^{(j)} & \wp_{41}^{(j)} & \wp_{42}^{(j)} & \wp_{42}^{(j)} & \wp_{43}^{(j)} & \wp_{43}^{(j)} & \wp_{44}^{(j)} & \wp_{44}^{(j)} & \wp_{45}^{(j)} & \wp_{45}^{(j)} \\
\wp_{31}^{(j)} & \wp_{31}^{(j)} & \wp_{32}^{(j)} & \wp_{32}^{(j)} & \wp_{33}^{(j)} & \wp_{33}^{(j)} & \wp_{34}^{(j)} & \wp_{34}^{(j)} & \wp_{35}^{(j)} & \wp_{35}^{(j)} \\
\wp_{11}^{(j)} & -\wp_{11}^{(j)} & \wp_{12}^{(j)} & -\wp_{12}^{(j)} & \wp_{13}^{(j)} & -\wp_{13}^{(j)} & \wp_{14}^{(j)} & -\wp_{14}^{(j)} & \wp_{15}^{(j)} & -\wp_{15}^{(j)} \\
\boldsymbol{\Phi}_1^{*\prime(j)} & -\boldsymbol{\Phi}_1^{*\prime(j)} & \boldsymbol{\Phi}_2^{*\prime(j)} & -\boldsymbol{\Phi}_2^{*\prime(j)} & \boldsymbol{\Phi}_3^{*\prime(j)} & -\boldsymbol{\Phi}_3^{*\prime(j)} & \boldsymbol{\Phi}_4^{*\prime(j)} & -\boldsymbol{\Phi}_4^{*\prime(j)} & \boldsymbol{\Phi}_5^{*\prime(j)} & -\boldsymbol{\Phi}_5^{*\prime(j)} \\
\wp_{51}^{(j)} & \wp_{51}^{(j)} & \wp_{52}^{(j)} & \wp_{52}^{(j)} & \wp_{53}^{(j)} & \wp_{53}^{(j)} & \wp_{54}^{(j)} & \wp_{54}^{(j)} & \wp_{55}^{(j)} & \wp_{55}^{(j)}
\end{bmatrix},$$

$$(\boldsymbol{V}^{(j)})^{-1} = \begin{bmatrix}
\vartheta_{41} & \varkappa_{41} & \varkappa_{42} & \vartheta_{42} & \varkappa_{43} & \vartheta_{43} & \vartheta_{21} & \varkappa_{21} & \varkappa_{22} & \vartheta_{22} \\
\vartheta_{41} & -\varkappa_{41} & -\varkappa_{42} & \vartheta_{42} & -\varkappa_{43} & \vartheta_{43} & \vartheta_{21} & -\varkappa_{21} & -\varkappa_{22} & \vartheta_{22} \\
\vartheta_{44} & \varkappa_{44} & \varkappa_{45} & \vartheta_{45} & \varkappa_{46} & \vartheta_{46} & \vartheta_{23} & \varkappa_{23} & \varkappa_{24} & \vartheta_{24} \\
\vartheta_{44} & -\varkappa_{44} & -\varkappa_{45} & \vartheta_{45} & -\varkappa_{46} & \vartheta_{46} & \vartheta_{23} & -\varkappa_{23} & -\varkappa_{24} & \vartheta_{24} \\
\vartheta_{47} & \varkappa_{47} & \varkappa_{48} & \vartheta_{48} & \varkappa_{49} & \vartheta_{49} & \vartheta_{25} & \varkappa_{25} & \varkappa_{26} & \vartheta_{26} \\
\vartheta_{47} & -\varkappa_{47} & -\varkappa_{48} & \vartheta_{48} & -\varkappa_{49} & \vartheta_{49} & \vartheta_{25} & -\varkappa_{25} & -\varkappa_{26} & \vartheta_{26} \\
\vartheta_{31} & \varkappa_{31} & \varkappa_{32} & \vartheta_{32} & \varkappa_{33} & \vartheta_{33} & \vartheta_{11} & \varkappa_{11} & \varkappa_{12} & \vartheta_{12} \\
\vartheta_{31} & -\varkappa_{31} & -\varkappa_{32} & \vartheta_{32} & -\varkappa_{33} & \vartheta_{33} & \vartheta_{11} & -\varkappa_{11} & -\varkappa_{12} & \vartheta_{12} \\
\vartheta_{34} & \varkappa_{34} & \varkappa_{35} & \vartheta_{35} & \varkappa_{36} & \vartheta_{36} & \vartheta_{13} & \varkappa_{13} & \varkappa_{14} & \vartheta_{14} \\
\vartheta_{34} & -\varkappa_{34} & -\varkappa_{35} & \vartheta_{35} & -\varkappa_{36} & \vartheta_{36} & \vartheta_{13} & -\varkappa_{13} & -\varkappa_{14} & \vartheta_{14}
\end{bmatrix},$$

Principal
Dyal Singh College
KARNAL

where

$$
\begin{aligned}
\varkappa_{11} &= s'_{14}/(s'_{11}\,s'_{14} - s'_{12}\,s'_{13}),\\
\varkappa_{12} &= -s'_{12}/(s'_{11}\,s'_{14} - s'_{12}\,s'_{13}),\\
\varkappa_{13} &= -s'_{13}/(s'_{11}\,s'_{14} - s'_{12}\,s'_{13}),\\
\varkappa_{14} &= s'_{11}/(s'_{11}\,s'_{14} - s'_{12}\,s'_{13}),\\
\varkappa_{21} &= -(\upsilon_{21}\,(\varkappa_{11}\,U'^{(j)}_{34} + \varkappa_{13}\,U'^{(j)}_{35}) + \upsilon_{12}\,(\varkappa_{11}\,U^{*'(j)}_{34} + \varkappa_{13}\,U^{*'(j)}_{35}) + \upsilon_{13}\,(\varkappa_{11}\,\Phi'^{(j)}_{4} + \varkappa_{13}\,\Phi'^{(j)}_{5})),\\
\varkappa_{22} &= -(\upsilon_{21}\,(\varkappa_{12}\,U'^{(j)}_{34} + \varkappa_{14}\,U'^{(j)}_{35}) + \upsilon_{12}\,(\varkappa_{12}\,U^{*'(j)}_{34} + \varkappa_{14}\,U^{*'(j)}_{35}) + \upsilon_{13}\,(\varkappa_{12}\,\Phi'^{(j)}_{4} + \varkappa_{14}\,\Phi'^{(j)}_{5})),\\
\varkappa_{23} &= -(\upsilon_{31}\,(\varkappa_{11}\,U'^{(j)}_{34} + \varkappa_{13}\,U'^{(j)}_{35}) + \upsilon_{22}\,(\varkappa_{11}\,U^{*'(j)}_{34} + \varkappa_{13}\,U^{*'(j)}_{35}) + \upsilon_{33}\,(\varkappa_{11}\,\Phi'^{(j)}_{4} + \varkappa_{13}\,\Phi'^{(j)}_{5})),\\
\varkappa_{24} &= -(\upsilon_{31}\,(\varkappa_{12}\,U'^{(j)}_{34} + \varkappa_{14}\,U'^{(j)}_{35}) + \upsilon_{22}\,(\varkappa_{12}\,U^{*'(j)}_{34} + \varkappa_{14}\,U^{*'(j)}_{35}) + \upsilon_{33}\,(\varkappa_{12}\,\Phi'^{(j)}_{4} + \varkappa_{14}\,\Phi'^{(j)}_{5})),\\
\varkappa_{25} &= -(\upsilon_{41}\,(\varkappa_{11}\,U'^{(j)}_{34} + \varkappa_{13}\,U'^{(j)}_{35}) + \upsilon_{42}\,(\varkappa_{11}\,U^{*'(j)}_{34} + \varkappa_{13}\,U^{*'(j)}_{35}) + \upsilon_{43}\,(\varkappa_{11}\,\Phi'^{(j)}_{4} + \varkappa_{13}\,\Phi'^{(j)}_{5})),\\
\varkappa_{26} &= -(\upsilon_{41}\,(\varkappa_{12}\,U'^{(j)}_{34} + \varkappa_{14}\,U'^{(j)}_{35}) + \upsilon_{42}\,(\varkappa_{12}\,U^{*'(j)}_{34} + \varkappa_{14}\,U^{*'(j)}_{35}) + \upsilon_{43}\,(\varkappa_{12}\,\Phi'^{(j)}_{4} + \varkappa_{14}\,\Phi'^{(j)}_{5})),\\
\varkappa_{31} &= -(\varkappa_{11}\,(\upsilon_{21}\,\wp^{(j)}_{11} + \upsilon_{31}\,\wp^{(j)}_{12} + \upsilon_{41}\,\wp^{(j)}_{13}) + \varkappa_{12}\,(\upsilon_{21}\,\Phi^{*'(j)}_{1} + \upsilon_{31}\,\Phi^{*'(j)}_{2} + \upsilon_{41}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{32} &= -(\varkappa_{11}\,(\upsilon_{12}\,\wp^{(j)}_{11} + \upsilon_{22}\,\wp^{(j)}_{12} + \upsilon_{42}\,\wp^{(j)}_{13}) + \varkappa_{12}\,(\upsilon_{12}\,\Phi^{*'(j)}_{1} + \upsilon_{22}\,\Phi^{*'(j)}_{2} + \upsilon_{42}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{33} &= -(\varkappa_{11}\,(\upsilon_{13}\,\wp^{(j)}_{11} + \upsilon_{33}\,\wp^{(j)}_{12} + \upsilon_{43}\,\wp^{(j)}_{13}) + \varkappa_{12}\,(\upsilon_{13}\,\Phi^{*'(j)}_{1} + \upsilon_{33}\,\Phi^{*'(j)}_{2} + \upsilon_{43}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{34} &= -(\varkappa_{13}\,(\upsilon_{21}\,\wp^{(j)}_{11} + \upsilon_{31}\,\wp^{(j)}_{12} + \upsilon_{41}\,\wp^{(j)}_{13}) + \varkappa_{14}\,(\upsilon_{21}\,\Phi^{*'(j)}_{1} + \upsilon_{31}\,\Phi^{*'(j)}_{2} + \upsilon_{41}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{35} &= -(\varkappa_{13}\,(\upsilon_{12}\,\wp^{(j)}_{11} + \upsilon_{22}\,\wp^{(j)}_{12} + \upsilon_{42}\,\wp^{(j)}_{13}) + \varkappa_{14}\,(\upsilon_{12}\,\Phi^{*'(j)}_{1} + \upsilon_{22}\,\Phi^{*'(j)}_{2} + \upsilon_{42}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{36} &= -(\varkappa_{13}\,(\upsilon_{13}\,\wp^{(j)}_{11} + \upsilon_{33}\,\wp^{(j)}_{12} + \upsilon_{43}\,\wp^{(j)}_{13}) + \varkappa_{14}\,(\upsilon_{13}\,\Phi^{*'(j)}_{1} + \upsilon_{33}\,\Phi^{*'(j)}_{2} + \upsilon_{43}\,\Phi^{*'(j)}_{3})),\\
\varkappa_{41} &= \upsilon_{21} - 2\,(\upsilon_{21}\,(\varkappa_{31}\,U'^{(j)}_{34} + \varkappa_{34}\,U'^{(j)}_{35}) + \upsilon_{12}\,(\varkappa_{31}\,U^{*'(j)}_{34} + \varkappa_{34}\,U^{*'(j)}_{35}) + \upsilon_{13}\,(\varkappa_{31}\,\Phi'^{(j)}_{4} + \varkappa_{34}\,\Phi'^{(j)}_{5})),\\
\varkappa_{42} &= \upsilon_{12} - 2\,(\upsilon_{21}\,(\varkappa_{32}\,U'^{(j)}_{34} + \varkappa_{35}\,U'^{(j)}_{35}) + \upsilon_{12}\,(\varkappa_{32}\,U^{*'(j)}_{34} + \varkappa_{35}\,U^{*'(j)}_{35}) + \upsilon_{13}\,(\varkappa_{32}\,\Phi'^{(j)}_{4} + \varkappa_{35}\,\Phi'^{(j)}_{5})),\\
\varkappa_{43} &= \upsilon_{13} - 2\,(\upsilon_{21}\,(\varkappa_{33}\,U'^{(j)}_{34} + \varkappa_{36}\,U'^{(j)}_{35}) + \upsilon_{12}\,(\varkappa_{33}\,U^{*'(j)}_{34} + \varkappa_{36}\,U^{*'(j)}_{35}) + \upsilon_{13}\,(\varkappa_{33}\,\Phi'^{(j)}_{4} + \varkappa_{36}\,\Phi'^{(j)}_{5})),\\
\varkappa_{44} &= \upsilon_{31} - 2\,(\upsilon_{31}\,(\varkappa_{31}\,U'^{(j)}_{34} + \varkappa_{34}\,U'^{(j)}_{35}) + \upsilon_{22}\,(\varkappa_{31}\,U^{*'(j)}_{34} + \varkappa_{34}\,U^{*'(j)}_{35}) + \upsilon_{33}\,(\varkappa_{31}\,\Phi'^{(j)}_{4} + \varkappa_{34}\,\Phi'^{(j)}_{5})),\\
\varkappa_{45} &= \upsilon_{22} - 2\,(\upsilon_{31}\,(\varkappa_{32}\,U'^{(j)}_{34} + \varkappa_{35}\,U'^{(j)}_{35}) + \upsilon_{22}\,(\varkappa_{32}\,U^{*'(j)}_{34} + \varkappa_{35}\,U^{*'(j)}_{35}) + \upsilon_{33}\,(\varkappa_{32}\,\Phi'^{(j)}_{4} + \varkappa_{35}\,\Phi'^{(j)}_{5})),\\
\varkappa_{46} &= \upsilon_{33} - 2\,(\upsilon_{31}\,(\varkappa_{33}\,U'^{(j)}_{34} + \varkappa_{36}\,U'^{(j)}_{35}) + \upsilon_{22}\,(\varkappa_{33}\,U^{*'(j)}_{34} + \varkappa_{36}\,U^{*'(j)}_{35}) + \upsilon_{33}\,(\varkappa_{33}\,\Phi'^{(j)}_{4} + \varkappa_{36}\,\Phi'^{(j)}_{5})),\\
\varkappa_{47} &= \upsilon_{41} - 2\,(\upsilon_{41}\,(\varkappa_{31}\,U'^{(j)}_{34} + \varkappa_{34}\,U'^{(j)}_{35}) + \upsilon_{42}\,(\varkappa_{31}\,U^{*'(j)}_{34} + \varkappa_{34}\,U^{*'(j)}_{35}) + \upsilon_{43}\,(\varkappa_{31}\,\Phi'^{(j)}_{4} + \varkappa_{34}\,\Phi'^{(j)}_{5})),\\
\varkappa_{48} &= \upsilon_{42} - 2\,(\upsilon_{41}\,(\varkappa_{32}\,U'^{(j)}_{34} + \varkappa_{35}\,U'^{(j)}_{35}) + \upsilon_{42}\,(\varkappa_{32}\,U^{*'(j)}_{34} + \varkappa_{35}\,U^{*'(j)}_{35}) + \upsilon_{43}\,(\varkappa_{32}\,\Phi'^{(j)}_{4} + \varkappa_{35}\,\Phi'^{(j)}_{5})),\\
\varkappa_{49} &= \upsilon_{43} - 2\,(\upsilon_{41}\,(\varkappa_{33}\,U'^{(j)}_{34} + \varkappa_{36}U'^{(j)}_{35}) + \upsilon_{42}\,(\varkappa_{33}\,U^{*'(j)}_{34} + \varkappa_{36}\,U^{*'(j)}_{35}) + \upsilon_{43}\,(\varkappa_{33}\,\Phi'^{(j)}_{4} + \varkappa_{36}\,\Phi'^{(j)}_{5})),\\
\vartheta_{11} &= t'_{14}/(t'_{11}\,t'_{14} - t'_{12}\,t'_{13}),\\
\vartheta_{12} &= -t'_{12}/(t'_{11}\,t'_{14} - t'_{12}\,t'_{13}),\\
\vartheta_{13} &= -t'_{13}/(t'_{11}\,t'_{14} - t'_{12}\,t'_{13}),\\
\vartheta_{14} &= t'_{11}/(t'_{11}\,t'_{14} - t'_{12}\,t'_{13}),\\
\vartheta_{21} &= -(\tau_{21}\,(\vartheta_{11} + \vartheta_{13}) + \tau_{12}\,(\vartheta_{11}\,\wp^{(j)}_{24} + \vartheta_{13}\,\wp^{(j)}_{25}) + \tau_{13}\,(\vartheta_{11}\,\wp^{(j)}_{44} + \vartheta_{13}\,\wp^{(j)}_{45})),\\
\vartheta_{22} &= -(\tau_{21}\,(\vartheta_{14} + \vartheta_{12}) + \tau_{12}\,(\vartheta_{12}\,\wp^{(j)}_{24} + \vartheta_{14}\,\wp^{(j)}_{25}) + \tau_{13}\,(\vartheta_{12}\,\wp^{(j)}_{44} + \vartheta_{14}\,\wp^{(j)}_{45})),\\
\vartheta_{23} &= -(\tau_{31}\,(\vartheta_{11} + \vartheta_{13}) + \tau_{22}\,(\vartheta_{11}\,\wp^{(j)}_{24} + \vartheta_{13}\,\wp^{(j)}_{25}) + \tau_{33}\,(\vartheta_{11}\,\wp^{(j)}_{44} + \vartheta_{13}\,\wp^{(j)}_{45})),\\
\vartheta_{24} &= -(\tau_{31}\,(\vartheta_{14} + \vartheta_{12}) + \tau_{22}\,(\vartheta_{12}\,\wp^{(j)}_{24} + \vartheta_{14}\,\wp^{(j)}_{25}) + \tau_{33}\,(\vartheta_{12}\,\wp^{(j)}_{44} + \vartheta_{14}\,\wp^{(j)}_{45})),\\
\vartheta_{25} &= -(\tau_{41}\,(\vartheta_{11} + \vartheta_{13}) + \tau_{42}\,(\vartheta_{11}\,\wp^{(j)}_{24} + \vartheta_{13}\,\wp^{(j)}_{25}) + \tau_{43}\,(\vartheta_{11}\,\wp^{(j)}_{44} + \vartheta_{13}\,\wp^{(j)}_{45})),\\
\vartheta_{26} &= -(\tau_{41}\,(\vartheta_{14} + \vartheta_{12}) + \tau_{42}\,(\vartheta_{12}\,\wp^{(j)}_{24} + \vartheta_{14}\,\wp^{(j)}_{25}) + \tau_{43}\,(\vartheta_{12}\,\wp^{(j)}_{44} + \vartheta_{14}\,\wp^{(j)}_{45})),\\
\vartheta_{31} &= -(\vartheta_{11}\,(\tau_{21}\,\wp^{(j)}_{31} + \tau_{31}\,\wp^{(j)}_{32} + \tau_{41}\,\wp^{(j)}_{33}) + \vartheta_{12}\,(\tau_{21}\,\wp^{(j)}_{51} + \tau_{31}\,\wp^{(j)}_{52} + \tau_{41}\,\wp^{(j)}_{53})),\\
\vartheta_{32} &= -(\vartheta_{11}\,(\tau_{12}\,\wp^{(j)}_{31} + \tau_{22}\,\wp^{(j)}_{32} + \tau_{42}\,\wp^{(j)}_{33}) + \vartheta_{12}\,(\tau_{12}\,\wp^{(j)}_{51} + \tau_{22}\,\wp^{(j)}_{52} + \tau_{42}\,\wp^{(j)}_{53})),\\
\vartheta_{33} &= -(\vartheta_{11}\,(\tau_{13}\,\wp^{(j)}_{31} + \tau_{33}\,\wp^{(j)}_{32} + \tau_{43}\,\wp^{(j)}_{33}) + \vartheta_{12}\,(\tau_{13}\,\wp^{(j)}_{51} + \tau_{33}\,\wp^{(j)}_{52} + \tau_{43}\,\wp^{(j)}_{53})),\\
\vartheta_{34} &= -(\vartheta_{13}\,(\tau_{21}\,\wp^{(j)}_{31} + \tau_{31}\,\wp^{(j)}_{32} + \tau_{41}\,\wp^{(j)}_{33}) + \vartheta_{14}\,(\tau_{21}\,\wp^{(j)}_{51} + \tau_{31}\,\wp^{(j)}_{52} + \tau_{41}\,\wp^{(j)}_{53})),\\
\vartheta_{35} &= -(\vartheta_{13}\,(\tau_{12}\,\wp^{(j)}_{31} + \tau_{22}\,\wp^{(j)}_{32} + \tau_{42}\,\wp^{(j)}_{33}) + \vartheta_{14}\,(\tau_{12}\,\wp^{(j)}_{51} + \tau_{22}\,\wp^{(j)}_{52} + \tau_{42}\,\wp^{(j)}_{53})),\\
\vartheta_{36} &= -(\vartheta_{13}\,(\tau_{13}\,\wp^{(j)}_{31} + \tau_{33}\,\wp^{(j)}_{32} + \tau_{43}\,\wp^{(j)}_{33}) + \vartheta_{14}\,(\tau_{13}\,\wp^{(j)}_{51} + \tau_{33}\,\wp^{(j)}_{52} + \tau_{43}\,\wp^{(j)}_{53})),\\
\vartheta_{41} &= \tau_{21} - 2(\tau_{21}(\vartheta_{31} + \vartheta_{34}) + \tau_{12}(\vartheta_{31}\,\wp^{(j)}_{24} + \vartheta_{34}\,\wp^{(j)}_{25}) + \tau_{13}(\vartheta_{31}\,\wp^{(j)}_{44} + \vartheta_{34}\,\wp^{(j)}_{45})),\\
\vartheta_{42} &= \tau_{12} - 2(\tau_{21}(\vartheta_{32} + \vartheta_{35}) + \tau_{12}(\vartheta_{32}\,\wp^{(j)}_{24} + \vartheta_{35}\,\wp^{(j)}_{25}) + \tau_{13}(\vartheta_{32}\,\wp^{(j)}_{44} + \vartheta_{35}\,\wp^{(j)}_{45})),\\
\vartheta_{43} &= \tau_{13} - 2(\tau_{21}(\vartheta_{33} + \vartheta_{36}) + \tau_{12}(\vartheta_{33}\,\wp^{(j)}_{24} + \vartheta_{36}\,\wp^{(j)}_{25}) + \tau_{13}(\vartheta_{33}\,\wp^{(j)}_{44} + \vartheta_{36}\,\wp^{(j)}_{45})),\\
\vartheta_{44} &= \tau_{31} - 2(\tau_{31}(\vartheta_{31} + \vartheta_{34}) + \tau_{22}(\vartheta_{31}\,\wp^{(j)}_{24} + \vartheta_{34}\,\wp^{(j)}_{25}) + \tau_{33}(\vartheta_{31}\,\wp^{(j)}_{44} + \vartheta_{34}\,\wp^{(j)}_{45})),\\
\vartheta_{45} &= \tau_{22} - 2(\tau_{31}(\vartheta_{32} + \vartheta_{35}) + \tau_{22}(\vartheta_{32}\,\wp^{(j)}_{24} + \vartheta_{35}\,\wp^{(j)}_{25}) + \tau_{33}(\vartheta_{32}\,\wp^{(j)}_{44} + \vartheta_{35}\,\wp^{(j)}_{45})),\\
\vartheta_{46} &= \tau_{33} - 2(\tau_{31}(\vartheta_{33} + \vartheta_{36}) + \tau_{22}(\vartheta_{33}\,\wp^{(j)}_{24} + \vartheta_{36}\,\wp^{(j)}_{25}) + \tau_{33}(\vartheta_{33}\,\wp^{(j)}_{44} + \vartheta_{36}\,\wp^{(j)}_{45})),
\end{aligned}
$$

Principal
Dyal Singh College
KARNAL

$$\vartheta_{47} = \tau_{41} - 2(\tau_{41}(\vartheta_{31}+\vartheta_{34}) + \tau_{42}(\vartheta_{31}\wp_{24}^{(j)} + \vartheta_{34}\wp_{25}^{(j)}) + \tau_{43}(\vartheta_{31}\wp_{44}^{(j)} + \vartheta_{34}\wp_{45}^{(j)})),$$
$$\vartheta_{48} = \tau_{42} - 2(\tau_{41}(\vartheta_{32}+\vartheta_{35}) + \tau_{42}(\vartheta_{32}\wp_{24}^{(j)} + \vartheta_{35}\wp_{25}^{(j)}) + \tau_{43}(\vartheta_{32}\wp_{44}^{(j)} + \vartheta_{35}\wp_{45}^{(j)})),$$
$$\vartheta_{49} = \tau_{43} - 2(\tau_{41}(\vartheta_{33}+\vartheta_{36}) + \tau_{42}(\vartheta_{33}\wp_{24}^{(j)} + \vartheta_{36}\wp_{25}^{(j)}) + \tau_{43}(\vartheta_{33}\wp_{44}^{(j)} + \vartheta_{36}\wp_{45}^{(j)})),$$
$$t'_{11} = \wp_{34}^{(j)} - 2(\tau_{21}\wp_{31}^{(j)} + \tau_{31}\wp_{32}^{(j)} + \tau_{41}\wp_{33}^{(j)} + (\tau_{12}\wp_{31}^{(j)} + \tau_{22}\wp_{32}^{(j)} + \tau_{42}\wp_{33}^{(j)})\wp_{24}^{(j)} + (\tau_{13}\wp_{31}^{(j)} + \tau_{33}\wp_{32}^{(j)} + \tau_{43}\wp_{33}^{(j)})\wp_{44}^{(j)}),$$
$$t'_{12} = \wp_{35}^{(j)} - 2(\tau_{21}\wp_{31}^{(j)} + \tau_{31}\wp_{32}^{(j)} + \tau_{41}\wp_{33}^{(j)} + (\tau_{12}\wp_{31}^{(j)} + \tau_{22}\wp_{32}^{(j)} + \tau_{42}\wp_{33}^{(j)})\wp_{25}^{(j)} + (\tau_{13}\wp_{31}^{(j)} + \tau_{33}\wp_{32}^{(j)} + \tau_{43}\wp_{33}^{(j)})\wp_{45}^{(j)}),$$
$$t'_{13} = \wp_{54}^{(j)} - 2(\tau_{21}\wp_{51}^{(j)} + \tau_{31}\wp_{52}^{(j)} + \tau_{41}\wp_{53}^{(j)} + (\tau_{12}\wp_{51}^{(j)} + \tau_{22}\wp_{52}^{(j)} + \tau_{42}\wp_{53}^{(j)})\wp_{24}^{(j)} + (\tau_{13}\wp_{51}^{(j)} + \tau_{33}\wp_{52}^{(j)} + \tau_{43}\wp_{53}^{(j)})\wp_{44}^{(j)}),$$
$$t'_{14} = \wp_{55}^{(j)} - 2(\tau_{21}\wp_{51}^{(j)} + \tau_{31}\wp_{52}^{(j)} + \tau_{41}\wp_{53}^{(j)} + (\tau_{12}\wp_{51}^{(j)} + \tau_{22}\wp_{52}^{(j)} + \tau_{42}\wp_{53}^{(j)})\wp_{25}^{(j)} + (\tau_{13}\wp_{51}^{(j)} + \tau_{33}\wp_{52}^{(j)} + \tau_{43}\wp_{53}^{(j)})\wp_{45}^{(j)}),$$
$$s'_{11} = \wp_{14}^{(j)} - 2((\upsilon_{21}\wp_{11}^{(j)} + \upsilon_{31}\wp_{12}^{(j)} + \upsilon_{41}\wp_{13}^{(j)})U_{34}^{\prime(j)} + (\upsilon_{12}\wp_{11}^{(j)} + \upsilon_{22}\wp_{12}^{(j)} + \upsilon_{42}\wp_{13}^{(j)})U_{34}^{*\prime(j)} + (\upsilon_{13}\wp_{11}^{(j)} + \upsilon_{33}\wp_{12}^{(j)} + \upsilon_{43}\wp_{13}^{(j)})\Phi_4^{\prime(j)}),$$
$$s'_{12} = \wp_{15}^{(j)} - 2((\upsilon_{21}\wp_{11}^{(j)} + \upsilon_{31}\wp_{12}^{(j)} + \upsilon_{41}\wp_{13}^{(j)})U_{35}^{\prime(j)} + (\upsilon_{12}\wp_{11}^{(j)} + \upsilon_{22}\wp_{12}^{(j)} + \upsilon_{42}\wp_{13}^{(j)})U_{35}^{*\prime(j)} + (\upsilon_{13}\wp_{11}^{(j)} + \upsilon_{33}\wp_{12}^{(j)} + \upsilon_{43}\wp_{13}^{(j)})\Phi_5^{\prime(j)}),$$
$$s'_{13} = \Phi_4^{*\prime(j)} - 2((\upsilon_{21}\Phi_1^{*\prime(j)} + \upsilon_{31}\Phi_2^{*\prime(j)} + \upsilon_{41}\Phi_3^{*\prime(j)})U_{34}^{\prime(j)} + (\upsilon_{12}\Phi_1^{*\prime(j)} + \upsilon_{22}\Phi_2^{*\prime(j)} + \upsilon_{42}\Phi_3^{*\prime(j)})U_{34}^{*\prime(j)} + (\upsilon_{13}\Phi_1^{*\prime(j)} + \upsilon_{33}\Phi_2^{*\prime(j)} + \upsilon_{43}\Phi_3^{*\prime(j)})\Phi_4^{\prime(j)}),$$
$$s'_{14} = \Phi_5^{*\prime(j)} - 2((\upsilon_{21}\Phi_1^{*\prime(j)} + \upsilon_{31}\Phi_2^{*\prime(j)} + \upsilon_{41}\Phi_3^{*\prime(j)})U_{35}^{\prime(j)} + (\upsilon_{12}\Phi_1^{*\prime(j)} + \upsilon_{22}\Phi_2^{*\prime(j)} + \upsilon_{42}\Phi_3^{*\prime(j)})U_{35}^{*\prime(j)} + (\upsilon_{13}\Phi_1^{*\prime(j)} + \upsilon_{33}\Phi_2^{*\prime(j)} + \upsilon_{43}\Phi_3^{*\prime(j)})\Phi_5^{\prime(j)}),$$
$$\upsilon_{11} = (U_{31}^{\prime(j)} + 2U_{32}^{\prime(j)}\upsilon_{32}U_{31}^{*\prime(j)})/2(U_{31}^{\prime(j)})^2,$$
$$\upsilon_{12} = (2\upsilon_{42}\upsilon_{32}U_{32}^{\prime(j)}U_{33}^{*\prime(j)} - \upsilon_{32}U_{32}^{\prime(j)} - 2\upsilon_{11}\upsilon_{42}U_{33}^{\prime(j)}U_{31}^{\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{13} = 2(\upsilon_{32}\upsilon_{43}U_{32}^{\prime(j)}U_{33}^{*\prime(j)} - \upsilon_{11}\upsilon_{43}U_{31}^{\prime(j)}U_{33}^{\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{21} = (\upsilon_{11}U_{31}^{\prime(j)} - 2\upsilon_{11}\upsilon_{41}U_{33}^{\prime(j)}U_{31}^{\prime(j)} + 2\upsilon_{32}\upsilon_{41}U_{32}^{\prime(j)}U_{33}^{*\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{22} = (\upsilon_{32}U_{31}^{\prime(j)} + 2\upsilon_{32}\upsilon_{42}U_{31}^{*\prime(j)}U_{33}^{\prime(j)} - 2\upsilon_{32}\upsilon_{42}U_{33}^{*\prime(j)}U_{31}^{\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{31} = (2\upsilon_{41}\upsilon_{32}U_{33}^{\prime(j)}U_{31}^{*\prime(j)} - \upsilon_{32}U_{31}^{*\prime(j)} - 2\upsilon_{32}\upsilon_{41}U_{31}^{\prime(j)}U_{33}^{*\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{32} = U_{31}^{\prime(j)}(U_{32}^{*\prime(j)}U_{31}^{\prime(j)} - U_{32}^{\prime(j)}U_{31}^{*\prime(j)})/2,$$
$$\upsilon_{33} = 2(\upsilon_{32}\upsilon_{43}U_{31}^{*\prime(j)}U_{33}^{\prime(j)} - \upsilon_{32}\upsilon_{43}U_{31}^{\prime(j)}U_{33}^{*\prime(j)})/U_{31}^{\prime(j)},$$
$$\upsilon_{41} = -(2\upsilon_{43}/U_{31}^{\prime(j)})(\upsilon_{11}\Phi_1^{\prime(j)}U_{31}^{\prime(j)} - \upsilon_{32}\Phi_2^{\prime(j)}U_{31}^{*\prime(j)}),$$
$$\upsilon_{42} = -(2\upsilon_{43}/U_{31}^{\prime(j)})(\upsilon_{32}\Phi_2^{\prime(j)}U_{31}^{\prime(j)} - \upsilon_{32}\Phi_1^{\prime(j)}U_{32}^{\prime(j)}),$$
$$\upsilon_{43} = U_{31}^{\prime(j)}/2(\Phi_3^{\prime(j)}U_{31}^{\prime(j)} - 2U_{33}^{\prime(j)}(\upsilon_{11}\Phi_1^{\prime(j)}U_{31}^{\prime(j)} - \upsilon_{32}\Phi_2^{\prime(j)}U_{31}^{*\prime(j)}) - 2U_{33}^{*\prime(j)}(\upsilon_{32}\Phi_2^{\prime(j)}U_{31}^{\prime(j)} - \upsilon_{32}\Phi_1^{\prime(j)}U_{32}^{\prime(j)})),$$
$$\tau_{11} = (1+2\tau_{32}\wp_{21}^{(j)})/2, \quad \tau_{12} = 2\tau_{32}\tau_{42}\wp_{23}^{(j)} - \tau_{32} - 2\tau_{11}\tau_{42},$$
$$\tau_{13} = 2(-\tau_{11}\tau_{43} + \tau_{32}\tau_{43}\wp_{23}^{(j)}), \quad \tau_{21} = \tau_{11} - 2\tau_{11}\tau_{41} + 2\tau_{32}\tau_{41}\wp_{23}^{(j)},$$
$$\tau_{22} = \tau_{32} + 2\tau_{32}\tau_{42}\wp_{21}^{(j)} - 2\tau_{32}\tau_{42}\wp_{23}^{(j)}, \quad \tau_{31} = 2\tau_{32}\tau_{41}\wp_{21}^{(j)} - \tau_{32}\wp_{21}^{(j)} - 2\tau_{32}\tau_{41}\wp_{23}^{(j)},$$
$$\tau_{32} = 1/2(\wp_{22}^{(j)} - \wp_{21}^{(j)}), \quad \tau_{33} = 2(\tau_{32}\tau_{43}\wp_{21}^{(j)} - \tau_{32}\tau_{43}\wp_{23}^{(j)}), \quad \tau_{41} = -2\tau_{43}(\tau_{11}\wp_{41}^{(j)} - \tau_{32}\wp_{21}^{(j)}\wp_{42}^{(j)}),$$
$$\tau_{42} = -2\tau_{43}(\tau_{32}\wp_{42}^{(j)} - \tau_{32}\wp_{41}^{(j)}), \tau_{43} = (\wp_{43}^{(j)} - 2\tau_{11}\wp_{41}^{(j)} + 2\tau_{32}\wp_{21}^{(j)}\wp_{42}^{(j)} - 2\wp_{23}^{(j)}(\tau_{32}\wp_{42}^{(j)} - \tau_{32}\wp_{41}^{(j)}))/2.$$

Appendix C

$$\begin{aligned}
&\Gamma_{11}^f = c_{11}^0/c^2 + c_{44}^0(q^f)^2 - \bar{\rho}_{11}^{11f} - ic_{44}^0 q^f\alpha/\omega, && \Gamma_{12}^f = (c_{13}^0 + c_{44}^0)q^f/c - ic_{44}^0\alpha/c\omega,\\
&\Gamma_{13}^f = m_{11}^0/c^2 - \bar{\rho}_{11}^{12f}, && \Gamma_{14}^f = m_{11}^0 q^f/c,\\
&\Gamma_{15}^f = (e_{15}^0 + e_{31}^0)q^f/c - ie_{15}^0\alpha/c\omega, && \Gamma_{16}^f = (\zeta_{15}^0 + \zeta_{31}^0)q^f/c - i\zeta_{15}^0\alpha/c\omega,\\
&\Gamma_{21}^f = (c_{13}^0 + c_{44}^0)q^f/c - ic_{13}^0\alpha/c\omega, && \Gamma_{22}^f = c_{44}^0/c^2 + c_{33}^0(q^f)^2 - \bar{\rho}_{33}^{11f} - ic_{33}^0 q^f\alpha/\omega,\\
&\Gamma_{23}^f = m_{33}^0 q^f/c - im_{33}^0\alpha/c\omega, && \Gamma_{24}^f = m_{33}^0(q^f)^2 - \bar{\rho}_{33}^{12f} - im_{33}^0\alpha q^f/\omega,\\
&\Gamma_{25}^f = e_{15}^0/c^2 + e_{33}^0(q^f)^2 - ie_{33}^0\alpha q^f/\omega, && \Gamma_{26}^f = \zeta_{15}^0/c^2 + \zeta_{33}^0(q^f)^2 - i\zeta_{33}^0\alpha q^f/\omega,\\
&\Gamma_{31}^f = \Gamma_{13}^f, && \Gamma_{32}^f = m_{33}^0 q^f/c,\\
&\Gamma_{33}^f = R^0/c^2 - \bar{\rho}_{11}^{22f}, && \Gamma_{34}^f = R^0 q^f/c,\\
&\Gamma_{35}^f = \zeta_3^{*0} q^f/c, && \Gamma_{36}^f = e_3^{*0} q^f/c,\\
&\Gamma_{41}^f = m_{11}^0 q^f/c - im_{11}^0\alpha/c\omega, && \Gamma_{42}^f = m_{33}^0(q^f)^2 - \bar{\rho}_{33}^{12f} - im_{33}^0\alpha q^f/\omega,\\
&\Gamma_{43}^f = R^0 q^f/c - iR^0\alpha/(c\omega), && \Gamma_{44}^f = R^0(q^f)^2 - \bar{\rho}_{33}^{22f} - iR^0 q^f\alpha/\omega,\\
&\Gamma_{45}^f = \zeta_3^{*0}(q^f)^2 - i\zeta_3^{*0} q^f\alpha/\omega, && \Gamma_{46}^f = e_3^{*0}(q^f)^2 - ie_3^{*0} q^f\alpha/\omega,\\
&\Gamma_{51}^f = (e_{15}^0 + e_{31}^0)q^f/c - ie_{31}^0\alpha/c\omega, && \Gamma_{52}^f = \Gamma_{25}^f,\\
&\Gamma_{53}^f = \zeta_3^{*0} q^f/c - i\zeta_3^{*0}\alpha/c\omega, && \Gamma_{54}^f = \Gamma_{45}^f,\\
&\Gamma_{55}^f = -\xi_{11}^0/c^2 - \xi_{33}^0(q^f)^2 + i\xi_{33}^0\alpha q^f/\omega, && \Gamma_{56}^f = -A_{11}^0/c^2 - A_{33}^0(q^f)^2 + iA_{33}^0\alpha q^f/\omega,\\
&\Gamma_{61}^f = (\zeta_{15}^0 + \zeta_{31}^0)q^f/c - i\zeta_{31}^0\alpha/c\omega, && \Gamma_{62}^f = \Gamma_{26}^f,\\
&\Gamma_{63}^f = e_3^{*0} q^f/c - ie_3^{*0}\alpha/c\omega, && \Gamma_{64}^f = \Gamma_{46}^f,\\
&\Gamma_{65}^f = \Gamma_{56}^f, && \Gamma_{66}^f = -\xi_{11}^{*0}/c^2 - \xi_{33}^{*0}(q^f)^2 + i\xi_{33}^{*0} q^f\alpha/\omega,
\end{aligned} \tag{C.1}$$

Principal
Dyal Singh College
KARNAL

where $\bar{\rho}^{11f} = (\rho^{11f})^{\mathbf{0}} + \frac{i}{\omega}\boldsymbol{b}^{\mathbf{0}}$, $\bar{\rho}^{12f} = (\rho^{12f})^{\mathbf{0}} - \frac{i}{\omega}\boldsymbol{b}^{\mathbf{0}}$, $\bar{\rho}^{22f} = (\rho^{22f})^{\mathbf{0}} + \frac{i}{\omega}\boldsymbol{b}^{\mathbf{0}}$.

$t_1 = l_1 + l_{12} + l_{23} + l_{34} + l_{45},\ t_2 = l_2 + l_{13} + l_{24} + l_{35} + l_{46},\ t_3 = l_3 + l_{14} + l_{25} + l_{36} + l_{47},$
$t_4 = l_4 + l_{15} + l_{26} + l_{37} + l_{48}, t_5 = l_5 + l_{16} + l_{27} + l_{38} + l_{49},\ t_6 = l_6 + l_{17} + l_{28} + l_{39} + l_{50},$
$t_7 = l_7 + l_{18} + l_{29} + l_{40} + l_{51},\ t_8 = l_8 + l_{19} + l_{30} + l_{41} + l_{52}, t_9 = l_9 + l_{20} + l_{31} + l_{42} + l_{53},$
$t_{10} = l_{10} + l_{21} + l_{32} + l_{43} + l_{54},\ t_{11} = l_{11} + l_{22} + l_{33} + l_{44} + l_{55}$, where $l_1 = y_1 s_1, l_2 = y_1 s_2 + v_1 s_1, l_3 = y_1 s_3 + v_1 s_2 + n_1 s_1, l_4 = y_1 s_4 + v_1 s_3 + n_1 s_2 + z_2 s_1,$
$l_5 = y_1 s_5 + v_1 s_4 + n_1 s_3 + z_2 s_2, l_6 = y_1 s_6 + v_1 s_5 + n_1 s_4 + z_2 s_3, l_7 = y_1 s_7 + v_1 s_6 + n_1 s_5 + z_2 s_4,$
$l_8 = y_1 s_8 + v_1 s_7 + n_1 s_6 + z_2 s_5, l_9 = v_1 s_8 + n_1 s_7 + z_2 s_6, l_{10} = n_1 s_8 + z_2 s_7, l_{11} = z_2 s_8,$
$l_{12} = -v_6 s_9, l_{13} = -v_6 s_{10} - n_5 s_9, l_{14} = -v_6 s_6 - n_5 s_{10} - z_7 s_9, l_{15} = -v_6 s_{12} - n_5 s_{11} - z_7 s_{10},$
$l_{16} = -v_6 s_{13} - n_5 s_{12} - z_7 s_{11}, l_{17} = -v_6 s_{14} - n_5 s_{13} - z_7 s_{12}, l_{18} = -v_6 s_{15} - n_5 s_{14} - z_7 s_{13},$
$l_{19} = -v_6 s_{16} - n_5 s_{15} - z_7 s_{14}, l_{20} = -v_6 s_{17} - n_5 s_{16}, l_{21} = -n_5 s_{17} - z_7 s_{16}, l_{22} = -z_7 s_{17},$
$l_{23} = v_{10} s_{18}, l_{24} = v_{10} s_{19} + n_{10} s_{18}, l_{25} = v_{10} s_{20} + n_{10} s_{19} - z_9 s_{18}, l_{26} = v_{10} s_{21} + n_{10} s_{20} - z_9 s_{19},$
$l_{27} = v_{10} s_{22} + n_{10} s_{21} - z_9 s_{20}, l_{28} = v_{10} s_{23} + n_{10} s_{22} - z_9 s_{21}, l_{29} = v_{10} s_{24} + n_{10} s_{23} - z_9 s_{22},$
$l_{30} = v_{10} s_{25} + n_{10} s_{24} - z_9 s_{23}, l_{31} = v_{10} s_{26} + n_{10} s_{25} - z_9 s_{24}, l_{32} = n_{10} s_{26} - z_9 s_{25}, l_{33} = -z_9 s_{26},$
$l_{34} = -v_{14} s_{27}, l_{35} = -v_{14} s_{28} - n_{15} s_{27}, l_{36} = -v_{14} s_{29} - n_{15} s_{28} - z_{18} s_{27}, l_{37} = -v_{14} s_{30} - n_{15} s_{29} - z_{18} s_{28},$
$l_{38} = -v_{14} s_{31} - n_{15} s_{30} - z_{18} s_{29}, l_{39} = -v_{14} s_{32} - n_{15} s_{31} - z_{18} s_{30}, l_{40} = -v_{14} s_{33} - n_{15} s_{32} - z_{18} s_{31},$
$l_{41} = -v_{14} s_{34} - n_{15} s_{33} - z_{18} s_{32}, l_{42} = -v_{14} s_{35} - n_{15} s_{34} - z_{18} s_{33}, l_{43} = -n_{15} s_{35} - z_{18} s_{34}, l_{44} = -z_{18} s_{35},$
$l_{45} = v_{18} s_{36}, l_{46} = v_{18} s_{37} + n_{20} s_{36}, l_{47} = v_{18} s_{38} + n_{20} s_{37} + z_{11} s_{36}, l_{48} = v_{18} s_{39} + n_{20} s_{38} + z_{11} s_{37},$
$l_{49} = v_{18} s_{40} + n_{20} s_{39} + z_{11} s_{38}, l_{50} = v_{18} s_{41} + n_{20} s_{40} + z_{11} s_{39}, l_{51} = v_{18} s_{42} + n_{20} s_{41} + z_{11} s_{40},$
$l_{52} = v_{18} s_{43} + n_{20} s_{42} + z_{11} s_{41}, l_{53} = v_{18} s_{44} + n_{20} s_{43} + z_{11} s_{42}, l_{54} = n_{20} s_{44} + z_{11} s_{43}, l_{55} = z_{11} s_{44},$

$s_1 = p_1 + p_9 + p_{17} + p_{25}, s_2 = p_2 + p_{10} + p_{18} + p_{26}, s_3 = p_3 + p_{11} + p_{19} + p_{27}, s_4 = p_4 + p_{12} + p_{20} + p_{28},$
$s_5 = p_5 + p_{13} + p_{21} + p_{29}, s_6 = p_6 + p_{14} + p_{22} + p_{30}, s_7 = p_7 + p_{15} + p_{23} + p_{31}, s_8 = p_8 + p_{16} + p_{24} + p_{32},$
$s_9 = p_{33} + p_{42} + p_{50} + p_{59}, s_{10} = p_{34} + p_{43} + p_{51} + p_{60}, s_{11} = p_{35} + p_{44} + p_{52} + p_{61}, s_{12} = p_{36} + p_{45} + p_{53} + p_{62},$
$s_{13} = p_{37} + p_{46} + p_{54} + p_{63}, s_{14} = p_{38} + p_{47} + p_{55} + p_{64}, s_{15} = p_{39} + p_{48} + p_{56} + p_{65}, s_{16} = p_{40} + p_{49} + p_{57} + p_{66},$
$s_{17} = p_{41} + p_{58} + p_{67}, s_{18} = p_{68} + p_{77} + p_{85} + p_{94}, s_{19} = p_{69} + p_{78} + p_{86} + p_{95}, s_{20} = p_{70} + p_{79} + p_{87} + p_{96},$
$s_{21} = p_{71} + p_{80} + p_{88} + p_{97}, s_{22} = p_{72} + p_{81} + p_{89} + p_{98}, s_{23} = p_{73} + p_{82} + p_{90} + p_{99}, s_{24} = p_{74} + p_{83} + p_{91} + p_{100},$
$s_{25} = p_{75} + p_{84} + p_{92} + p_{101}, s_{26} = p_{76} + p_{93} + p_{102}, s_{27} = p_{103} + p_{112} + p_{120} + p_{129},$
$s_{28} = p_{104} + p_{113} + p_{121} + p_{130}, s_{29} = p_{105} + p_{114} + p_{122} + p_{131}, s_{30} = p_{106} + p_{115} + p_{123} + p_{132},$
$s_{31} = p_{107} + p_{116} + p_{124} + p_{133}, s_{32} = p_{108} + p_{117} + p_{125} + p_{134}, s_{33} = p_{109} + p_{118} + p_{126} + p_{135},$
$s_{34} = p_{110} + p_{119} + p_{127} + p_{136}, s_{35} = p_{111} + p_{128} + p_{137}, s_{36} = p_{138} + p_{147} + p_{155} + p_{164},$
$s_{37} = p_{139} + p_{148} + p_{156} + p_{165}, s_{38} = p_{140} + p_{149} + p_{157} + p_{166}, s_{39} = p_{141} + p_{150} + p_{158} + p_{167},$
$s_{40} = p_{142} + p_{151} + p_{159} + p_{168}, s_{41} = p_{143} + p_{152} + p_{160} + p_{169},$
$s_{42} = p_{144} + p_{153} + p_{161} + p_{170}, s_{43} = p_{145} + p_{154} + p_{162} + p_{171}, s_{44} = p_{146} + p_{163} + p_{172}, p_1 = h_1 n_6, p_2 = n_6 h_2 + d_2 h_1, p_3 = n_6 h_3 + d_2 h_2, p_4 = n_6 h_4 + d_2 h_3, p_5 = n_6 h_5 + d_2 h_4, p_6 = n_6 h_6 + d_2 h_5,$
$p_7 = n_6 h_7 + d_2 h_6, p_8 = d_2 h_7, p_9 = -n_{11} h_8, p_{10} = -n_{11} h_9 - d_3 h_8, p_{11} = -n_{11} h_{10} - d_3 h_9,$
$p_{12} = -n_{11} h_{11} - d_3 h_{10}, p_{13} = -n_{11} h_{12} - d_3 h_{11}, p_{14} = -n_{11} h_{13} - d_3 h_{12}, p_{15} = -n_{11} h_{14} - d_3 h_{13},$
$p_{16} = -d_3 h_{14}, p_{17} = n_{16} h_{15}, p_{18} = n_{16} h_{16} + d_4 h_{15}, p_{19} = d_4 h_{16} + n_{16} h_{17}, p_{20} = n_{16} h_{18} + d_4 h_{17},$
$p_{21} = d_4 h_{18} + n_{16} h_{19}, p_{22} = n_{16} h_{20} + d_4 h_{19}, p_{23} = n_{16} h_{21} + d_4 h_{20}, p_{24} = d_4 h_{21}, p_{25} = -n_{21} h_{22},$
$p_{26} = -n_{21} h_{23} - d_5 h_{22}, p_{27} = -n_{21} h_{24} - d_5 h_{23}, p_{28} = -n_{21} h_{25} - d_5 h_{24}, p_{29} = -n_{21} h_{26} - d_5 h_{25},$
$p_{30} = -n_{21} h_{27} - d_5 h_{26}, p_{31} = -n_{21} h_{28} - d_5 h_{27}, p_{32} = -d_5 h_{28}, p_{33} = v_2 h_{29}, p_{34} = v_2 h_{30} + n_2 h_{29},$
$p_{35} = v_2 h_{31} + n_2 h_{30} + d_1 h_{29}, p_{36} = v_2 h_{32} + n_2 h_{31} + d_1 h_{30}, p_{37} = v_2 h_{33} + n_2 h_{32} + d_1 h_{31},$
$p_{38} = v_2 h_{34} + n_2 h_{33} + d_1 h_{32}, p_{39} = v_2 h_{35} + n_2 h_{34} + d_1 h_{33}, p_{40} = n_2 h_{35} + d_1 h_{34}, p_{41} = d_1 h_{35},$
$p_{42} = -y_2 h_{36}, p_{43} = -y_2 h_{37} - v_3 h_{36}, p_{44} = -y_2 h_{38} - v_3 h_{37} - n_3 h_{36}, p_{45} = -y_2 h_{39} - v_3 h_{38} - n_3 h_{37},$
$p_{46} = -y_2 h_{40} - v_3 h_{39} - n_3 h_{38}, p_{47} = -y_2 h_{41} - v_3 h_{40} - n_3 h_{39}, p_{48} = -v_3 h_{41} - n_3 h_{40}, p_{49} = -n_3 h_{41},$
$p_{50} = y_3 h_{42}, p_{51} = y_3 h_{43} + v_4 h_{42}, p_{52} = y_3 h_{44} + v_4 h_{43} + n_{25} h_{42}, p_{53} = y_3 h_{45} + v_4 h_{44} + n_{25} h_{43} + z_4 h_{42},$
$p_{54} = y_3 h_{46} + v_4 h_{45} + n_{25} h_{44} + z_4 h_{43}, p_{55} = y_3 h_{47} + v_4 h_{46} + n_{25} h_{45} + z_4 h_{44}, p_{56} = v_4 h_{47} + n_{25} h_{46} + z_4 h_{45},$
$p_{57} = n_{25} h_{47} + z_4 h_{46}, p_{58} = z_4 h_{47}, p_{59} = -y_4 h_{48}, p_{60} = -y_4 h_{49} - v_5 h_{48}, p_{61} = -y_4 h_{50} - v_5 h_{49} - n_4 h_{48},$
$p_{62} = -y_4 h_{51} - v_5 h_{50} - n_4 h_{49} - z_5 h_{48}, p_{63} = -y_4 h_{52} - v_5 h_{51} - n_4 h_{50} - z_5 h_{49},$
$p_{64} = -y_4 h_{53} - v_5 h_{52} - n_4 h_{51} - z_5 h_{50}, p_{65} = -v_5 h_{53} - n_4 h_{52} - z_5 h_{51}, p_{66} = -n_4 h_{53} - z_5 h_{52},$
$p_{67} = -z_5 h_{53}, p_{68} = v_2 h_{54}, p_{69} = v_2 h_{55} + n_2 h_{54}, p_{70} = d_1 h_{54} + n_2 h_{55} + v_2 h_{56},$
$p_{71} = v_2 h_{57} + n_2 h_{56} + d_1 h_{55}, p_{72} = v_2 h_{58} + n_2 h_{57} + d_1 h_{56}, p_{73} = v_2 h_{59} + n_2 h_{58} + d_1 h_{57},$
$p_{74} = v_2 h_{60} + n_2 h_{59} + d_1 h_{58}, p_{75} = n_2 h_{60} + d_1 h_{59}, p_{76} = d_1 h_{60}, p_{77} = -y_2 h_{61}, p_{78} = -y_2 h_{62} - v_3 h_{61},$
$p_{79} = -y_2 h_{63} - v_3 h_{62} - n_3 h_{61}, p_{80} = -y_2 h_{64} - v_3 h_{63} - n_3 h_{62}, p_{81} = -y_2 h_{65} - v_3 h_{64} - n_3 h_{63},$
$p_{82} = -y_2 h_{66} - v_3 h_{65} - n_3 h_{64}, p_{83} = -v_3 h_{66} - n_3 h_{65}, p_{84} = -n_3 h_{66}, p_{85} = y_3 h_{67}, p_{86} = y_3 h_{68} + v_4 h_{67},$
$p_{87} = y_3 h_{69} + v_4 h_{68} + n_{25} h_{67}, p_{88} = y_3 h_{70} + v_4 h_{69} + n_{25} h_{68} + z_4 h_{67}, p_{89} = y_3 h_{71} + v_4 h_{70} + n_{25} h_{69} + z_4 h_{68},$
$p_{90} = y_3 h_{72} + v_4 h_{71} + n_{25} h_{70} + z_4 h_{69}, p_{91} = v_4 h_{72} + n_{25} h_{71} + z_4 h_{70}, p_{92} = n_{25} h_{72} + z_4 h_{71},$
$p_{93} = z_4 h_{72}, p_{94} = -y_4 h_{73}, p_{95} = -y_4 h_{74} - v_5 h_{73}, p_{96} = -y_4 h_{75} - v_5 h_{74} - n_4 h_{73},$
$p_{97} = -y_4 h_{76} - v_5 h_{75} - n_4 h_{74} - z_5 h_{73}, p_{98} = -y_4 h_{77} - v_5 h_{76} - n_4 h_{75} - z_5 h_{74},$
$p_{99} = -y_4 h_{78} - v_5 h_{77} - n_4 h_{76} - z_5 h_{75}, p_{100} = -v_5 h_{78} - n_4 h_{77} - z_5 h_{76}, p_{101} = -n_4 h_{78} - z_5 h_{77},$
$p_{102} = z_5 h_{78}, p_{103} = v_2 h_{79}, p_{104} = v_2 h_{80} + n_2 h_{79}, p_{105} = v_2 h_{81} + n_2 h_{80} + d_1 h_{79},$
$p_{106} = v_2 h_{82} + n_2 h_{81} + d_1 h_{80}, p_{107} = v_2 h_{83} + n_2 h_{82} + d_1 h_{81}, p_{108} = v_2 h_{84} + n_2 h_{83} + d_1 h_{82},$
$p_{109} = v_2 h_{85} + n_2 h_{84} + d_1 h_{83}, p_{110} = n_2 h_{85} + d_1 h_{84}, p_{111} = d_1 h_{85}, p_{112} = -y_2 h_{86},$
$p_{113} = -y_2 h_{87} - v_3 h_{86}, p_{114} = -y_2 h_{88} - v_3 h_{87} - n_3 h_{86}, p_{115} = -y_2 h_{89} - v_3 h_{88} - n_3 h_{87},$
$p_{116} = -y_2 h_{90} - v_3 h_{89} - n_3 h_{88}, p_{117} = -y_2 h_{91} - v_3 h_{90} - n_3 h_{89}, p_{118} = -v_3 h_{91} - n_3 h_{90}, p_{119} = -n_3 h_{91},$
$p_{120} = y_3 h_{92}, p_{121} = y_3 h_{93} + v_4 h_{92}, p_{122} = y_3 h_{94} + v_4 h_{93} + n_{25} h_{92}, p_{123} = y_3 h_{95} + v_4 h_{94} + n_{25} h_{93} + z_4 h_{92},$
$p_{124} = y_3 h_{96} + v_4 h_{95} + n_{25} h_{94} + z_4 h_{93}, p_{125} = y_3 h_{97} + v_4 h_{96} + n_{25} h_{95} + z_4 h_{94},$

Principal
Dyal Singh College
KARNAL

$p_{126} = v_4h_{97} + n_{25}h_{96} + z_4h_{95}, p_{127} = n_{25}h_{97} + z_4h_{96}, p_{128} = z_4h_{97}, p_{129} = -y_4h_{98},$
$p_{130} = -y_4h_{99} - v_5h_{98}, p_{131} = -y_4h_{100} - v_5h_{99} - n_4h_{98}, p_{132} = -y_4h_{101} - v_5h_{100} - n_4h_{99} - z_5h_{98},$
$p_{133} = -y_4h_{102} - v_5h_{101} - n_4h_{100} - z_5h_{99}, p_{134} = -y_4h_{103} - v_5h_{102} - n_4h_{101} - z_5h_{100},$
$p_{135} = -v_5h_{103} - n_4h_{102} - z_5h_{101}, p_{136} = -n_4h_{103} - z_5h_{102}, p_{137} = -z_5h_{103}, p_{138} = v_2h_{104},$
$p_{139} = v_2h_{105} + n_2h_{104}, p_{140} = v_2h_{106} + n_2h_{105} + d_1h_{104}, p_{141} = v_2h_{107} + n_2h_{106} + d_1h_{105},$
$p_{142} = v_2h_{108} + n_2h_{107} + d_1h_{106}, p_{143} = v_2h_{109} + n_2h_{108} + d_1h_{107}, p_{144} = v_2h_{110} + n_2h_{109} + d_1h_{108},$
$p_{145} = n_2h_{110} + d_1h_{109}, p_{146} = d_1h_{110}, p_{147} = -y_2h_{111}, p_{148} = -y_2h_{112} - v_3h_{111},$
$p_{149} = -y_2h_{113} - v_3h_{112} - n_3h_{111}, p_{150} = -y_2h_{114} - v_3h_{113} - n_3h_{112}, p_{151} = -y_2h_{115} - v_3h_{114} - n_3h_{113},$
$p_{152} = -y_2h_{116} - v_3h_{115} - n_3h_{114}, p_{153} = -v_3h_{116} - n_3h_{115}, p_{154} = -n_3h_{116}, p_{155} = y_3h_{117},$
$p_{156} = v_4h_{117} + y_3h_{118}, p_{157} = y_3h_{119} + v_4h_{118} + n_{25}h_{117}, p_{158} = y_3h_{120} + v_4h_{119} + n_{25}h_{118} + z_4h_{117},$
$p_{159} = y_3h_{121} + v_4h_{120} + n_{25}h_{119} + z_4h_{118}, p_{160} = y_3h_{122+}v_4h_{121} + n_{25}h_{120} + z_4h_{119},$
$p_{161} = v_4h_{122} + n_{25}h_{121} + z_4h_{120}, p_{162} = n_{25}h_{122} + z_4h_{121}, p_{163} = z_4h_{122}, p_{164} = -y_4h_{123},$
$p_{165} = -y_4h_{124} - v_5h_{123}, p_{166} = -y_4h_{125} - v_5h_{124} - n_4h_{123}, p_{167} = -y_4h_{126} - v_5h_{125} - n_4h_{124} - z_5h_{123},$
$p_{168} = -y_4h_{127} - v_5h_{126} - n_4h_{125} - z_5h_{124}, p_{169} = -y_4h_{128} - v_5h_{127} - n_4h_{126} - z_5h_{125},$
$p_{170} = -v_5h_{128} - n_4h_{127} - z_5h_{126}, p_{171} = -n_4h_{128} - z_5h_{127}, p_{172} = -z_5h_{128}, h_1 = v_{11}v_{16}v_{21} - v_{11}v_{17}v_{20} - v_{12}v_{15}v_{21} + v_{12}v_{17}v_{19} + v_{13}v_{15}v_{20} - v_{13}v_{16}v_{19},$
$h_2 = n_{12}v_{16}v_{21} - n_{12}v_{17}v_{20} - n_{13}v_{15}v_{21} + n_{13}v_{17}v_{19} + n_{14}v_{15}v_{20} - n_{14}v_{16}v_{19} - n_{17}v_{12}v_{21} + n_{17}v_{13}v_{20} + n_{18}v_{11}v_{21} - n_{18}v_{13}v_{19} - n_{19}v_{11}v_{20} + n_{19}v_{12}v_{19} + n_{22}v_{12}v_{17} - n_{22}v_{13}v_{16} - n_{23}v_{11}v_{17} + n_{23}v_{13}v_{15} + n_{24}v_{11}v_{16} - n_{24}v_{12}v_{15},$
$h_3 = n_{12}n_{18}v_{21} - n_{12}n_{19}v_{20} - n_{13}n_{17}v_{21} + n_{13}n_{19}v_{19} + n_{14}n_{17}v_{20} - n_{14}n_{18}v_{19} - n_{12}n_{23}v_{17} + n_{12}n_{24}v_{16} + n_{13}n_{22}v_{17} - n_{13}n_{24}v_{15} - n_{14}n_{22}v_{16} + n_{14}n_{23}v_{15} + n_{17}n_{23}v_{13} - n_{17}n_{24}v_{12} - n_{18}n_{22}v_{13} + n_{18}n_{24}v_{11} + n_{19}n_{22}v_{12} - n_{19}n_{23}v_{11} + v_{11}v_{17}z_{17} - v_{13}v_{15}z_{17} - v_{11}v_{16}z_{20} + v_{12}v_{15}z_{20} + v_{11}v_{20}z_{17} - v_{12}v_{19}z_{17} - v_{11}v_{21}z_{19} + v_{13}v_{19}z_{19} - v_{16}v_{21}z_{15} + v_{17}v_{20}z_{15},$
$h_4 = n_{12}n_{18}n_{24} - n_{12}n_{19}n_{23} - n_{13}n_{17}n_{24} + n_{13}n_{19}n_{22} + n_{14}n_{17}n_{23} - n_{14}n_{18}n_{22} + n_{12}v_{17}z_{17} - n_{14}v_{15}z_{17} - n_{17}v_{13}z_{17} + n_{19}v_{11}z_{17} - n_{12}v_{16}z_{20} + n_{13}v_{15}z_{20} + n_{12}v_{20}z_{17} - n_{13}v_{19}z_{17} + n_{17}v_{12}z_{20} - n_{18}v_{11}z_{20} - n_{22}v_{12}z_{17} + n_{23}v_{11}z_{17} - n_{12}v_{21}z_{19} + n_{14}v_{19}z_{19} - n_{18}v_{21}z_{15} + n_{19}v_{20}z_{15} + n_{22}v_{13}z_{19} - n_{24}v_{11}z_{19} + n_{23}v_{17}z_{15} - n_{24}v_{16}z_{15},$
$h_5 = -v_{11}z_{17}^2 + n_{12}n_{19}z_{17} - n_{14}n_{17}z_{17} - n_{12}n_{18}z_{20} + n_{13}n_{17}z_{20} + n_{12}n_{23}z_{17} - n_{13}n_{22}z_{17} - n_{12}n_{24}z_{19} + n_{14}n_{22}z_{19} - n_{18}n_{24}z_{15} + n_{19}n_{23}z_{15} - v_{17}z_{15}z_{17} + v_{11}z_{19}z_{20} + v_{16}z_{15}z_{20} - v_{20}z_{15}z_{17} + v_{21}z_{15}z_{19},$
$h_6 = -n_{12}z_{17}^2 + n_{12}z_{19}z_{20} - n_{19}z_{15}z_{17} + n_{18}z_{15}z_{20} - n_{23}z_{15}z_{17} + n_{24}z_{15}z_{19},$
$h_7 = z_{15}z_{17}^2 - z_{15}z_{19}z_{20},$
$h_8 = +v_7v_{16}v_{21} - v_7v_{17}v_{20} - v_8v_{15}v_{21} + v_8v_{17}v_{19} + v_9v_{15}v_{20} - v_9v_{16}v_{19},$
$h_9 = n_7v_{16}v_{21} - n_7v_{17}v_{20} - n_8v_{15}v_{21} + n_8v_{17}v_{19} + n_9v_{15}v_{20} - n_9v_{16}v_{19} - n_{17}v_8v_{21} + n_{17}v_9v_{20} + n_{18}v_7v_{21} - n_{18}v_9v_{19} - n_{19}v_7v_{20} + n_{19}v_8v_{19} + n_{22}v_8v_{17} - n_{22}v_9v_{16} - n_{23}v_7v_{17} + n_{23}v_9v_{15} + n_{24}v_7v_{16} - n_{24}v_8v_{15},$
$h_{10} = n_7n_{18}v_{21} - n_7n_{19}v_{20} - n_8n_{17}v_{21} + n_8n_{19}v_{19} + n_9n_{17}v_{20} - n_9n_{18}v_{19} - n_7n_{23}v_{17} + n_7n_{24}v_{16} + n_8n_{22}v_{17} - n_8n_{24}v_{15} - n_9n_{22}v_{16} + n_9n_{23}v_{15} + n_{17}n_{23}v_9 - n_{17}n_{24}v_8 - n_{18}n_{22}v_9 + n_{18}n_{24}v_7 + n_{19}n_{22}v_8 - n_{19}n_{23}v_7 + v_7v_{17}z_{17} - v_9v_{15}z_{17} - v_7v_{16}z_{20} + v_8v_{15}z_{20} + v_7v_{20}z_{17} - v_8v_{19}z_{17} + v_{15}v_{20}z_{11} - v_{15}v_{21}z_{10} - v_{16}v_{19}z_{11} - v_{16}v_{21}z_9 + v_{17}v_{19}z_{10} + v_{17}v_{20}z_9 - v_7v_{21}z_{19} + v_9v_{19}z_{19},$
$h_{11} = +n_7n_{18}n_{24} - n_7n_{19}n_{23} - n_8n_{17}n_{24} + n_8n_{19}n_{22} + n_9n_{17}n_{23} - n_9n_{18}n_{22},$
$h_{12} = -v_7z_{17}^2 + n_7n_{19}z_{17} - n_9n_{17}z_{17} - n_7n_{18}z_{20} + n_8n_{17}z_{20} + n_7n_{23}z_{17} - n_8n_{22}z_{17} - n_7n_{24}z_{19} + n_9n_{22}z_{19} + n_{17}n_{23}z_{11} - n_{17}n_{24}z_{10} - n_{18}n_{22}z_{11} - n_{18}n_{24}z_9 + n_{19}n_{22}z_{10} + n_{19}n_{23}z_9 - v_{15}z_{11}z_{17} - v_{17}z_9z_{17} + v_{15}z_{10}z_{20} + v_{16}z_9z_{20} + v_7z_{19}z_{20} - v_{19}z_{10}z_{17} - v_{20}z_9z_{17} + v_{19}z_{11}z_{19} + v_{21}z_9z_{19},$
$h_{13} = -n_7z_{17}^2 - n_{17}z_{11}z_{17} - n_{19}z_9z_{17} + n_7z_{19}z_{20} + n_{17}z_{10}z_{20} + n_{18}z_9z_{20} - n_{22}z_{10}z_{17} - n_{23}z_9z_{17} + n_{22}z_{11}z_{19} + n_{24}z_9z_{19},$
$h_{14} = z_9z_{17}^2 - z_9z_{19}z_{20},$
$h_{15} = v_7v_{12}v_{21} - v_7v_{13}v_{20} - v_8v_{11}v_{21} + v_8v_{13}v_{19} + v_9v_{11}v_{20} - v_9v_{12}v_{19},$
$h_{16} = n_7v_{12}v_{21} - n_7v_{13}v_{20} - n_8v_{11}v_{21} + n_8v_{13}v_{19} + n_9v_{11}v_{20} - n_9v_{12}v_{19} - n_{12}v_8v_{21} + n_{12}v_9v_{20} + n_{13}v_7v_{21} - n_{13}v_9v_{19} - n_{14}v_7v_{20} + n_{14}v_{80}v_{19} + n_{22}v_8v_{13} - n_{22}v_9v_{12} - n_{23}v_7v_{13} + n_{23}v_9v_{11} + n_{24}v_7v_{12} - n_{24}v_8v_{11},$
$h_{17} = n_7n_{13}v_{21} - n_7n_{14}v_{20} - n_8n_{12}v_{21} + n_8n_{14}v_{19} + n_9n_{12}v_{20} - n_9n_{13}v_{19} - n_7n_{23}v_{13} + n_7n_{24}v_{12} + n_8n_{22}v_{13} - n_8n_{24}v_{11} - n_9n_{22}v_{12} + n_9n_{23}v_{11} + n_{12}n_{23}v_9 - n_{12}n_{24}v_8 - n_{13}n_{22}v_9 + n_{13}n_{24}v_7 + n_{14}n_{22}v_8 - n_{14}n_{23}v_7 + v_7v_{13}z_{17} - v_9v_{11}z_{17} - v_7v_{12}z_{20} + v_8v_{11}z_{20} + v_{11}v_{20}z_{11} - v_{11}v_{21}z_{10} - v_{12}v_{19}z_{11} - v_{12}v_{21}z_9 + v_{13}v_{19}z_{10} + v_{13}v_{20}z_9 + v_8v_{21}z_{15} - v_9v_{20}z_{15},$
$h_{18} = n_7n_{13}n_{24} - n_7n_{14}n_{23} - n_8n_{12}n_{24} + n_8n_{14}n_{22} + n_9n_{12}n_{23} - n_9n_{13}n_{22} + n_7v_{13}z_{17} - n_9v_{11}z_{17} - n_{12}v_9z_{17} + n_{14}v_7z_{17} - n_7v_{12}z_{20} + n_8v_{11}z_{20} + n_{12}v_8z_{20} - n_{13}v_7z_{20} + n_{12}v_{20}z_{11} - n_{12}v_{21}z_{10} - n_{13}v_{19}z11 - n_{13}v_{21}z_9 + n_{14}v_{19}z_{10} + n_{14}v_{20}z_9 + n_8v_{21}z_{15} - n_9v_{20}z_{15} - n_{22}v_{12}z_{11} + n_{22}v_{13}z_{10} + n_{23}v_{11}z_{11} + n_{23}v_{13}z_9 - n_{24}v_{11}z_{10} - n_{24}v_{12}z_9 - n_{23}v_9z_{15} + n_{24}v_8z_{15},$
$h_{19} = n_7n_{14}z_{17} - n_9n_{12}z_{17} - n_7n_{13}z_{20} + n_8n_{12}z_{20} + n_{12}n_{23}z_{11} - n_{12}n_{24}z_{10} - n_{13}n_{22}z_{11} - n_{13}n_{24}z_9 + n_{14}n_{22}z_{10} + n_{14}n_{23}z_9 + n_8n_{24}z_{15} - n_9n_{23}z_{15} - v_{11}z_{11}z_{17} - v_{13}z_9z_{17} + v_9z_{15}z_{17} + v_{11}z_{10}z_{20} + v_{12}z_9z_{20} - v_8z_{15}z_{20} - v_{20}z_{11}z_{15} + v_{21}z_{10}z_{15},$
$h_{20} = -n_{12}z_{11}z_{17} - n_{14}z_9z_{17} + n_9z_{15}z_{17} + n_{12}z_{10}z_{20} + n_{13}z_9z_{20} - n_8z_{15}z_{20} - n_{23}z_{11}z_{15} + n_{24}z_{10}z_{15},$
$h_{21} = z_{11}z_{15}z_{17} - z_{10}z_{15}z_{20},$
$h_{22} = v_7v_{12}v_{17} - v_7v_{13}v_{16} - v_8v_{11}v_{17} + v_8v_{13}v_{15} + v_9v_{11}v_{16} - v_9v_{12}v_{15},$
$h_{23} = n_7v_{12}v_{17} - n_7v_{13}v_{16} - n_8v_{11}v_{17} + n_8v_{13}v_{15} + n_9v_{11}v_{16} - n_9v_{12}v_{15} - n_{12}v_8v_{17} + n_{12}v_9v_{16} + n_{13}v_7v_{17} - n_{13}v_9v_{15} - n_{14}v_7v_{16} + n_{14}v_8v_{15} + n_{17}v_8v_{13} - n_{17}v_9v_{12} - n_{18}v_7v_{13} + n_{18}v_9v_{11} + n_{19}v_7v_{12} - n_{19}v_8v_{11},$
$h_{24} = n_7n_{13}v_{17} - n_7n_{14}v_{16} - n_8n_{12}v_{17} + n_8n_{14}v_{15} + n_9n_{12}v_{16} - n_9n_{13}v_{15} - n_7n_{18}v_{13} + n_7n_{19}v_{12} + n_8n_{17}v_{13} - n_8n_{19}v_{11} - n_9n_{17}v_{12} + n_9n_{18}v_{11} + n_{12}n_{18}v_9 - n_{12}n_{19}v_8 - n_{13}n_{17}v_9 + n_{13}n_{19}v_7 + n_{14}n_{17}v_8 - n_{14}n_{18}v_7 - v_7v_{12}z_{17} + v_8v_{11}z_{17} + v_{11}v_{16}z_{11} - v_{11}v_{17}z_{10} - v_{12}v_{15}z_{11} - v_{12}v_{17}z_9 + v_{13}v_{15}z_{10} + v_{13}v_{16}z_9 + v_7v_{13}z_{19} - v_9v_{11}z_{19} + v_8v_{17}z_{15} - v_9v_{16}z_{15},$
$h_{25} = n_7n_{13}n_{19} - n_7n_{14}n_{18} - n_8n_{12}n_{19} + n_8n_{14}n_{17} + n_9n_{12}n_{18} - n_9n_{13}n_{17} - n_7v_{12}z_{17} + n_8v_{11}z_{17} + n_{12}v_8z_{17} - n_{13}v_7z_{17} + n_7v_{13}z_{19} - n_9v_{11}z_{19} + n_{12}v_{16}z_{11} - n_{12}v_{17}z_{10} - n_{13}v_{15}z_{11} - n_{13}v_{17}z_9 + n_{14}v_{15}z_{10} + n_{14}v_{16}z_9 + n_8v_{17}z_{15} - n_9v_{16}z_{15} - n_{12}v_9z_{19} + n_{14}v_7z_{19} - n_{17}v_{12}z_{11} + n_{17}v_{13}z_{10} + n_{18}v_{11}z_{11} + n_{18}v_{13}z_9 - n_{19}v_{11}z_{10} - n_{19}v_{12}z_9 - n_{18}v_9z_{15} + n_{19}v_8z_{15},$
$h_{26} = -n_7n_{13}z_{17} + n_8n_{12}z_{17} + n_7n_{14}z_{19} - n_9n_{12}z_{19} + n_{12}n_{18}z_{11} - n_{12}n_{19}z_{10} - n_{13}n_{17}z_{11} - n_{13}n_{19}z_9 + n_{14}n_{17}z_{10} + n_{14}n_{18}z_9 + n_8n_{19}z_{15} - n_9n_{18}z_{15} + v_{11}z_{10}z_{17} + v_{12}z_9z_{17} - v_8z_{15}z_{17} - v_{11}z_{11}z_{19} - v_{13}z_9z_{19} - v_{16}z_{11}z_{15} + v_{17}z_{10}z_{15} + v_9z_{15}z_{19},$
$h_{27} = n_{12}z_{10}z_{17} + n_{13}z_9z_{17} - n_8z_{15}z_{17} - n_{12}z_{11}z_{19} - n_{14}z_9z_{19} + n_9z_{15}z_{19} - n_{18}z_{11}z_{15} + n_{19}z_{10}z_{15},$
$h_{28} = z_{11}z_{15}z_{19} - z_{10}z_{15}z_{17},$
$h_{29} = v_{11}v_{16}v_{21} - v_{11}v_{17}v_{20} - v_{12}v_{15}v_{21} + v_{12}v_{17}v_{19} + v_{13}v_{15}v_{20} - v_{13}v_{16}v_{19},$
$h_{30} = n_{12}v_{16}v_{21} - n_{12}v_{17}v_{20} - n_{13}v_{15}v_{21} + n_{13}v_{17}v_{19} + n_{14}v_{15}v_{20} - n_{14}v_{16}v_{19} - n_{17}v_{12}v_{21} + n_{17}v_{13}v_{20} + n_{18}v_{11}v_{21} - n_{18}v_{13}v_{19} - n_{19}v_{11}v_{20} + n_{19}v_{12}v_{19} + n_{22}v_{12}v_{17} - n_{22}v_{13}v_{16} - n_{23}v_{11}v_{17} + n_{23}v_{13}v_{15} + n_{24}v_{11}v_{16} - n_{24}v_{12}v_{15},$

Principal
Dyal Singh College
KARNAL

$h_{31} = n_{12}n_{18}v_{21} - n_{12}n_{19}v_{20} - n_{13}n_{17}v_{21} + n_{13}n_{19}v_{19} + n_{14}n_{17}v_{20} - n_{14}n_{18}v_{19} - n_{12}n_{23}v_{17} + n_{12}n_{24}v_{16} + n_{13}n_{22}v_{17} - n_{13}n_{24}v_{15} - n_{14}n_{22}v_{16} + n_{14}n_{23}v_{15} + n_{17}n_{23}v_{13} - n_{17}n_{24}v_{12} - n_{18}n_{22}v_{13} + n_{18}n_{24}v_{11} + n_{19}n_{22}v_{12} - n_{19}n_{23}v_{11} + v_{11}v_{17}z_{17} - v_{13}v_{15}z_{17} - v_{11}v_{16}z_{20} + v_{12}v_{15}z_{20} + v_{11}v_{20}z_{17} - v_{12}v_{19}z_{17} - v_{11}v_{21}z_{19} + v_{13}v_{19}z_{19} - v_{16}v_{21}z_{15} + v_{17}v_{20}z_{15},$

$h_{32} = n_{12}n_{18}n_{24} - n_{12}n_{19}n_{23} - n_{13}n_{17}n_{24} + n_{13}n_{19}n_{22} + n_{14}n_{17}n_{23} - n_{14}n_{18}n_{22} + n_{12}v_{17}z_{17} - n_{14}v_{15}z_{17} - n_{17}v_{13}z_{17} + n_{19}v_{11}z_{17} - n_{12}v_{16}z_{20} + n_{13}v_{15}z_{20} + n_{12}v_{20}z_{17} - n_{13}v_{19}z_{17} + n_{17}v_{12}z_{20} - n_{18}v_{11}z_{20} - n_{22}v_{12}z_{17} + n_{23}v_{11}z_{17} - n_{12}v_{21}z_{19} + n_{14}v_{19}z_{19} - n_{18}v_{21}z_{15} + n_{19}v_{20}z_{15} + n_{22}v_{13}z_{19} - n_{24}v_{11}z_{19} + n_{23}v_{17}z_{15} - n_{24}v_{16}z_{15},$

$h_{33} = -v_{11}z_{17}^2 + n_{12}n_{19}z_{17} - n_{14}n_{17}z_{17} - n_{12}n_{18}z_{20} + n_{13}n_{17}z_{20} + n_{12}n_{23}z_{17} - n_{13}n_{22}z_{17} - n_{12}n_{24}z_{19} + n_{14}n_{22}z_{19} - n_{18}n_{24}z_{15} + n_{19}n_{23}z_{15} - v_{17}z_{15}z_{17} + v_{11}z_{19}z_{20} + v_{16}z_{15}z_{20} - v_{20}z_{15}z_{17} + v_{21}z_{15}z_{19},$

$h_{34} = -n_{12}z_{17}^2 + n_{12}z_{19}z_{20} - n_{19}z_{15}z_{17} + n_{18}z_{15}z_{20} - n_{23}z_{15}z_{17} + n_{24}z_{15}z_{19}, h_{35} = z_{15}z_{17}^2 - z_{15}z_{19}z_{20},$

$h_{36} = n_{11}v_{16}v_{21} - n_{11}v_{17}v_{20} - n_{16}v_{12}v_{21} + n_{16}v_{13}v_{20} + n_{21}v_{12}v_{17} - n_{21}v_{13}v_{16},$

$h_{37} = d_5v_{12}v_{17} - d_5v_{13}v_{16} - d_4v_{12}v_{21} + d_4v_{13}v_{20} + d_3v_{16}v_{21} - d_3v_{17}v_{20} + n_{11}n_{18}v_{21} - n_{11}n_{19}v_{20} - n_{13}n_{16}v_{21} + n_{14}n_{16}v_{20} - n_{11}n_{23}v_{17} + n_{11}n_{24}v_{16} + n_{13}n_{21}v_{17} - n_{14}n_{21}v_{16} + n_{16}n_{23}v_{13} - n_{16}n_{24}v_{12} - n_{18}n_{21}v_{13} + n_{19}n_{21}v_{12},$

$h_{38} = d_5n_{13}v_{17} - d_5n_{14}v_{16} - d_5n_{18}v_{13} + d_5n_{19}v_{12} - d_4n_{13}v_{21} + d_4n_{14}v_{20} + d_4n_{23}v_{13} - d_4n_{24}v_{12} + d_3n_{18}v_{21} - d_3n_{19}v_{20} - d_3n_{23}v_{17} + d_3n_{24}v_{16} + n_{11}n_{18}n_{24} - n_{11}n_{19}n_{23} - n_{13}n_{16}n_{24} + n_{13}n_{19}n_{21} + n_{14}n_{16}n_{23} - n_{14}n_{18}n_{21} + n_{11}v_{17}z_{17} - n_{16}v_{13}z_{17} - n_{11}v_{16}z_{20} + n_{11}v_{20}z_{17} + n_{16}v_{12}z_{20} - n_{21}v_{12}z_{17} - n_{11}v_{21}z_{19} + n_{21}v_{13}z_{19},$

$h_{39} = d_5n_{13}n_{19} - d_5n_{14}n_{18} - d_4n_{13}n_{24} + d_4n_{14}n_{23} + d_3n_{18}n_{24} - d_3n_{19}n_{23} - d_4v_{13}z_{17} - d_5v_{12}z_{17} + d_4v_{12}z_{20} + d_3v_{17}z_{17} + d_5v_{13}z_{19} - d_3v_{16}z_{20} + d_3v_{20}z_{17} - d_3v_{21}z_{19} + n_{11}n_{19}z_{17} - n_{14}n_{16}z_{17} - n_{11}n_{18}z_{20} + n_{13}n_{16}z_{20} + n_{11}n_{23}z_{17} - n_{13}n_{21}z_{17} - n_{11}n_{24}z_{19} + n_{14}n_{21}z_{19},$

$h_{40} = -n_{11}z_{17}^2 - d_4n_{14}z_{17} - d_5n_{13}z_{17} + d_4n_{13}z_{20} + d_5n_{14}z_{19} + d_3n_{19}z_{17} - d_3n_{18}z_{20} + d_3n_{23}z_{17} - d_3n_{24}z_{19} + n_{11}z_{19}z_{20},$

$h_{41} = d_3z_{19}z_{20} - d_3z_{17}^2,$

$h_{42} = n_{11}v_{15}v_{21} - n_{11}v_{17}v_{19} - n_{16}v_{11}v_{21} + n_{16}v_{13}v_{19} + n_{21}v_{11}v_{17} - n_{21}v_{13}v_{15},$

$h_{43} = d_5v_{11}v_{17} - d_5v_{13}v_{15} - d_4v_{11}v_{21} + d_4v_{13}v_{19} + d_3v_{15}v_{21} - d_3v_{17}v_{19} + n_{11}n_{17}v_{21} - n_{11}n_{19}v_{19} - n_{12}n_{16}v_{21} + n_{14}n_{16}v_{19} - n_{11}n_{22}v_{17} + n_{11}n_{24}v_{15} + n_{12}n_{21}v_{17} - n_{14}n_{21}v_{15} + n_{16}n_{22}v_{13} - n_{16}n_{24}v_{11} - n_{17}n_{21}v_{13} + n_{19}n_{21}v_{11},$

$h_{44} = d_5n_{12}v_{17} - d_5n_{14}v_{15} - d_5n_{17}v_{13} + d_5n_{19}v_{11} - d_4n_{12}v_{21} + d_4n_{14}v_{19} + d_4n_{22}v_{13} - d_4n_{24}v_{11} + d_3n_{17}v_{21} - d_3n_{19}v_{19} - d_3n_{22}v_{17} + d_3n_{24}v_{15} + n_{11}n_{17}n_{24} - n_{11}n_{19}n_{22} - n_{12}n_{16}n_{24} + n_{12}n_{19}n_{21} + n_{14}n_{16}n_{22} - n_{14}n_{17}n_{21} - n_{11}v_{15}z_{20} + n_{11}v_{19}z_{17} + n_{16}v_{11}z_{20} - n_{21}v_{11}z_{17} + n_{16}v_{21}z_{15} - n_{21}v_{17}z_{15},$

$h_{45} = d_5n_{12}n_{19} - d_5n_{14}n_{17} - d_4n_{12}n_{24} + d_4n_{14}n_{22} + d_3n_{17}n_{24} - d_3n_{19}n_{22} - d_5v_{11}z_{17} + d_4v_{11}z_{20} - d_5v_{17}z_{15} - d_3v_{15}z_{20} + d_3v_{19}z_{17} + d_4v_{21}z_{15} - n_{11}n_{17}z_{20} + n_{12}n_{16}z_{20} + n_{11}n_{22}z_{17} - n_{12}n_{21}z_{17} + n_{16}n_{24}z_{15} - n_{19}n_{21}z_{15},$

$h_{46} = -d_5n_{12}z_{17} + d_4n_{12}z_{20} - d_5n_{19}z_{15} - d_3n_{17}z_{20} + d_3n_{22}z_{17} + d_4n_{24}z_{15} - n_{16}z_{15}z_{20} + n_{21}z_{15}z_{17},$

$h_{47} = d_5z_{15}z_{17} - d_4z_{15}z_{20},$

$h_{48} = n_{11}v_{15}v_{20} - n_{11}v_{16}v_{19} - n_{16}v_{11}v_{20} + n_{16}v_{12}v_{19} + n_{21}v_{11}v_{16} - n_{21}v_{12}v_{15},$

$h_{49} = +d_5v_{11}v_{16} - d_5v_{12}v_{15} - d_4v_{11}v_{20} + d_4v_{12}v_{19} + d_3v_{15}v_{20} - d_3v_{16}v_{19} + n_{11}n_{17}v_{20} - n_{11}n_{18}v_{19} - n_{12}n_{16}v_{20} + n_{13}n_{16}v_{19} - n_{11}n_{22}v_{16} + n_{11}n_{23}v_{15} + n_{12}n_{21}v_{16} - n_{13}n_{21}v_{15} + n_{16}n_{22}v_{12} - n_{16}n_{23}v_{11} - n_{17}n_{21}v_{12} + n_{18}n_{21}v_{11},$

$h_{50} = d_5n_{12}v_{16} - d_5n_{13}v_{15} - d_5n_{17}v_{12} + d_5n_{18}v_{11} - d_4n_{12}v_{20} + d_4n_{13}v_{19} + d_4n_{22}v_{12} - d_4n_{23}v_{11} + d_3n_{17}v_{20} - d_3n_{18}v_{19} - d_3n_{22}v_{16} + d_3n_{23}v_{15} + n_{11}n_{17}n_{23} - n_{11}n_{18}n_{22} - n_{12}n_{16}n_{23} + n_{12}n_{18}n_{21} + n_{13}n_{16}n_{22} - n_{13}n_{17}n_{21} - n_{11}v_{15}z_{17} + n_{16}v_{11}z_{17} + n_{11}v_{19}z_{19} + n_{16}v_{20}z_{15} - n_{21}v_{11}z_{19} - n_{21}v_{16}z_{15},$

$h_{51} = d_5n_{12}n_{18} - d_5n_{13}n_{17} - d_4n_{12}n_{23} + d_4n_{13}n_{22} + d_3n_{17}n_{23} - d_3n_{18}n_{22} + d_4v_{11}z_{17} - d_3v_{15}z_{17} - d_5v_{11}z_{19} - d_5v_{16}z_{15} + d_4v_{20}z_{15} + d_3v_{19}z_{19} - n_{11}n_{17}z_{17} + n_{12}n_{16}z_{17} + n_{11}n_{22}z_{19} - n_{12}n_{21}z_{19} + n_{16}n_{23}z_{15} - n_{18}n_{21}z_{15},$

$h_{52} = d_4n_{12}z_{17} - d_5n_{12}z_{19} - d_3n_{17}z_{17} - d_5n_{18}z_{15} + d_4n_{23}z_{15} + d_3n_{22}z_{19} - n_{16}z_{15}z_{17} + n_{21}z_{15}z_{19},$

$h_{53} = d_5z_{15}z_{19} - d_4z_{15}z_{17},$

$h_{54} = v_7v_{16}v_{21} - v_7v_{17}v_{20} - v_8v_{15}v_{21} + v_8v_{17}v_{19} + v_9v_{15}v_{20} - v_9v_{16}v_{19},$

$h_{55} = n_7v_{16}v_{21} - n_7v_{17}v_{20} - n_8v_{15}v_{21} + n_8v_{17}v_{19} + n_9v_{15}v_{20} - n_9v_{16}v_{19} - n_{17}v8v_{21} + n_{17}v_9v_{20} + n_{18}v_7v_{21} - n_{18}v_9v_{19} - n_{19}v_7v_{20} + n_{19}v_8v_{19} + n_{22}v_8v_{17} - n_{22}v_9v_{16} - n_{23}v_7v_{17} + n_{23}v_9v_{15} + n_{24}v_7v_{16} - n_{24}v_8v_{15},$

$h_{56} = n_7n_{18}v_{21} - n_7n_{19}v_{20} - n_8n_{17}v_{21} + n_8n_{19}v_{19} + n_9n_{17}v_{20} - n_9n_{18}v_{19} - n_7n_{23}v_{17} + n_7n_{24}v_{16} + n_8n_{22}v_{17} - n_8n_{24}v_{15} - n_9n_{22}v_{16} + n_9n_{23}v_{15} + n_{17}n_{23}v_9 - n_{17}n_{24}v_8 - n_{18}n_{22}v_9 + n_{18}n_{24}v_7 + n_{19}n_{22}v_8 - n_{19}n_{23}v_7 + v_7v_{17}z_{17} - v_9v_{15}z_{17} - v_7v_{16}z_{20} + v_8v_{15}z_{20} + v_7v_{20}z_{17} - v_8v_{19}z_{17} + v_{15}v_{20}z_{11} - v_{15}v_{21}z_{10} - v_{16}v_{19}z_{11} - v_{16}v_{21}z_9 + v_{17}v_{19}z_{10} + v_{17}v_{20}z_9 - v_7v_{21}z_{19} + v_9v_{19}z_{19},$

$h_{57} = n_7n_{18}n_{24} - n_7n_{19}n_{23} - n_8n_{17}n_{24} + n_8n_{19}n_{22} + n_9n_{17}n_{23} - n_9n_{18}n_{22} + n_7v_{17}z_{17} - n_9v_{15}z_{17} - n_7v_{16}z_{20} + n_8v_{15}z_{20} - n_{17}v_9z_{17} + n_{19}v_7z_{17} + n_7v_{20}z_{17} - n_8v_{19}z_{17} + n_{17}v_8z_{20} - n_{18}v_7z_{20} - n_7v_{21}z_{19} + n_9v_{19}z_{19} - n_{22}v_8z_{17} + n_{23}v_7z_{17} + n_{17}v_{20}z_{11} - n_{17}v_{21}z_{10} - n_{18}v_{19}z_{11} - n_{18}v_{21}z_9 + n_{19}v_{19}z_{10} + n_{19}v_{20}z_9 - n_{22}v_{16}z_{11} + n_{22}v_{17}z_{10} + n_{23}v_{15}z_{11} + n_{23}v_{17}z_9 - n_{24}v_{15}z_{10} - n_{24}v_{16}z_9 + n_{22}v_9z_{19} - n_{24}v_7z_{19},$

$h_{58} = -v_7z_{17}^2 + n_7n_{19}z_{17} - n_9n_{17}z_{17} - n_7n_{18}z_{20} + n_8n_{17}z_{20} + n_7n_{23}z_{17} - n_8n_{22}z_{17} - n_7n_{24}z_{19} + n_9n_{22}z_{19} + n_{17}n_{23}z_{11} - n_{17}n_{24}z_{10} - n_{18}n_{22}z_{11} - n_{18}n_{24}z_9 + n_{19}n_{22}z_{10} + n_{19}n_{23}z_9 - v_{15}z_{11}z_{17} - v_{17}z_9z_{17} + v_{15}z_{10}z_{20} + v_{16}z_9z_{20} + v_7z_{19}z_{20} - v_{19}z_{10}z_{17} - v_{20}z_9z_{17} + v_{19}z_{11}z_{19} + v_{21}z_9z_{19},$

$h_{59} = -n_7z_{17}^2 - n_{17}z_{11}z_{17} - n_{19}z_9z_{17} + n_7z_{19}z_{20} + n_{17}z_{10}z_{20} + n_{18}z_9z_{20} - n_{22}z_{10}z_{17} - n_{23}z_9z_{17} + n_{22}z_{11}z_{19} + n_{24}z_9z_{19},$

$h_{60} = z_9z_{17}^2 - z_9z_{19}z_{20},$

$h_{61} = n_6v_{16}v_{21} - n6v_{17}v_{20} - n_{16}v_8v_{21} + n_{16}v_9v_{20} + n_{21}v_8v_{17} - n_{21}v_9v_{16},$

$h_{62} = d_5v_8v_{17} - d_5v_9v_{16} - d_4v_8v_{21} + d_4v_9v_{20} + d_2v_{16}v_{21} - d_2v_{17}v_{20} + n_6n_{18}v_{21} - n_6n_{19}v_{20} - n_8n_{16}v_{21} + n_9n_{16}v_{20} - n_6n_{23}v_{17} + n_6n_{24}v_{16} + n_8n_{21}v_{17} - n_9n_{21}v_{16} + n_{16}n_{23}v_9 - n_{16}n_{24}v_8 - n_{18}n_{21}v_9 + n_{19}n_{21}v_8,$

$h_{63} = d_5n_8v_{17} - d_5n_9v_{16} - d_5n_{18}v_9 + d_5n_{19}v_8 - d_4n_8v_{21} + d_4n_9v_{20} + d_4n_{23}v_9 - d_4n_{24}v_8 + d_2n_{18}v_{21} - d_2n_{19}v_{20} - d_2n_{23}v_{17} + d_2n_{24}v_{16} + n_6n_{18}n_{24} - n_6n_{19}n_{23} - n_8n_{16}n_{24} + n_8n_{19}n_{21} + n_9n_{16}n_{23} - n_9n_{18}n_{21} + n_6v_{17}z_{17} - n_6v_{16}z_{20} - n_{16}v_9z_{17} + n_6v_{20}z_{17} + n_{16}v_8z_{20} - n_6v_{21}z_{19} - n_{21}v_8z_{17} + n_{16}v_{20}z_{11} - n_{16}v_{21}z_{10} - n_{21}v_{16}z_{11} + n_{21}v_{17}z_{10} + n_{21}v_9z_{19},$

$h_{64} = d_5n_8n_{19} - d_5n_9n_{18} - d_4n_8n_{24} + d_4n_9n_{23} + d_2n_{18}n_{24} - d_2n_{19}n_{23} - d_4v_9z_{17} - d_5v_8z_{17} + d_4v_8z_{20} - d_5v_{16}z_{11} + d_5v_{17}z_{10} + d_5v_9z_{19} + d_4v_{20}z_{11} - d_4v_{21}z_{10} + d_2v_{17}z_{17} - d_2v_{16}z_{20} + d_2v_{20}z_{17} - d_2v_{21}z_{19} + n_6n_{19}z_{17} - n_9n_{16}z_{17} - n_6n_{18}z_{20} + n_8n_{16}z_{20} + n_6n_{23}z_{17} - n_8n_{21}z_{17} - n_6n_{24}z_{19} + n_9n_{21}z_{19} + n_{16}n_{23}z_{11} - n_{16}n_{24}z_{10} - n_{18}n_{21}z_{11} + n_{19}n_{21}z_{10},$

$h_{65} = -n_6z_{17}^2 - d_4n_9z_{17} - d_5n_8z_{17} + d_4n_8z_{20} + d_5n_9z_{19} - d_5n_{18}z_{11} + d_5n_{19}z_{10} + d_2n_{19}z_{17} + d_4n_{23}z_{11} - d_4n_{24}z_{10} - d_2n_{18}z_{20} + d_2n_{23}z_{17} - d_2n_{24}z_{19} - n_{16}z_{11}z_{17} + n_6z_{19}z_{20} + n_{16}z_{10}z_{20} - n_{21}z_{10}z_{17} + n_{21}z_{11}z_{19},$

$h_{66} = d_4z_{10}z_{20} - d_4z_{11}z_{17} - d_5z_{10}z_{17} - d_2z_{17}^2 + d_5z_{11}z_{19} + d_2z_{19}z_{20},$

$h_{67} = n_6v_{15}v_{21} - n_6v_{17}v_{19} - n_{16}v_7v_{21} + n_{16}v_9v_{19} + n_{21}v_7v_{17} - n_{21}v_9v_{15},$

$h_{68} = d_5v_7v_{17} - d_5v_9v_{15} - d_4v_7v_{21} + d_4v_9v_{19} + d_2v_{15}v_{21} - d_2v_{17}v_{19} + n_6n_{17}v_{21} - n_6n_{19}v_{19} - n_7n_{16}v_{21} + n_9n_{16}v_{19} - n_6n_{22}v_{17} + n_6n_{24}v_{15} + n_7n_{21}v_{17} - n_9n_{21}v_{15} + n_{16}n_{22}v_9 - n_{16}n_{24}v_7 - n_{17}n_{21}v_9 + n_{19}n_{21}v_7,$

$h_{69} = d_5n_7v_{17} - d_5n_9v_{15} - d_5n_{17}v_9 + d_5n_{19}v_7 - d_4n_7v_{21} + d_4n_9v_{19} + d_4n_{22}v_9 - d_4n_{24}v_7 + d_2n_{17}v_{21} - d_2n_{19}v_{19} - d_2n_{22}v_{17} + d_2n_{24}v_{15} + n_6n_{17}n_{24} - n_6n_{19}n_{22} - n_7n_{16}n_{24} + n_7n_{19}n_{21} + n_9n_{16}n_{22} - n_9n_{17}n_{21} - n_6v_{15}z_{20} + n_6v_{19}z_{17} + n_{16}v_7z_{20} - n_{21}v_7z_{17} + n_{16}v_{19}z_{11} + n_{16}v_{21}z_9 - n_{21}v_{15}z_{11} - n_{21}v_{17}z_9,$

$h_{70} = d_5n_7n_{19} - d_5n_9n_{17} - d_4n_7n_{24} + d_4n_9n_{22} + d_2n_{17}n_{24} - d_2n_{19}n_{22} - d_5v_7z_{17} + d_4v_7z_{20} - d_5v_{15}z_{11} - d_5v_{17}z_9 + d_4v_{19}z_{11} + d_4v_{21}z_9 - d_2v_{15}z_{20} + d_2v_{19}z_{17} - n_6n_{17}z_{20} + n_7n_{16}z_{20} + n_6n_{22}z_{17} - n_7n_{21}z_{17} + n_{16}n_{22}z_{11} + n_{16}n_{24}z_9 - n_{17}n_{21}z_{11} - n_{19}n_{21}z_9,$

$h_{71} = -d_5n_7z_{17} + d_4n_7z_{20} - d_5n_{17}z_{11} - d_5n_{19}z_9 + d_4n_{22}z_{11} + d_4n_{24}z_9 - d_2n_{17}z_{20} + d_2n_{22}z_{17} - n_{16}z_9z_{20} + n_{21}z_9z_{17},$

Principal
Dyal Singh College
KARNAL

$h_{72} = d_5 z_9 z_{17} - d_4 z_9 z_{20},$
$h_{73} = n_6 v_{15} v_{20} - n_6 v_{16} v_{19} - n_{16} v_7 v_{20} + n_{16} v_8 v_{19} + n_{21} v_7 v_{16} - n_{21} v_8 v_{15},$
$h_{74} = d_5 v_7 v_{16} - d_5 v_8 v_{15} - d_4 v_7 v_{20} + d_4 v_8 v_{19} + d_2 v_{15} v_{20} - d_2 v_{16} v_{19} + n_6 n_{17} v_{20} - n_6 n_{18} v_{19} - n_7 n_{16} v_{20} + n_8 n_{16} v_{19} - n_6 n_{22} v_{16} + n_6 n_{23} v_{15} + n_7 n_{21} v_{16} - n_8 n_{21} v_{15} + n_{16} n_{22} v_8 - n_{16} n_{23} v_7 - n_{17} n_{21} v_8 + n_{18} n_{21} v_7,$
$h_{75} = d_5 n_7 v_{16} - d_5 n_8 v_{15} - d_5 n_{17} v_8 + d_5 n_{18} v_7 - d_4 n_7 v_{20} + d_4 n_8 v_{19} + d_4 n_{22} v_8 - d_4 n_{23} v_7 + d_2 n_{17} v_{20} - d_2 n_{18} v_{19} - d_2 n_{22} v_{16} + d_2 n_{23} v_{15} + n_6 n_{17} n_{23} - n_6 n_{18} n_{22} - n_7 n_{16} n_{23} + n_7 n_{18} n_{21} + n_8 n_{16} n_{22} - n_8 n_{17} n_{21} - n_6 v_{15} z_{17} + n_{16} v_7 z_{17} + n_6 v_{19} z_{19} + n_{16} v_{19} z_{10} + n_{16} v_{20} z_9 - n_{21} v_{15} z_{10} - n_{21} v_{16} z_9 - n_{21} v_7 z_{19},$
$h_{76} = d_5 n_7 n_{18} - d_5 n_8 n_{17} - d_4 n_7 n_{23} + d_4 n_8 n_{22} + d_2 n_{17} n_{23} - d_2 n_{18} n_{22} + d_4 v_7 z_{17} - d_5 v_{15} z_{10} - d_5 v_{16} z_9 - d_5 v_7 z_{19} + d_4 v_{19} z_{10} + d_4 v_{20} z_9 - d_2 v_{15} z_{17} + d_2 v_{19} z_{19} - n_6 n_{17} z_{17} + n_7 n_{16} z_{17} + n_6 n_{22} z_{19} - n_7 n_{21} z_{19} + n_{16} n_{22} z_{10} + n_{16} n_{23} z_9 - n_{17} n_{21} z_{10} - n_{18} n_{21} z_9,$
$h_{77} = d_4 n_7 z_{17} - d_5 n_7 z_{19} - d_5 n_{17} z_{10} - d_5 n_{18} z_9 - d_2 n_{17} z_{17} + d_4 n_{22} z_{10} + d_4 n_{23} z_9 + d_2 n_{22} z_{19} - n_{16} z_9 z_{17} + n_{21} z_9 z_{19},$
$h_{78} = d_5 z_9 z_{19} - d_4 z_9 z_{17},$
$h_{79} = v_7 v_{12} v_{21} - v_7 v_{13} v_{20} - v_8 v_{11} v_{21} + v_8 v_{13} v_{19} + v_9 v_{11} v_{20} - v_9 v_{12} v_{19},$
$h_{80} = n_7 v_{12} v_{21} - n_7 v_{13} v_{20} - n_8 v_{11} v_{21} + n_8 v_{13} v_{19} + n_9 v_{11} v_{20} - n_9 v_{12} v_{19} - n_{12} v_8 v_{21} + n_{12} v_9 v_{20} + n_{13} v_7 v_{21} - n_{13} v_9 v_{19} - n_{14} v_7 v_{20} + n_{14} v_8 v_{19} + n_{22} v_8 v_{13} - n_{22} v_9 v_{12} - n_{23} v_7 v_{13} + n_{23} v_9 v_{11} + n_{24} v_7 v_{12} - n_{24} v_8 v_{11},$
$h_{81} = n_7 n_{13} v_{21} - n_7 n_{14} v_{20} - n_8 n_{12} v_{21} + n_8 n_{14} v_{19} + n_9 n_{12} v_{20} - n_9 n_{13} v_{19} - n_7 n_{23} v_{13} + n_7 n_{24} v_{12} + n_8 n_{22} v_{13} - n_8 n_{24} v_{11} - n_9 n_{22} v_{12} + n_9 n_{23} v_{11} + n_{12} n_{23} v_9 - n_{12} n_{24} v_8 - n_{13} n_{22} v_9 + n_{13} n_{24} v_7 + n_{14} n_{22} v_8 - n_{14} n_{23} v_7 + v_7 v_{13} z_{17} - v_9 v_{11} z_{17} - v_7 v_{12} z_{20} + v_8 v_{11} z_{20} + v_{11} v_{20} z_{11} - v_{11} v_{21} z_{10} - v_{12} v_{19} z_{11} - v_{12} v_{21} z_9 + v_{13} v_{19} z_{10} + v_{13} v_{20} z_9 + v_8 v_{21} z_{15} - v_9 v_{20} z_{15},$
$h_{82} = n_7 n_{13} n_{24} - n_7 n_{14} n_{23} - n_8 n_{12} n_{24} + n_8 n_{14} n_{22} + n_9 n_{12} n_{23} - n_9 n_{13} n_{22} + n_7 v_{13} z_{17} - n_9 v_{11} z_{17} - n_{12} v_9 z_{17} + n_{14} v_7 z_{17} - n_7 v_{12} z_{20} + n_8 v_{11} z_{20} + n_{12} v_8 z_{20} - n_{13} v_7 z_{20} + n_{12} v_{20} z_{11} - n_{12} v_{21} z_{10} - n_{13} v_{19} z_{11} - n_{13} v_{21} z_9 + n_{14} v_{19} z_{10} + n_{14} v_{20} z_9 + n_8 v_{21} z_{15} - n_9 v_{20} z_{15} - n_{22} v_{12} z_{11} + n_{22} v_{13} z_{10} + n_{23} v_{11} z_{11} + n_{23} v_{13} z_9 - n_{24} v_{11} z_{10} - n_{24} v_{12} z_9 - n_{23} v_9 z_{15} + n_{24} v_8 z_{15},$
$h_{83} = n_7 n_{14} z_{17} - n_9 n_{12} z_{17} - n_7 n_{13} z_{20} + n_8 n_{12} z_{20} + n_{12} n_{23} z_{11} - n_{12} n_{24} z_{10} - n_{13} n_{22} z_{11} - n_{13} n_{24} z_9 + n_{14} n_{22} z_{10} + n_{14} n_{23} z_9 + n_8 n_{24} z_{15} - n_9 n_{23} z_{15} - v_{11} z_{11} z_{17} - v_{13} z_9 z_{17} + v_9 z_{15} z_{17} + v_{11} z_{10} z_{20} + v_{12} z_9 z_{20} - v_8 z_{15} z_{20} - v_{20} z_{11} z_{15} + v_{21} z_{10} z_{15},$
$h_{84} = -n_{12} z_{11} z_{17} - n_{14} z_9 z_{17} + n_9 z_{15} z_{17} + n_{12} z_{10} z_{20} + n_{13} z_9 z_{20} - n_8 z_{15} z_{20} - n_{23} z_{11} z_{15} + n_{24} z_{10} z_{15},$
$h_{85} = z_{11} z_{15} z_{17} - z_{10} z_{15} z_{20},$
$h_{86} = n_6 v_{12} v_{21} - n_6 v_{13} v_{20} - n_{11} v_8 v_{21} + n_{11} v_9 v_{20} + n_{21} v_8 v_{13} - n_{21} v_9 v_{12},$
$h_{87} = d_5 v_8 v_{13} - d_5 v_9 v_{12} - d_3 v_8 v_{21} + d_3 v_9 v_{20} + d_2 v_{12} v_{21} - d_2 v_{13} v_{20} + n_6 n_{13} v_{21} - n_6 n_{14} v_{20} - n_8 n_{11} v_{21} + n_9 n_{11} v_{20} - n_6 n_{23} v_{13} + n_6 n_{24} v_{12} + n_8 n_{21} v_{13} - n_9 n_{21} v_{12} + n_{11} n_{23} v_9 - n_{11} n_{24} v_8 - n_{13} n_{21} v_9 + n_{14} n_{21} v_8,$
$h_{88} = d_5 n_8 v_{13} - d_5 n_9 v_{12} - d_5 n_{13} v_9 + d_5 n_{14} v_8 - d_3 n_8 v_{21} + d_3 n_9 v_{20} + d_3 n_{23} v_9 - d_3 n_{24} v_8 + d_2 n_{13} v_{21} - d_2 n_{14} v_{20} - d_2 n_{23} v_{13} + d_2 n_{24} v_{12} + n_6 n_{13} n_{24} - n_6 n_{14} n_{23} - n_8 n_{11} n_{24} + n_8 n_{14} n_{21} + n_9 n_{11} n_{23} - n_9 n_{13} n_{21} + n_6 v_{13} z_{17} - n_{11} v_9 z_{17} - n_6 v_{12} z_{20} + n_{11} v_8 z_{20} + n_{11} v_{20} z_{11} - n_{11} v_{21} z_{10} - n_{21} v_{12} z_{11} + n_{21} v_{13} z_{10},$
$h_{89} = d_5 n_8 n_{14} - d_5 n_9 n_{13} - d_3 n_8 n_{24} + d_3 n_9 n_{23} + d_2 n_{13} n_{24} - d_2 n_{14} n_{23} - d_5 v_{12} z_{11} + d_5 v_{13} z_{10} - d_3 v_9 z_{17} + d_3 v_8 z_{20} + d_2 v_{13} z_{17} - d_2 v_{12} z_{20} + d_3 v_{20} z_{11} - d_3 v_{21} z_{10} + n_6 n_{14} z_{17} - n_9 n_{11} z_{17} - n_6 n_{13} z_{20} + n_8 n_{11} z_{20} + n_{11} n_{23} z_{11} - n_{11} n_{24} z_{10} - n_{13} n_{21} z_{11} + n_{14} n_{21} z_{10},$
$h_{90} = -d_3 n_9 z_{17} - d_5 n_{13} z_{11} + d_5 n_{14} z_{10} + d_3 n_8 z_{20} + d_2 n_{14} z_{17} - d_2 n_{13} z_{20} + d_3 n_{23} z_{11} - d_3 n_{24} z_{10} - n_{11} z_{11} z_{17} + n_{11} z_{10} z_{20},$
$h_{91} = d_3 z_{10} z_{20} - d_3 z_{11} z_{17},$
$h_{92} = n_6 v_{11} v_{21} - n_6 v_{13} v_{19} - n_{11} v_7 v_{21} + n_{11} v_9 v_{19} + n_{21} v_7 v_{13} - n_{21} v_9 v_{11},$
$h_{93} = d_5 v_7 v_{13} - d_5 v_9 v_{11} - d_3 v_7 v_{21} + d_3 v_9 v_{19} + d_2 v_{11} v_{21} - d_2 v_{13} v_{19} + n_6 n_{12} v_{21} - n_6 n_{14} v_{19} - n_7 n_{11} v_{21} + n_9 n_{11} v_{19} - n_6 n_{22} v_{13} + n_6 n_{24} v_{11} + n_7 n_{21} v_{13} - n_9 n_{21} v_{11} + n_{11} n_{22} v_9 - n_{11} n_{24} v_7 - n_{12} n_{21} v_9 + n_{14} n_{21} v_7,$
$h_{94} = d_5 n_7 v_{13} - d_5 n_9 v_{11} - d_5 n_{12} v_9 + d_5 n_{14} v_7 - d_3 n_7 v_{21} + d_3 n_9 v_{19} + d_3 n_{22} v_9 - d_3 n_{24} v_7 + d_2 n_{12} v_{21} - d_2 n_{14} v_{19} - d_2 n_{22} v_{13} + d_2 n_{24} v_{11} + n_6 n_{12} n_{24} - n_6 n_{14} n_{22} - n_7 n_{11} n_{24} + n_7 n_{14} n_{21} + n_9 n_{11} n_{22} - n_9 n_{12} n_{21} - n_6 v_{11} z_{20} + n_{11} v_7 z_{20} + n_{11} v_{19} z_{11} + n_{11} v_{21} z_9 - n_6 v_{21} z_{15} - n_{21} v_{11} z_{11} - n_{21} v_{13} z_9 + n_{21} v_9 z_{15},$
$h_{95} = d_5 n_7 n_{14} - d_5 n_9 n_{12} - d_3 n_7 n_{24} + d_3 n_9 n_{22} + d_2 n_{12} n_{24} - d_2 n_{14} n_{22} - d_5 v_{11} z_{11} - d_5 v_{13} z_9 + d_5 v_9 z_{15} + d_3 v_7 z_{20} - d_2 v_{11} z_{20} + d_3 v_{19} z_{11} + d_3 v_{21} z_9 - d_2 v_{21} z_{15} - n_6 n_{12} z_{20} + n_7 n_{11} z_{20} + n_{11} n_{22} z_{11} + n_{11} n_{24} z_9 - n_{12} n_{21} z_{11} - n_{14} n_{21} z_9 - n_6 n_{24} z_{15} + n_9 n_{21} z_{15},$
$h_{96} = -d_5 n_{12} z_{11} - d_5 n_{14} z_9 + d_5 n_9 z_{15} + d_3 n_7 z_{20} - d_2 n_{12} z_{20} + d_3 n_{22} z_{11} + d_3 n_{24} z_9 - d_2 n_{24} z_{15} - n_{11} z_9 z_{20} + n_6 z_{15} z_{20} + n_{21} z_{11} z_{15},$
$h_{97} = d_5 z_{11} z_{15} - d_3 z_9 z_{20} + d_2 z_{15} z_{20},$
$h_{98} = n_6 v_{11} v_{20} - n_6 v_{12} v_{19} - n_{11} v_7 v_{20} + n_{11} v_8 v_{19} + n_{21} v_7 v_{12} - n_{21} v_8 v_{11},$
$h_{99} = d_5 v_7 v_{12} - d_5 v_8 v_{11} - d_3 v_7 v_{20} + d_3 v_8 v_{19} + d_2 v_{11} v_{20} - d_2 v_{12} v_{19} + n_6 n_{12} v_{20} - n_6 n_{13} v_{19} - n_7 n_{11} v_{20} + n_8 n_{11} v_{19} - n_6 n_{22} v_{12} + n_6 n_{23} v_{11} + n_7 n_{21} v_{12} - n_8 n_{21} v_{11} + n_{11} n_{22} v_8 - n_{11} n_{23} v_7 - n_{12} n_{21} v_8 + n_{13} n_{21} v_7,$
$h_{100} = d_5 n_7 v_{12} - d_5 n_8 v_{11} - d_5 n_{12} v_8 + d_5 n_{13} v_7 - d_3 n_7 v_{20} + d_3 n_8 v_{19} + d_3 n_{22} v_8 - d_3 n_{23} v_7 + d_2 n_{12} v_{20} - d_2 n_{13} v_{19} - d_2 n_{22} v_{12} + d_2 n_{23} v_{11} + n_6 n_{12} n_{23} - n_6 n_{13} n_{22} - n_7 n_{11} n_{23} + n_7 n_{13} n_{21} + n_8 n_{11} n_{22} - n_8 n_{12} n_{21} - n_6 v_{11} z_{17} + n_{11} v_7 z_{17} + n_{11} v_{19} z_{10} + n_{11} v_{20} z_9 - n_6 v_{20} z_{15} - n_{21} v_{11} z_{10} - n_{21} v_{12} z_9 + n_{21} v_8 z_{15},$
$h_{101} = d_5 n_7 n_{13} - d_5 n_8 n_{12} - d_3 n_7 n_{23} + d_3 n_8 n_{22} + d_2 n_{12} n_{23} - d_2 n_{13} n_{22} - d_5 v_{11} z_{10} - d_5 v_{12} z_9 + d_3 v_7 z_{17} + d_5 v_8 z_{15} - d_2 v_{11} z_{17} + d_3 v_{19} z_{10} + d_3 v_{20} z_9 - d_2 v_{20} z_{15} - n_6 n_{12} z_{17} + n_7 n_{11} z_{17} + n_{11} n_{22} z_{10} + n_{11} n_{23} z_9 - n_{12} n_{21} z_{10} - n_{13} n_{21} z_9 - n_6 n_{23} z_{15} + n_8 n_{21} z_{15},$
$h_{102} = d_3 n_7 z_{17} - d_5 n_{12} z_{10} - d_5 n_{13} z_9 + d_5 n_8 z_{15} - d_2 n_{12} z_{17} + d_3 n_{22} z_{10} + d_3 n_{23} z_9 - d_2 n_{23} z_{15} - n_{11} z_9 z_{17} + n_6 z_{15} z_{17} + n_{21} z_{10} z_{15},$
$h_{103} = d_5 z_{10} z_{15} - d_3 z_9 z_{17} + d_2 z_{15} z_{17},$
$h_{104} = v_7 v_{12} v_{17} - v_7 v_{13} v_{16} - v_8 v_{11} v_{17} + v_8 v_{13} v_{15} + v_9 v_{11} v_{16} - v_9 v_{12} v_{15},$
$h_{105} = n_7 v_{12} v_{17} - n_7 v_{13} v_{16} - n_8 v_{11} v_{17} + n_8 v_{13} v15 + n_9 v_{11} v_{16} - n_9 v_{12} v_{15} - n_{12} v_8 v_{17} + n_{12} v_9 v_{16} + n_{13} v_7 v_{17} - n_{13} v_9 v_{15} - n_{14} v_7 v_{16} + n_{14} v_8 v_{15} + n_{17} v_8 v_{13} - n_{17} v_9 v_{12} - n_{18} v_7 v_{13} + n_{18} v_9 v_{11} + n_{19} v_7 v_{12} - n_{19} v_8 v_{11},$
$h_{106} = n_7 n_{13} v_{17} - n_7 n_{14} v_{16} - n_8 n_{12} v_{17} + n_8 n_{14} v_{15} + n_9 n_{12} v_{16} - n_9 n_{13} v_{15} - n_7 n_{18} v_{13} + n_7 n_{19} v_{12} + n_8 n_{17} v_{13} - n_8 n_{19} v_{11} - n_9 n_{17} v_{12} + n_9 n_{18} v_{11} + n_{12} n_{18} v_9 - n_{12} n_{19} v_8 - n_{13} n_{17} v_9 + n_{13} n_{19} v_7 + n_{14} n_{17} v_8 - n_{14} n_{18} v_7 - v_7 v_{12} z_{17} + v_8 v_{11} z_{17} + v_{11} v_{16} z_{11} - v_{11} v_{17} z_{10} - v_{12} v_{15} z_{11} - v_{12} v_{17} z_9 + v_{13} v_{15} z_{10} + v_{13} v_{16} z_9 + v_7 v_{13} z_{19} - v_9 v_{11} z_{19} + v_8 v_{17} z_{15} - v_9 v_{16} z_{15},$
$h_{107} = n_7 n_{13} n_{19} - n_7 n_{14} n_{18} - n_8 n_{12} n_{19} + n_8 n_{14} n_{17} + n_9 n_{12} n_{18} - n_9 n_{13} n_{17} - n_7 v_{12} z_{17} + n_8 v_{11} z_{17} + n_{12} v_8 z_{17} - n_{13} v_7 z_{17} + n_7 v_{13} z_{19} - n_9 v_{11} z_{19} + n_{12} v_{16} z_{11} - n_{12} v_{17} z_{10} - n_{13} v_{15} z_{11} - n_{13} v_{17} z_9 + n_{14} v_{15} z_{10} + n_{14} v_{16} z_9 + n_8 v_{17} z_{15} - n_9 v_{16} z_{15} - n_{12} v_9 z_{19} + n_{14} v_7 z_{19} - n_{17} v_{12} z_{11} + n_{17} v_{13} z_{10} + n_{18} v_{11} z_{11} + n_{18} v_{13} z_9 - n_{19} v_{11} z_{10} - n_{19} v_{12} z_9 - n_{18} v_9 z_{15} + n_{19} v_8 z_{15},$
$h_{108} = -n_7 n_{13} z_{17} + n_8 n_{12} z_{17} + n_7 n_{14} z_{19} - n_9 n_{12} z_{19} + n_{12} n_{18} z_{11} - n_{12} n_{19} z_{10} - n_{13} n_{17} z_{11} - n_{13} n_{19} z_9 + n_{14} n_{17} z_{10} + n_{14} n_{18} z_9 + n_8 n_{19} z_{15} - n_9 n_{18} z_{15} + v_{11} z_{10} z_{17} + v_{12} z_9 z_{17} - v_8 z_{15} z_{17} - v_{11} z_{11} z_{19} - v_{13} z_9 z_{19} - v_{16} z_{11} z_{15} + v_{17} z_{10} z_{15} + v_9 z_{15} z_{19},$
$h_{109} = n_{12} z_{10} z_{17} + n_{13} z_9 z_{17} - n_8 z_{15} z_{17} - n_{12} z_{11} z_{19} - n_{14} z_9 z_{19} + n_9 z_{15} z_{19} - n_{18} z_{11} z_{15} + n_{19} z_{10} z_{15}, h_{110} = z_{11} z_{15} z_{19} - z_{10} z_{15} z_{17},$
$h_{111} = n_6 v_{12} v_{17} - n_6 v_{13} v_{16} - n_{11} v_8 v_{17} + n_{11} v_9 v_{16} + n_{16} v_8 v_{13} - n_{16} v_9 v_{12},$
$h_{112} = d_4 v_8 v_{13} - d_4 v_9 v_{12} - d_3 v_8 v_{17} + d_3 v_9 v_{16} + d_2 v_{12} v_{17} - d_2 v_{13} v_{16} + n_6 n_{13} v_{17} - n_6 n_{14} v_{16} - n_8 n_{11} v_{17} + n_9 n_{11} v_{16} - n_6 n_{18} v_{13} + n_6 n_{19} v_{12} + n_8 n_{16} v_{13} - n_9 n_{16} v_{12} + n_{11} n_{18} v_9 - n_{11} n_{19} v_8 - n_{13} n_{16} v_9 + n_{14} n_{16} v_8,$
$h_{113} = d_4 n_8 v_{13} - d_4 n_9 v_{12} - d_4 n_{13} v_9 + d_4 n_{14} v_8 - d_3 n_8 v_{17} + d_3 n_9 v_{16} + d_3 n_{18} v_9 - d_3 n_{19} v_8 + d_2 n_{13} v_{17} - d_2 n_{14} v_{16} - d_2 n_{18} v_{13} + d_2 n_{19} v_{12} + n_6 n_{13} n_{19} - n_6 n_{14} n_{18} -$

Principal
Dyal Singh College
KARNAL

$n_8n_{11}n_{19}+n_8n_{14}n_{16}+n_9n_{11}n_{18}-n_9n_{13}n_{16}-n_6v_{12}z_{17}+n_{11}v_8z_{17}+n_6v_{13}z_{19}+n_{11}v_{16}z_{11}-n_{11}v_{17}z_{_{10}}-n_{11}v_9z_{19}-n_{16}v_{12}z_{11}+n_{16}v_{13}z_{10}$,
$h_{114}=d_4n_8n_{14}-d_4n_9n_{13}-d_3n_8n_{19}+d_3n_9n_{18}+d_2n_{13}n_{19}-d_2n_{14}n_{18}-d_4v_{12}z_{11}+d_4v_{13}z_{_{10}}+d_3v_8z_{17}+d_3v_{16}z_{11}-d_3v_{17}z_{_{10}}-d_2v_{12}z_{17}-d_3v_9z_{19}+d_2v_{13}z_{19}-n_6n_{13}z_{17}+n_8n_{11}z_{17}+n_6n_{14}z_{19}-n_9n_{11}z_{19}+n_{11}n_{18}z_{11}-n_{11}n_{19}z_{_{10}}-n_{13}n_{16}z_{11}+n_{14}n_{16}z_{_{10}}$,
$h_{115}=d_3n_8z_{17}-d_4n_{13}z_{11}+d_4n_{14}z_{_{10}}-d_3n_9z_{19}-d_2n_{13}z_{17}+d_3n_{18}z_{11}-d_3n_{19}z_{_{10}}+d_2n_{14}z_{19}+n_{11}z_{_{10}}z_{17}-n_{11}z_{11}z_{19}$,
$h_{116}=d_3z_{_{10}}z_{17}-d_3z_{11}z_{19}$,
$h_{117}=n_6v_{11}v_{17}-n_6v_{13}v_{15}-n_{11}v_7v_{17}+n_{11}v_9v_{15}+n_{16}v_7v_{13}-n_{16}v_9v_{11}$,
$h_{118}=d_4v_7v_{13}-d_4v_9v_{11}-d_3v_7v_{17}+d_3v_9v_{15}+d_2v_{11}v_{17}-d_2v_{13}v_{15}+n_6n_{12}v_{17}-n_6n_{14}v_{15}-n_7n_{11}v_{17}+n_9n_{11}v_{15}-n_6n_{17}v_{13}+n_6n_{19}v_{11}+n_7n_{16}v_{13}-n_9n_{16}v_{11}+n_{11}n_{17}v_9-n_{11}n_{19}v_7-n_{12}n_{16}v_9+n_{14}n_{16}v_7$,
$h_{119}=d_4n_7v_{13}-d_4n_9v_{11}-d_4n_{12}v_9+d_4n_{14}v_7-d_3n_7v_{17}+d_3n_9v_{15}+d_3n_{17}v_9-d_3n_{19}v_7+d_2n_{12}v_{17}-d_2n_{14}v_{15}-d_2n_{17}v_{13}+d_2n_{19}v_{11}+n_6n_{12}n_{19}-n_6n_{14}n_{17}-n_7n_{11}n_{19}+n_7n_{14}n_{16}+n_9n_{11}n_{17}-n_9n_{12}n_{16}-n_6v_{11}z_{17}+n_{11}v_7z_{17}+n_{11}v_{15}z_{11}+n_{11}v_{17}z_9-n_6v_{17}z_{15}-n_{16}v_{11}z_{11}-n_{16}v_{13}z_9+n_{16}v_9z_{15}$,
$h_{120}=d_4n_7n_{14}-d_4n_9n_{12}-d_3n_7n_{19}+d_3n_9n_{17}+d_2n_{12}n_{19}-d_2n_{14}n_{17}-d_4v_{11}z_{11}-d_4v_{13}z_9+d_3v_7z_{17}+d_4v_9z_{15}+d_3v_{15}z_{11}+d_3v_{17}z_9-d_2v_{11}z_{17}-d_2v_{17}z_{15}-n_6n_{12}z_{17}+n_7n_{11}z_{17}+n_{11}n_{17}z_{11}+n_{11}n_{19}z_9-n_{12}n_{16}z_{11}-n_{14}n_{16}z_9-n_6n_{19}z_{15}+n_9n_{16}z_{15}$,
$h_{121}=d_3n_7z_{17}-d_4n_{12}z_{11}-d_4n_{14}z_9+d_4n_9z_{15}-d_2n_{12}z_{17}+d_3n_{17}z_{11}+d_3n_{19}z_9-d_2n_{19}z_{15}-n_{11}z_9z_{17}+n_6z_{15}z_{17}+n_{16}z_{11}z_{15}$,
$h_{122}=d_4z_{11}z_{15}-d_3z_9z_{17}+d_2z_{15}z_{17}$,
$h_{123}=n_6v_{11}v_{16}-n_6v_{12}v_{15}-n_{11}v_7v_{16}+n_{11}v_8v_{15}+n_{16}v_7v_{12}-n_{16}v_8v_{11}$,
$h_{124}=d_4v_7v_{12}-d_4v_8v_{11}-d_3v_7v_{16}+d_3v_8v_{15}+d_2v_{11}v_{16}-d_2v_{12}v_{15}+n_6n_{12}v_{16}-n_6n_{13}v_{15}-n_7n_{11}v_{16}+n_8n_{11}v_{15}-n_6n_{17}v_{12}+n_6n_{18}v_{11}+n_7n_{16}v_{12}-n_8n_{16}v_{11}+n_{11}n_{17}v_8-n_{11}n_{18}v_7-n_{12}n_{16}v_8+n_{13}n_{16}v_7$,
$h_{125}=d_4n_7v_{12}-d_4n_8v_{11}-d_4n_{12}v_8+d_4n_{13}v_7-d_3n_7v_{16}+d_3n_8v_{15}+d_3n_{17}v_8-d_3n_{18}v_7+d_2n_{12}v_{16}-d_2n_{13}v_{15}-d_2n_{17}v_{12}+d_2n_{18}v_{11}+n_6n_{12}n_{18}-n_6n_{13}n_{17}-n_7n_{11}n_{18}+n_7n_{13}n_{16}+n_8n_{11}n_{17}-n_8n_{12}n_{16}-n_6v_{11}z_{19}+n_{11}v_{15}z_{_{10}}+n_{11}v_{16}z_9-n_6v_{16}z_{15}+n_{11}v_7z_{19}-n_{16}v_{11}z_{_{10}}-n_{16}v_{12}z_9+n_{16}v_8z_{15}$,
$h_{126}=d_4n_7n_{13}-d_4n_8n_{12}-d_3n_7n_{18}+d_3n_8n_{17}+d_2n_{12}n_{18}-d_2n_{13}n_{17}-d_4v_{11}z_{_{10}}-d_4v_{12}z_9+d_4v_8z_{15}+d_3v_{15}z_{10}+d_3v_{16}z_9+d_3v_7z_{19}-d_2v_{11}z_{19}-d_2v_{16}z_{15}-n_6n_{12}z_{19}+n_7n_{11}z_{19}+n_{11}n_{17}z_{_{10}}+n_{11}n_{18}z_9-n_{12}n_{16}z_{_{10}}-n_{13}n_{16}z_9-n_6n_{18}z_{15}+n_8n_{16}z_{15}$,
$h_{127}=-d_4n_{12}z_{_{10}}-d_4n_{13}z_9+d_4n_8z_{15}+d_3n_7z_{19}+d_3n_{17}z_{_{10}}+d_3n_{18}z_9-d_2n_{12}z_{19}-d_2n_{18}z_{15}-n_{11}z_9z_{19}+n_6z_{15}z_{19}+n_{16}z_{_{10}}z_{15}$,
$h_{128}=d_4z_{10}z_{15}-d_3z_9z_{19}+d_2z_{15}z_{19}$, $d_1=z_3-z_{12}z_1/z_3, d_2=z_8-z_6z_{12}/z_3, d_3=z_{14}-z_{13}z_{12}/z_3, d_4=z_{18}-z_{16}z_{12}/z_3, d_5=z_{22}-z_{21}z_{12}/z_3$,
$n_1=-\bar{x}_7z_1/z_3+\bar{x}_2, n_2=-\bar{x}_1z_{12}/z_3, n_3=-z_1\bar{x}_{10}/z_3+\bar{x}_3, n_4=-z_1\bar{x}_{12}/z_3+\bar{x}_5, n_5=\bar{x}_6-z_6\bar{x}_7/z_3$,
$n_6=\bar{x}_7-\bar{x}_2z_{12}/z_3, n_7=\bar{x}_8-z_6\bar{x}_{10}/z_3, n_8=\bar{x}_9-z_6\bar{x}_{11}/z_3, n_9=\bar{x}_{13}-z_6\bar{x}_{12}/z_3, n_{10}=\bar{x}_8-z_{13}\bar{x}_7/z_3$,
$n_{11}=\bar{x}_{10}-\bar{x}_3z_{12}/z_3, n_{12}=\bar{x}_{14}-z_{13}\bar{x}_{10}/z_3, n_{13}=\bar{x}_{15}-z_{13}\bar{x}_{11}/z_3, n_{14}=\bar{x}_{16}-z_{13}\bar{x}_{12}/z_3$,
$n_{15}=\bar{x}_9-z_{16}\bar{x}_7/z_3, n_{16}=\bar{x}_{11}-\bar{x}_4z_{12}/z_3, n_{17}=\bar{x}_{15}-z_{16}\bar{x}_{10}/z_3, n_{18}=\bar{x}_{17}-z_{16}\bar{x}_{11}/z_3$,
$n_{19}=\bar{x}_{18}-z_{16}\bar{x}_{12}/z_3, n_{20}=\bar{x}_{13}-z_{21}\bar{x}_7/z_3, n_{21}=\bar{x}_{12}-\bar{x}_5z_{12}/z_3, n_{22}=\bar{x}_{16}-z_{21}\bar{x}_{10}/z_3$,
$n_{23}=\bar{x}_{18}-z_{21}\bar{x}_{11}/z_3, n_{24}=\bar{x}_{19}-z_{21}\bar{x}_{12}/z_3, n_{25}=-z_1\bar{x}_{11}/z_3+\bar{x}_4$,

$v_1=-\bar{x}_7\bar{x}_1/z_3, v_2=-c^0_{44}z_{12}/z_3, v_3=-\bar{x}_1\bar{x}_{10}/z_3, v_4=-\bar{x}_1\bar{x}_{11}/z_3, v_5=-\bar{x}_1\bar{x}_{12}/z_3$,
$v_6=c^0_{33}-\bar{x}_2\bar{x}_7/z_3, v_7=m^0_{33}-\bar{x}_2\bar{x}_{10}/z_3, v_8=e^0_{33}-\bar{x}_2\bar{x}_{11}/z_3, v_9=\zeta^0_{33}\bar{x}_2\bar{x}_{12}/z_3$,
$v_{10}=m^0_{33}\bar{x}_3\bar{x}_7/z_3, v_{11}=R^0-\bar{x}_3\bar{x}_{10}/z_3, v_{12}=\tilde{\zeta}^{\,0}_3-\bar{x}_3\bar{x}_{11}/z_3, v_{13}=e^{*0}_3-\bar{x}_3\bar{x}_{12}/z_3$,
$v_{14}=e^0_{33}-\bar{x}_4\bar{x}_7/z_3, v_{15}=\tilde{\zeta}^{\,0}_3-\bar{x}_4\bar{x}_{10}/z_3, v_{16}=-\xi^0_{33}-\bar{x}_4\bar{x}_{11}/z_3, v_{17}=-A^0_{33}-\bar{x}_4\bar{x}_{12}/z_3$,
$v_{18}=\zeta^0_{33}-\bar{x}_5\bar{x}_7/z_3, v_{19}=e^{*0}_3-\bar{x}_5\bar{x}_{10}/z_3, v_{20}=-A^0_{33}-\bar{x}_5\bar{x}_{11}/z_3, v_{21}=-\xi^{*0}_{33}-\bar{x}_5\bar{x}_{12}/z_3$,
$y_1=-c^0_{44}\bar{x}_7/z_3, y_2=-c^0_{44}\bar{x}_{10}/z_3, y_3=-c^0_{44}\bar{x}_{11}/z_3, y_4=-c^0_{44}\bar{x}_{12}/z_3$,

$z_1=c^0_{11}/c^2-\bar{\rho}^{11f}_{11}, z_2=-ic^0_{44}\alpha/(c\omega), z_3=m^0_{11}/c^2-\bar{\rho}^{12f}_{11}, z_4=-ie^0_{15}\alpha/(c\omega), z_5=-i\zeta^0_{15}\alpha/(c\omega)$,
$z_6=-ic^0_{13}\alpha/(c\omega), z_7=c^0_{44}/c^2-\bar{\rho}^{11f}_{33}, z_8=-im^0_{33}\alpha/(c\omega), z_9=\bar{\rho}^{12f}_{33}, z_{10}=e^0_{15}/c^2, z_{11}=\zeta^0_{15}/c^2$,
$z_{12}=R^0/c^2-\bar{\rho}^{22f}_{11}, z_{13}=-im^0_{11}\alpha/(c\omega), z_{14}=-iR^0\alpha/(c\omega), z_{15}=\bar{\rho}^{22f}_{33}, z_{16}=-ie^0_{31}\alpha/(c\omega)$,
$z_{17}=A^0_{11}/c^2, z_{18}=-i\tilde{\zeta}^{\,0}_3\alpha/(c\omega), z_{19}=\xi^0_{11}/c^2, z_{20}=\xi^{*0}_{11}/c^2, z_{21}=-i\zeta^0_{31}\alpha/(c\omega), z_{22}=-ie^{*0}_3\alpha/(c\omega)$,
$\bar{x}_1=-ic^0_{44}\alpha/\omega, \bar{x}_2=(c^0_{44}+c^0_{13})/c, \bar{x}_3=m^0_{11}/c, \bar{x}_4=(e^0_{15}+e^0_{31})/c, \bar{x}_5=(\zeta^0_{15}+\zeta^0_{31})/c, \bar{x}_6=-ic^0_{33}\alpha/\omega$,
$\bar{x}_7=m^0_{33}/c, \bar{x}_8=-im^0_{33}\alpha/\omega, \bar{x}_9=-ie^0_{33}\alpha/\omega, \bar{x}_{10}=R^0/c, \bar{x}_{11}=\tilde{\zeta}^{\,0}_3/c, \bar{x}_{12}=e^{*0}_3/c, \bar{x}_{13}=-i\xi^0_{33}\alpha/\omega$,
$\bar{x}_{14}=-iR^0\alpha/\omega, \bar{x}_{15}=-i\tilde{\zeta}^{\,0}_3\alpha/\omega, \bar{x}_{16}=-ie^{*0}_3\alpha/\omega, \bar{x}_{17}=i\xi^0_{33}\alpha/\omega, \bar{x}_{18}=iA^0_{33}\alpha/\omega, \bar{x}_{19}=i\xi^{*0}_{33}\alpha/\omega$.

Appendix D

$$\wp^f_{1i}=i\omega(c^0_{44}\,q^f_i+(c^0_{44}\,U^{f'}_{3i}+e^0_{15}\,\Phi^{f'}_i+\zeta^0_{15}\,\Phi^{*f'}_i))/c,$$

$$\wp^f_{2i}=i\omega((c^0_{33}\,U^{f'}_{3i}+m^0_{33}\,U^{*f'}_{3i}+e^0_{33}\,\Phi^{f'}_i+\zeta^0_{33}\,\Phi^{*f'}_i)\,q^f_i+(c^0_{31}+m^0_{33}\,U^{*f'}_{1i}))/c,$$

$$\wp^f_{3i}=i\omega((m^0_{33}\,U^{f'}_{3i}+R^0\,U^{*f'}_{3i}+\tilde{\zeta}^0_3\,\Phi^{f'}_i+e^{*0}_3\,\Phi^{*f'}_i)\,q^f_i+(m^0_{11}+R^0\,U^{*f'}_{1i}))/c,$$

$$\wp^f_{4i}=i\omega((e^0_{33}\,U^{f'}_{3i}+\tilde{\zeta}^0_3\,U^{*f'}_{3i}-\xi^0_{33}\,\Phi^{f'}_i-A^0_{33}\,\Phi^{*f'}_i)\,q^f_i+(e^0_{31}+\tilde{\zeta}^0_3\,U^{*f'}_{1i}))/c,$$

$$\wp^f_{5i}=i\omega((\zeta^0_{33}\,U^{f'}_{3i}+e^{*0}_3\,U^{*f'}_{3i}-A^0_{33}\,\Phi^{f'}_i-\xi^{*0}_{33}\,\Phi^{*f'}_i)\,q^f_i+(\zeta^0_{31}+e^{*0}_3\,U^{*f'}_{1i}))/c. \quad (D.1)$$

Principal
Dyal Singh College
KARNAL

References

[1] X.Y. Li, Z.K. Wang, S.H. Huang, Love waves in functionally graded piezoelectric materials, Int. J. Solids Struct. 41 (26) (2004) 7309–7328.
[2] C. Othmani, F. Takali, A. Njeh, Investigating and modeling of effect of piezoelectric material parameters on shear horizontal (SH) waves propagation in PZT-5H, PMN-0.33 PT and PMN-0.29 PT plates, Optik 148 (2017) 63–75.
[3] B. Karami, M. Janghorban, A. Tounsi, Variational approach for wave dispersion in anisotropic doubly-curved nanoshells based on a new nonlocal strain gradient higher order shell theory, Thin-Walled Struct. 129 (2018) 251–264.
[4] B. Karami, M. Janghorban, L. Li, On guided wave propagation in fully clamped porous functionally graded nanoplates, Acta Astronautica. 143 (2018) 380–390.
[5] B. Karami, M. Janghorban, A. Tounsi, Novel study on functionally graded anisotropic doubly curved nanoshells, Eur. Phys. J. Plus 135 (1) (2020) 1–31.
[6] A.K. Vashishth, U. Bareja, Analysis of Love waves propagation in a functionally graded porous piezoelectric composite structure, Waves Random Complex Media (2022) 1–32.
[7] A.A. Oliner, Acoustic Surface Waves, Berlin, New York, 1978.
[8] J.W. Grate, S.J. Martin, R.M. White, Acoustic wave microsensors part II, Anal. Chem. 65 (22) (1993) 987A–996A.
[9] D.P. Morgan, A history of surface acoustic wave devices, Int. J. High Speed Electron. Syst. 10 (03) (2000) 553–602.
[10] R.V. Schmidt, F.W. Voltmer, Piezoelectric elastic surface waves in anisotropic layered media, IEEE Trans. Microw. Theory Tech. 17 (11) (1969) 920–926.
[11] B. Collet, M. Destrade, Explicit secular equations for piezoacoustic surface waves: Rayleigh modes, J. Appl. Phys. 98 (5) (2005) 054903.
[12] J.N. Sharma, M. Pal, D. Ch, Propagation characteristics of rayleigh waves in transversely isotropic piezothermoelastic materials, J. Sound Vib. 284 (1–2) (2005) 227–248.
[13] Y. Pang, J.X. Liu, Y.S. Wang, X.F. Zhao, Propagation of rayleigh-type surface waves in a transversely isotropic piezoelectric layer on a piezomagnetic half-space, J. Appl. Phys. 103 (7) (2008) 074901.
[14] B. Singh, R. Singh, Rayleigh wave in a rotating initially stressed piezoelectric half-space, J. Theoret. Appl. Mech. 43 (2) (2013) 55.
[15] S. Chaudhary, S.A. Sahu, A. Singhal, Analytic model for rayleigh wave propagation in piezoelectric layer overlaid orthotropic substratum, Acta Mech. 228 (2) (2017) 495–529.
[16] A.K. Vashishth, H. Sukhija, Coupled rayleigh waves in a 2-mm piezoelectric layer over a porous piezo-thermoelastic half-space, Acta Mech. 228 (3) (2017) 773–803.
[17] X. Cao, S. Hu, J. Liu, J. Shi, Generalized rayleigh surface waves in a piezoelectric semiconductor half space, Meccanica 54 (1) (2019) 271–281.
[18] R. Tian, G. Nie, J. Liu, E. Pan, Y. Wang, On rayleigh waves in a piezoelectric semiconductor thin film over an elastic half-space, Int. J. Mech. Sci. 204 (2021) 106565.
[19] C. Xu, P. Wei, Z. Wei, X. Guo, Rayleigh wave in layered piezoelectric semiconductor with consideration of PN junction effects, Math. Mech. Solids (2022) 10812865221133742.
[20] Y. Liu, S. Lin, Y. Li, C. Li, Y. Liang, Numerical investigation of rayleigh waves in layered composite piezoelectric structures using the SIGA-PML approach, Compos. B: Eng. 158 (2019) 230–238.
[21] D.X. Tung, Dispersion equation of rayleigh waves in transversely isotropic nonlocal piezoelastic solids half-space, Vietnam. J. Math. 41 (4) (2019) 363–371.
[22] M.D. Sharma, Propagation of generalised rayleigh wave at the surface of piezoelectric medium with arbitrary anisotropy, Z. Angew. Math. Mech. 103 (3) (2022) e202000160.
[23] C. Othmani, H. Zhang, C. Lü, Y.Q. Wang, A.R. Kamali, Orthogonal polynomial methods for modeling elastodynamic wave propagation in elastic, piezoelectric and magneto-electro-elastic composites—A review, Compos. Struct. 286 (2022) 115245.
[24] X. Cao, F. Jin, Z. Wang, On dispersion relations of rayleigh waves in a functionally graded piezoelectric material (FGPM) half-space, Acta Mech. 200 (3) (2008) 247–261.
[25] X. Cao, F. Jin, I. Jeon, Rayleigh surface wave in a piezoelectric wafer with subsurface damage, Appl. Phys. Lett. 95 (26) (2009) 261906.
[26] I.B. Salah, A. Njeh, M.H.B. Ghozlen, A theoretical study of the propagation of rayleigh waves in a functionally graded piezoelectric material (FGPM), Ultrason 52 (2) (2012) 306–314.
[27] H. Ezzin, M. Mkaoir, M.B. Amor, Rayleigh wave behavior in functionally graded magneto electro-elastic material, Superlatt. Microstruct. 112 (2017) 455–469.
[28] L. Li, P. Wei, X. Guo, Rayleigh wave on the half-space with a gradient piezoelectric layer and imperfect interface, Appl. Math. Model. 40 (19–20) (2016) 8326–8337.
[29] K. Li, S. Jing, J. Yu, X. Zhang, B. Zhang, The complex rayleigh waves in a functionally graded piezoelectric half-space: An improvement of the laguerre polynomial approach, Mater 13 (10) (2020) 2320.
[30] S. Manna, T. Anjali, Rayleigh type wave dispersion in an incompressible functionally graded orthotropic half-space loaded by a thin fluid-saturated aeolotropic porous layer, Appl. Math. Model. 83 (2020) 590–613.
[31] K. Li, S. Jing, J. Yu, B. Zhang, Complex rayleigh waves in nonhomogeneous magneto-electro elastic half-spaces, Mater 14 (4) (2021) 1011.
[32] L.E. Khaldi, M. Sanbi, Numerical analysis of the dispersion of acoustic rayleigh waves in a functionally graded piezoelectric half-space, in: MATEC Web of Conferences, Vol. 360, EDP Sciences, 2022, 00009.
[33] K. Hemalatha, S. Kumar, D. Prakash, Dispersion of rayleigh wave in a functionally graded piezoelectric layer over elastic substrate, Forces Mech. 2023, 100171.
[34] L. Zinchuk, A. Podlipenets, Dispersion equations for rayleigh waves in a piezoelectric periodically layered structure, J. Math. Sci. 103 (3) (2001) 398–403.
[35] A.K. Vashishth, P. Khurana, Rayleigh modes in anisotropic, heterogeneous poroelastic layers, J. Seismol. 9 (4) (2005) 431–448.
[36] Y.Z. Wang, F.M. Li, W.H. Huang, Y.S. Wang, The propagation and localization of rayleigh waves in disordered piezoelectric phononic crystals, J. Mech. Phys. Solids 56 (4) (2008) 1578–1590.
[37] Y.Z. Wang, F.M. Li, K. Kishimoto, Effects of the initial stress on the propagation and localization properties of rayleigh waves in randomly disordered layered piezoelectric phononic crystals, Acta Mech. 216 (1) (2011) 291–300.
[38] Z. Zhang, Z. Wen, J. Hu, Calculation of surface acoustic waves in a multilayered piezoelectric structure, J. Semicond. 34 (1) (2013) 012002.
[39] S. Mseddi, F. Tekeli, A. Njeh, W. Donner, M.H.B. Ghozlen, Effect of initial stress on the propagation behavior of saw in a layered piezoelectric structure of ZnO/Al_2O_3, Mech. Res. Commun. 76 (2016) 24–31.
[40] C. Fu, Y. Ke, A. Quan, C. Li, X. Fan, J. Ou, J. Luo, Investigation of rayleigh wave and love wave modes in $(11\bar{2}0)$ ZnO film based multilayer structure, Surf. Coat. Tech. 363 (2019) 330–337.
[41] A. Ghorbanpour Arani, M.H. Zamani, Investigation of electric field effect on size-dependent bending analysis of functionally graded porous shear and normal deformable sandwich nanoplate on silica Aerogel foundation, J. Sandw. Struct. Mater. 21 (8) (2019) 2700–2734.
[42] B. Karami, D. Shahsavari, L. Li, M. Karami, M. Janghorban, Thermal buckling of embedded sandwich piezoelectric nanoplates with functionally graded core by a nonlocal second-order shear deformation theory, Proc. Inst. Mech. Eng. C J. Mech. Eng. Sci. 233 (1) (2019) 287–301.
[43] B. Karami, M.H. Ghayesh, Vibration characteristics of sandwich microshells with porous functionally graded face sheets, Int. J. Eng. Sci. 189 (2023) 103884.
[44] P. Kumar, M. Mahanty, A. Chattopadhyay, A.K. Singh, Effect of interfacial imperfection on shear wave propagation in a piezoelectric composite structure: Wentzel–Kramers–Brillouin asymptotic approach, J. Intell. Mater. Syst. Struct. 30 (18–19) (2019) 2789–2807.
[45] C. Enzevaee, H.M. Shodja, Torsional surface wave propagation in a transversely isotropic FG substrate with piezoelectric over-layer within surface/interface theory, Acta Mech. 231 (6) (2020) 2203–2216.
[46] A. Ray, A.K. Singh, Electromechanical coupling and mass loading sensitivity of SH waves in a dielectrically imperfect piezoelectric structure, Int. J. Solids Struct. 210 (2021) 49–65.
[47] P. Alam, S. Kundu, S. Gupta, Love-type wave propagation in a hydrostatic stressed magneto-elastic transversely isotropic strip over an inhomogeneous substrate caused by a disturbance point source, J. Intell. Mater. Syst. Struct. 29 (11) (2018) 2508–2521.
[48] A.K. Singh, S. Singh, R. Kumari, A. Ray, Impact of point source and mass loading sensitivity on the propagation of an SH wave in an imperfectly bonded FGPPM layered structure, Acta Mech. 231 (6) (2020) 2603–2627.
[49] A.K. Vashishth, V. Gupta, Wave propagation in transversely isotropic porous piezoelectric materials, Int. J. Solids Struct. 46 (20) (2009) 3620–3632.
[50] B.A. Auld, Acoustic fields and waves in solids, Florida (1973).
[51] A.H. Nayfeh, Wave Propagation in Layered Anisotropic Media: with Application to Composites, Elsevier, 1995.
[52] A.K. Vashishth, V. Gupta, Reflection and transmission of plane waves from a fluid-porous piezoelectric solid interface, J. Acoust. Soc. Am. 129 (6) (2011) 3690–3701.
[53] C. Othmani, H. Zhang, C. Lü, Effects of initial stresses on guided wave propagation in multilayered PZT-4/PZT-5A composites: A polynomial expansion approach, Appl. Math. Model. 78 (2020) 148–168.
[54] I.B. Salah, A. Njeh, A Theoretical study of Propagation of Rayleigh surface waves in functionally graded piezoelectric (FGPM) half-space, IOP Conf. Ser. Mater. Sci. Eng. (2012) 012047.
[55] P.W. Zhang, J.G. Yu, X.M. Zhang, B. Zhang, Rayleigh waves in functionally graded material half-space by orthogonal polynomial method, in: Symposium on Piezoelectricity, Acoustic Waves, and Device Applications, SPAWDA, 2017, pp. 533–536.

Principal
Dyal Singh College
KARNAL

[56] W. Pytel, K. Fuławka, P. Mertuszka, B. Pałac-Walko, Validation of rayleigh wave theoretical formulation with single-station rotational records of mine tremors in lower silesian copper basin, Sensors 21 (10) (2021) 3566.
[57] J.L. Rose, Ultrasonic waves in solid media, 2014.
[58] S. Foti, Multistation methods for geotechnical characterization using surface waves, 2000.
[59] C. Hakoda, C. Pantea, V.K. Chillara, Engineering the beat phenomenon of quasi-Rayleigh waves for regions with minimal Surface Acoustic Wave (SAW) amplitude, J. Sound Vib. 515 (2021) 116444.
[60] V. Gupta, Wave propagation in porous piezoelectric materials, 2013.
[61] A.K. Vashishth, U. Bareja, Gradation and porosity's effect on love waves in a composite structure of piezoelectric layers and functionally graded porous piezoelectric material, Eur. J. Mech. A/Solids (2023) 104908.
[62] D. Royer, E. Dieulesaint, Elastic Waves in Solids I: Free and Guided Propagation, Springer, 1996.
[63] C. Othmani, Effects of initial stresses on the electromechanical coupling coefficient of SH wave propagation in multilayered PZT-5H structures, Eur. Phys. J. Plus 134 (2019) 551.
[64] A. Arora, N. Bala, The effect of composite material on Rayleigh wave at free surface of composite matrix saturated by fluids, Math. Model. Nat. Phenom. 17 (2022) 37.
[65] J. Xia, R.D. Miller, C.B. Park, Estimation of near-surface shear-wave velocity by inversion of Rayleigh waves, Geophysics 64 (3) (1999) 691–700.
[66] J. Liu, Z.K. Wang, The propagation behavior of Love waves in a functionally graded layered piezoelectric structure, Smart Mater. Struct. 14 (1) (2004) 137.

Principal
Dyal Singh College
KARNAL

21:25

iopscience.iop.org/art

physicsworld LIVE
in partnership with Reports on Progress in Physics
Sponsored by
The Electrochemical Society

IOPscience

Physica Scripta

PAPER

Reflection and transmission of ultrasonic waves in a layered structure with a functionally graded porous piezoelectric base

Anil K Vashishth[1], Umang Bareja[2,4] and Vishakha Gupta[3]

Published 20 June 2024 • © 2024 IOP Publishing Ltd

Physica Scripta, Volume 99, Number 7

Citation Anil K Vashishth *et al* 2024 *Phys. Scr.* 99 075260

DOI 10.1088/1402-4896/ad5631

Article metrics

97 Total downloads

Submit

Submit to this Journal

Permissions

Get permission to re-use this article

Share this article

Principal
Dyal Singh College
KARNAL

Article and author information

Abstract

Development of English Novel: A Historical Perspective

[1]Dinesh Kumar

Abstract

In English literature, we come across different genres: poetry, fiction, drama, short story and memoirs. As we know that literature is the mirror of society as well as our life, so is novel that projects human life in different hues and colours. Since the beginning of English literature, novel developed in one form or another. But, the reality is that English literature took a new turn and direction with the growth of fictional works. Its presence on the literary scene can be witnessed in the eighteenth century when Daniel Defoe and Jonathan Swift showed their interest in novel writing. With the rise of the "four wheels" in English literature, novel as a genre was liked and constantly read by reading public in England. Richardson started writing novel with his famous work, *Pamela*, or Virtue Rewarded in which he dealt with the idea of morality. Henry Fielding, who is known as the father of English novel, wrote parody of Pamela through his small pamphlet, *Shamela* which, later on, it came to forefront with his masterpiece, *Joseph Andrews*.

Keywords: Fiction, reality, rise, growth, society, literature.

Corresponding author

Assistant Professor, Department of English, Dyal Singh College, Karnal email dineshkarnal1@gmail.com

Introduction

Novel as a literary genre gained currency in the eighteenth century, but its genesis and origin can be traced back to 612 B.C. During this time, *Epic of Gilgamesh* came into existence. Homer, a notable Epic writer, produced *Iliad*, and *Odyssey* during his time period from 700 BC to 800 B.C. He started writing epic, a long narrative dealing with serious subject-matter. Treading the footprints of Homer, Virgil wrote *Aeneid* which was followed by John Milton who wrote *Paradise Lost* in ten books, followed by the eleventh book, *Paradise Regained*.

Principal
Dyal Singh College
KARNAL

After epics were practiced by a number of literary men, in the 12th century writing of romances gained popularity. It was also called chivalric romance flourished between1000 A.D. to 1450 A.D. The writers during this period shifted their interest from Epic writing to deal with the subjects like bravery, honour, adventure and courtly love. They also assimilated some features like magic, spell, necromancy and enchantment to change the interests and eagerness of the readers. Malory's Morte d'Arthur (1470) is an illustration of chivalric life centred on King Arthur's legend.

Geoffrey Chaucer's *The Canterbury Tales* is written both in poetry and prose. It embodies 24 stories. Besides, he also wrote *Troilus and Criseyde*. It is remarkable for its socio-religious aspects of life instead of farfetched reality of romances as done by his predecessors. Boccaccio's *Decameron* started the tradition of prose tales of amorous adventure before Malory and Chaucer.

With advent of new literary style, Burlesque, the popularity of romances was still in fashion till 1600. *Don Quixote* by Miguel de Cervantes has been written to mock at the seriousness of chivalric romances. It also illustrates a new type of fiction- picaresque novel which started with the publication of Lazarillo de Tormes. Picaresque tradition was a source of inspiration for the writers to come in subsequent centuries which is evident through the writing of Mark Twain (*Huckleburry Finn*), and Saul Bellow (*The Adventures of Augie March*)

In the sixteenth century, Aphra Behn wrote *Oroonoko*, or *The History of the Royal Slave*. The main thematic concerns and ideas of the novel are encouraged by the quest of adventures life by knights who search love of a beautiful lady. John Bunyan also wrote *Pilgrim's Progress*, a religious allegory based on the pilgrimage of Christians. With its compact plot, art of characterization and narrative strategy followed by the writer, *Pilgrim Progress* is a model for the future generation of writers

The eighteenth century is generally known as the age of prose and reason. This century saw emergence of two important genres-novel and periodical essay. In fact, periodical essay came into existence as a mini rehearsal of novel writing. Many reasons contributed in making the periodical essay popular-rise of the middle-class, faithful mirror of the society, reflection of the temper of the age, appeal to women, avoidance of religious and political controversies, interest in trade and commerce, decline of drama, readymade material, rise of common people and, last but not the least, no cramping limitation of classicism. Addison and Steele, pioneer of periodical essay gave a new direction to periodical essay by introducing an element of realism

Principal
Dyal Singh College
KARNAL

of the contemporary age.

The real beginning of novel in England took place in eighteenth century with the emergence of Daniel Defoe as a novelist who dealt with the stories of adventures in his works *Robinson Crusoe, Moll Flanders, Roxana,* and *Plague.* His main focus was on the story rather on characterization. His narrative strategy was the main strength of his works.

In this way, the eighteenth-century novel before the four wheels, rejected characterization. It paved the way for a new type of novel-domestic novel practiced by Oliver Goldsmith as is evident through his work, *The Vicar of Wakefield.* The rise of novel in the eighteenth century was the direct result of industrial revolution, decline of romance and drama, rise of the middle class. Moreover, the efforts of four wheels Samuel Richardson, Henry Fielding, Laurence Sterne and Tobias Smollett were very instrumental in lifting novel to the glorious heights. Through his novel, Pamela, or *Virtue Rewarded,* Richardson introduced a new form of fiction, epistolary novel written in letter form. The present book focuses readers' attention on the concept of morality through its female protagonist, Pamela. Richardson's chief contribution lies in the field of plot-construction, the sentimental note, morality, allegorical method and characterization.

The weaknesses left behind Richardson in his works were improved by Henry Fielding. Although popular as a dramatist in his early career, he provided new height and gravity to English fiction through his masterpieces-*Tom Jones, Joseph Andrews, Jonathan Wild,* and *Amelia.* His fictional works are marked by realism, morality, characterization and artistic craftsmanship. As a parody of Richardson's *Pamela,* he wrote a small pamphlet, *Shamela* which was, later on, produced as a novel, *Joseph Andrews.* Fielding's contribution in the field of realism, humour and irony, common sense morality and plot-construction cannot be underestimated.

Laurence Sterne, discarding the conventional style of novel writing, practiced a different type of novel, known as the novel of impressionism. He is primarily known for his two masterpieces- *The Life and Opinion of Tristram Shandy,* Gentlemen, and *Sentimental Journey.* His main focus in his works is on subtlety of humour, sentimentalism, impressionism and style.

Besides, the contribution of female authors was also equally important and noteworthy. For the first time, the readers came across a galaxy of female novelists- Sarah Fielding, Hanna More, Fanny Burney, Maria Edgeworth, Susan Ferrier, Miss Mary Russell Mitford and Mrs. Radcliffe wrote with same enthusiasm, vigour and

Principal
Dyal Singh College
KARNAL

zeal as the male novelists did.

In addition to it, the Gothic novelists Horace Walpole, Mrs. Ann Radcliffe, Matthew Gregory Lewis, Charles Robert Maturin, Robert Bage, Clara Reeve and Mary Shelley tried to create an atmosphere of horror and terror which was one of the main tendencies of Gothic fiction. Gothic novel is also known as the novel of terror. Contrary to the realistic novel cultivated by Daniel Defoe and Henry Fielding, the gothic novelists introduced romantic spirit focusing on farfetched imagination.

A new type of the novel, the novel of manners, got popular with the advent of Jane Austen on the literary scene. The cult of feeling and emotion during the romantic age resulted into the novel of sensibility as can be seen through her novels-*Pride and Prejudice, Mansfield Park and Sense, and Sensibility.* Historical novel, a term used by Walter Scott for his novels, was popular as can be witnessed through his works *Ivanhoe, Old Mortality, Talisman,* and *The Heart of Midlothian.*

The novel during the Victorian period was a social force that honestly reflected the social condition of the age. Thomas Hardy, George Meredith, W.M. Thackeray and Charles Dickens depicted the realistic picture of the age acting as the social reformers. Besides, the contribution of female authors George Eliot, Elizabeth Gaskell, Charlotte Brontë and Emily Brontë is also prominent and significant. These female novelists brought glory and laurel to Victorian fiction. Hardy practiced a new type of genre-regional novel as he depicts a faithful and authentic environment of Wessex region in his woks *The Mayor of Casterbridge, Jude the Obscure,* and *Far From the Madding Crowd.*

Among the modern novelists, we come across a galaxy of fiction writers: James Joyce, Joseph Conrad, D.H. Lawrence, Virginia Woolf, Franz Kafka, Albert Camus, H.G. Wells, Henry James, Rudyard Kipling, E.M. Forster and Aldous Huxley are worthy of detailed consideration. The stream of consciousness novel and psychological novel is the product of modern age. The impact of Carl Jung, Sigmund Freud and Friedrich Nietzsche can be seen on the modern fiction.

Among the diverse tendencies of modern novel can be included the art form of fiction. It was a significant form of fiction writing during the modern period. The twentieth century fiction writers discarded the moralising sentiments and irrelevances of great Victorian writers. The compactness and well-knit plot of modern novelists are an advantage on the rambling and lose plot of Victorian writers.

In fact, modern novel has few frills, few redundancies, it is more like a well-cut

Principal
Dyal Singh College
KARNAL

garden then an opulent tropical Jungle which the novel undoubtedly was in the hands of Charles Dickens and W.M. Thackeray.

During the early years of the twentieth century, the modern novelists were preoccupied with the problems related to social life. During the Edwardian period, the novelists dealt with the novel of ideas in every walk of life-social, political, industrial, and scientific and so on. Being the true Edwardian, H.G. Wells, Galsworthy, Arnold Bennet threw light on the social issues of the contemporary period. In this way, the novel appeared to be a mean of social propaganda.

In other words, they had a specific purpose and mission in their minds while writing novel. They focused primary on social and domestic problems coupled with problems arising out of ups and downs of life. In the words of H.G. Wells, one finds a perfervid articulation of Edwardian novel when he says: "a novel is in essence a discursive thing, a waxen tapestry multifarious interest sufficiently elastic in form to take the whole of life within its compass-business, finance and politics, till it becomes a proper medium for canvassing all social and political problems as they are." In their works, the Edwardians manifested problems of middle and upper middle class as they were also the product of the same environment.

H.G. Wells' works-*John and Peter,* and *The History of Mr. Polly* are powerful illustration of the evils associated with education system. In the field of education, he tried to bring social reforms. Besides, his work, *Tono-Bungay* is a scathing indictment of modern commercial practices as well as fraudulent advertisement. In addition to it, his work, *Kipps* is a powerful exploration of the issues related to servant employed in business houses. The struggle between materialism, philistinism and cultural values is the key-concern in Galsworthy's novel, *The Forsyte Saga.*

Realism is the keynote of modern fiction. The two world wars change the ideology of the contemporary novelists. H.G. Wells treading the footprints of Dickens and Thackeray realistically delineated the misery and predicaments in his novel *Kipps,* and *Mr. Polly.* In George Moore's fiction, one finds the realistic portrayal of lower sections of the society as is evident through his works, *A modern Lover,* and *A Mummer's Wife. Esther Waters* that depict the ugly and unpleasant side of the poor masses in a compassionate manner. In George Gissing's works, we come across pathetic life lived by lower strata of people.

His works *Thyrza, The Nether World, Grub Street,* and *Private Papers of Henry Ryecroft* are the powerful exploration of life lived by downtrodden people. Arnold

Principal
Dyal Singh College
KARNAL

Bennet's *The Old Wives*, and *Clayhanger* are beautiful illustration of life lived in five towns. Deflecting from the romanticism, the central concern of his works is the sordid and unpleasant life of individuals. In order to reflect a faithful and authentic picture of the five towns, he has minutely focused on objective analysis of these towns.

As the twentieth century was an age of realism coupled with the social problems of the age, one finds in this age the announcement of materialism and inclination and adventure the note of disappointment against the religion in the works of authors. The despair and disillusionment against modern realism in novel and excessive focus on materialistic values was beautifully expressed by the writers of the age- Dorothy Richardson, Virginia Woolf, Somerset Maugham, Samuel Butler and E.M Forster. Their works are replete with the realistic portrayal of absurdity of life. Butler's *Erewhon* is a satirical exposure of the modern tendencies in modern period.

The despair and immortality of the age find its powerful expression in Aldous Huxley's *Yellow Chrome. Those Barren Leaves* is a condemnation of sordid and ugliness of the age. *E.M. Forster's Howard End is scathing* attack on the materialistic tendencies of the age in the mechanised world of England. Condemning the Edwardian realism, Virginia Woolf has rightly and aptly remarked: "it is because they are spirit but with the body that they have disappointed us and left us with the feelings the sooner English fiction turns. It back upon them, as politely as maybe, as marches, is only into the desert, the better for its soul."

Joseph Conrad has dealt with a new type of novel in his works as he delineates the scenes of jungle as is evident through his works, *The Nigger of Narcissus, Lord Jim*, rescue, and *Jim and River*. He has beautifully portrayed the adventurous life of sea full of election and infused with struggle, adventure and odor of romantic adventure.

The glorification of sex, human emotions and passions as a new tendency was the product of modern novel. During the Victorian period, there were excessive checks and hindrances on sex and love. They favoured exalted married love over illegal flirtation. All this find a blow in the Georgian novel as many of the Georgian novelists delineated sex-relationship in their works. Among these, Aldous Huxley, D.H. Lawrence, Somerset Maugham and James Joyce are worthy of detailed consideration. D.H. Lawrence's novels *Sons and Lovers, Women in Love, The White Peacock*, and The Rainbow are powerful illustration of the idea of love and sex.

Principal
Dyal Singh College
KARNAL

The influence of psychological theories propounded by Sigmund Freud and Friedrich Nietzsche can be witnessed on modern writers. As a new technique, stream of consciousness technique was popularised by William James, Dorothy Richardson, James Joyce and Virginia Woolf. Virginia Woolf's To *the Lighthouse*, and *Mrs. Dalloway*, James Joyce's *A Portrait of Artist as a Young Man*, and *Ulysses* are imbued with stream of consciousness technique.

Science fiction is also a new trend in novel writing during the modern age. Closely connected with the psychological novel in modern age is the new tendency called scientific novel. As a new type of genre, science fiction has opened the new ways of ideas and imagination to be reflected in fiction. The novels by H.G. Wells *The Invisible Man*, and *The Time Machine* are full of scientific love. *Brave New World* by Aldous Huxley is also an epitome of scientific outlook.

Detective fiction is also one of the popular forms of novel that emerged during the modern period. This tendency of fiction was popularised by Arthur Conan Doyle in his work *The Adventures of Sherlock Holmes*. This type of fiction was further popularised by G.K. Chesterton, Edgar Wallace, Agatha Christie and Dorothy Sayers.

Regional novel, one of the popular forms of fiction, can be seen flourishing during te modern age. Among the regional novelists of the age Thomas Hardy and Arnold Bennet are the chief exponents in this type of fiction. Arnold Bennet's *Old Wives' Tales*, and *Clayhanger series* are the prominent and significant works that can be labeled as regional novel.

Biographical novel, one of the important type of novels, emerged during the modern period. This type of fiction concentrated on family life that won recognition during the modern period. Among the biographical fiction, we can quote the example of *The World of William Clissold*, *The Forsyte Saga*, and *Clayhanger* which are representative and significant works in this direction.

In this way, a close and incisive study of the growth of novel reflects that it had been a powerful genre to depict the reality in every age.

Acknowledgement

The authors are thankful to the anonymous referees of the journal for their handy suggestions to improve the quality of the article.

Declaration of Conflict of Interest

Principal
Dyal Singh College
KARNAL

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

References

1 .Abrams, M.H. A Glossary of Literary Terms. Madras: Macmillan India Limited, 1978.

2. Albert, E. History of English Literature. New Delhi: Oxford University Press, 1979.

3. Compton-Rickett, A. A History of English Literature. New Delhi: UPS, 1995.

4. Kettle, A. An Introduction to the English Novel. New Delhi: Universal Book Stall, 1967.

5. Rajimwale, S. A History of English Literature. New Delhi: Rama Brothers, 2004.

6. Rees, R.J. English Literature: An Introduction for Foreign Readers. Delhi: Macmillan India Limited, 1973.

7. Sanders, A. The Short Oxford History of English Literature. New Delhi: Oxford University Press, 1994.

Principal
Dyal Singh College
KARNAL

INTERDISCIPLINARY JOURNAL OF AFRICAN & ASIAN STUDIES (IJAAS) VOL. 9 NO. 3, 2023 (ISSN: 2504-8694).
Indexed in Google Scholar (Email: ijaasng@gmail.com) Nnamdi Azikiwe University, Awka, Nigeria

Conflict Between Culture and Identity in Derek Walcott's *A Far Cry in Africa*: A Critical Assessment

Dinesh Kumar
Assistant Professor of English
Dyal Singh College
Karnal
dineshkarnal1@gmail.com

Abstract
It is beyond doubts that Derek Walcott's *A Far Cry from Africa* is not only a brilliant exposition of the imbalance relationship between the colonizer and the colonized, but also the portrayal of the pains and agonies of a man who is torn between two cultures. The poem deals with the question of the conflict of the identity he goes through due to his state of in-betweenness. Throughout the poem, he continues searching his identity, but at the end, he remains a bewildered and enigmatic personality as he finally confesses his love for the English language as well as for his origin. In other words, the idea that pervades the entire poem is the conflict of culture and identity, from where the poet finds no way out.
Keywords: Origin, In-betweenness, Dilemma, Culture, identity, hybridity

Introduction

Derek Walcott is a famous poet and playwright born on the island of St. Lucia, a former British Colony in West Indies. The present poem, *A Far Cry from Africa* is a powerful exploration of the socio-political and epistemological implications of post-colonialism. It is a painful and agonized expression of the poet's own state of mind who feels himself torn between two cultures. It is a well-known fact that Walcott was the product of mixed heritage or cultures. Walcott has both African and European roots; his grandmothers belonged to black race and both grandfathers were white.

The present poem is a powerful illustration of the time during which the poet's country of birth St. Lucia was still a colony of Great Britain. The poem throws ample light on Walcott's opposition of colonialism and therefore, he seems to be kind and considerate to a revolution with an anti-colonial cause. He not only found insurgence of Mau Mau movement as extremely exploitive-not only to animals and whites, but also this terrorist organisation to the Mau Mau cause.

There is no doubt in denying the fact that of *A Far Cry for Africa* by Derek Walcott is an exposition of the poet's dilemma of colonialism. It is an authentic and honest delineation of the speaker's predicaments of painful legacy between the colonizers and the colonized. At the same time, it also focuses on the Mau Mau rebellion that occurred in the mid twentieth century when African Kenyan struggled hard for freedom against the British colonial rule.

Analysis on Culture Conflict and Identity in Derek Walcott's *A Far Cry in Africa*: A Critical Assessment

The narrator of the poem is very much conscious of his bonding to both Africa and England, and he seems to be perplexed how to explain the violence of this conflict. As the speaker identifies himself with the poet Walcott, he is painfully divided even among the African colonists in his connection with English. So, what the poem vividly and graphically represent is totally misguided identity, and it seems a bit alarming because colonialism is an element tha exercises a firm control over the veins of painful legacy.

Principal
Dyal Singh College
KARNAL

At the same time, the poet continues to search his true identity as he, despite of his love for the English language, cannot embrace of the culture of the colonizer and, consequently, attempts to came at a point when he describes the conflict within himself by blaming his state of in betweeness when he asserts:

I who am poisoned with the blood of both

Where shall I turn, divided to the vein?(11)

The title of the poem is symbolic of the narrator's cultural instability. The above cited lines reflect how the poet believes that he is cursed because of his mixed race. In the title of the poem, the readers perceive an ambiguity as the title of the poem, *A For Cry from Africa* connotes two meanings-at one level, it suggests that the real state of Africa is far away from what we have read in descriptions of the fascinating flora and fauna, while the title can be read on a different level putting forward that the unsuccessful attempt to write about African from a distance, but the poet himself experiences challenges in writing a culture that he is factually far from

Walcott has graphically used various metaphors and sarcastic statements in order to manifest critics of the cruel and damaging nature of both African and European cultures as is evident through the following lines

Only the worms, Colonel of carrion cries:
"Waste no compassion on these separate dead!(11)

Here, the poet blames the British because of their imperialistic technique to control the native culture (African) devoid of any sympathy and compassion. Through the above quoted lines, the poet shatters the image of a paradise that many associate with Africa by describing a landscape littered with corpses. The poet, further, adds a sickening detail by referring to a worm or maggot that reigns in this setting of decaying human flesh. The worm's admonishment 'to waste no compassion on the separate dead' is very complex and puzzling as it is an implication of the victims somehow got what they deserved.

In other words, Walcott tries to hold both the cultures responsible without showing any kind of discrimination either towards Africa or towards British. In the lines quoted above, the poet blames the British for their imperialistic ways to grasp the culture of the natives, but without creating compassion and kindness towards the colonized.

Bharatender Sheron, in his well-known article, "A Dilemma of Caribbean Populace: Post Colonial and Identity Crisis in Derek Walcott's Play" explores the postcolonial concerns dealing with dual identity and culture which, as a problematic legacy of colonialism, affects postcolonial people.

In this diversity and hybridity, the colonisers have lost their original selves. Those, once colonized are multicultural people, and colonized cultures cannot be considered pure, rather they are heterogeneous cultures. Colonialism, even though it is said to have ended, has left its traces in the postcolonial age making the people a mixture of Western and indigenous qualities.

Principal
Dyal Singh College
KARNAL

INTERDISCIPLINARY JOURNAL OF AFRICAN & ASIAN STUDIES (IJAAS) VOL. 9 NO. 3, 2023 (ISSN: 2504-8694)
Indexed in Google Scholar (Email: ijaasng@gmail.com) Nnamdi Azikiwe University, Awka, Nigeria

Derek Walcott, being a postcolonial writer, has used in *A Far Cry from Africa* the advantages of hybridity to illustrate unhomliness by describing himself as a 'mongrel'. He hates the English culture, but loved the English language and emphasized with the Irish for they were also the victims of colonization as he assets while dealing with his own identity: "I am a kind of split writer, I have one tradition inside me going in one way, and another going another." *A Far Cry from Africa* is an attempt by the poet that does not provide him any way out to solve the problem of his hybrid inheritance as he has propounded efficiently in the present poem.

In this way, the idea of Identity crisis lies at the centre of the poem, but this search for identity is more complex with the progression of ideas in poem. The poet, in his ambiguous state, is not left with any option. Inspite of the diverse questions, Walcott asks:

How to choose between this Africa
And English tongue I love(11)

Being an admirer of both cultures, the poet does not know answer to this question which indicates that the poet chooses to remain an African partially in his way of life, but he prefers English language and literary tradition which resemble the colonizers.

The pull that both cultures have for Walcott results into a considerable conflict and tension with the progression of the poem. The poet's divided loyalty and devotion create a sense in him not to accept and appreciate a culture of his own but, on the other hand, he admits the civilized side of British culture. This is also an exposition of Walcott's efforts to acknowledge the faults of both African and British cultures without the depiction of any form of biasness.

Walcott's mixed identity and existence between the two cultures portrays him with the scope to pull apart the wickedness of both the cultures- colonized and colonized. In this way, the idea of post colonialism is generally concerned with the double identity where the colonised lost their original selves and the coloniser's culture is imposed on them. The fragmented and divided identity of the poet is the direct result of the idea that Indigenous people are empty of compatible identity.

This also brings to the light that they are uncertain of who exactly they are and where they belong. It is a fact that Indigenous people are embodiment of both traits-Western culture and native culture, and hence, they are in between therefore, the colonised cultures are never considered pure and real, but manifests multicultural features with mixed cultures.

It is a fact that the poet shows his inclination towards African culture. The main reason behind it is that they have been colonised and he cannot turn his back from their miseries, sufferings and predicaments. It also reflects the poet's compassion and sympathy for those who are oppressed and humiliated. This is evident through the following lines when the poet points or asks a question:

How can I turn from Africa and live?(12)

The above quoted lines reflect Walcott's strong inclination towards the nature African who are tortured and exploited mercilessly by the colonizers. The poet's sympathy lies with the fellow beings who are deprived of equality in all spheres of life-social, cultural, political and economical.

Principal
Dyal Singh College
KARNAL

The last two lines of the poem, *A Far Cry from Africa* are realistic portrayal of the poet's present situation as he is torn apart between both the cultures. He feels inferiority regarding the situation. This perplexed state of mind is the direct result outcome of his mixed hybridity that enables him to decide to which he should be partial.

Although it is a fact that there is an end of colonialism, but still there are some features and significant elements left during the postcoloanism that delineate colonised culture as a bending of Western and native qualities. Walcott's use of the phrase 'mixed blood' is a demonstration of his mixed identity is time and again haunting him. He does not he recognise the cruel done to African by the British claiming to civilize them.

The line 'I who am poisoned with the blood of both with where I shall turn divide to the vein' is a reflection of the poet's psyche. It manifests the poet's sensibility and sensitivity to avoid hypocrisy. Colonial history has given him a mixed blood. It has forged in many Africans, like him, peculiar relationship with England and its white people. He is bold and frank enough to say that his compassion extends to the stupidity of the whites and the waste of the blacks. The compassion reaches the colonisers' language English.

The word 'poisoned' conveys powerful idea of provoking the Mau Mau rebellion in the narrator's mind. Being the product of both cultures-European and African, meaning descendants of either side- his blood feel poisonous connecting the speaker to violence no matter it would be.

This tradition also makes the poet poisonous as he finds him divided into veins. It is evident through this twist that half of the speaker's blood is half violent. That is the main reason why the poet thinks the present poem as personal and even physically divided by composing this conflict. For the speaker, this is not a matter of abstract politics, but truly intimate struggle that has taken place within him struggle over the legacy of colonialism. In this way, colonial history has compelled the speaker divided by colonised and colonizers.

The poet endures his search to establish his true identity and uses phrase including 'poison' to support the conviction that his mixed identity haunts him. It also develops a certain level of guiltiness for failing to trace his origin. He feels being alienated and deportation despite him expressing his love and passion for English and technology; he cannot clap to his bosom the culture of the colonizer, similarly he cannot fully associate himself with the culture of 'darkness'. Consequently, he grapples with the question of identity and the conflict within himself by excusing sense of in-betweeness.

The last six lines are a powerful dramatization that portrays Walcott's confusion more vividly and graphically in his essay "The Muse of History" where he says: "most Black writers cripple themselves by this separatism. You cannot be apart and believe in the division of man." (*The Muse of History*, 12)In fact, here we witness a shift in the author's viewpoint as he deals with the changed scene, that is, of Africa. Being torn between two cultures, the poet is unable to decide and feel about the Mau Mau struggle as he is not convinced with the multiple responses of those from the outside. Walcott is depressed and disillusioned by the behaviour of Mau Mau rebellion just as he has been disappointed by the British.

The pessimistic ending of the poem with the line:
'How can I face such slaughter and be cool?' is suggestive of his contemplation being an alien because of his mixed identity which is the chief reason of his sense of isolation, alienation,

Principal
Dyal Singh College
KARNAL

detachment and devolution. It is a fact that culture effects play a significant role in confirming the identity of an individual's character by a particular society's values.

Due to this fact, Walcott's doubts are obvious as he suspects and doubts towards both cultures-Africa and British that make him confess in typical function of victorious and conquered. Although, he criticizes the cruel regime of England for its imperialistic domination, but he does not show sympathy and consideration for his African kinsmen. This is perhaps it is the main reason why he failed to identify his true identity.

Another challenge encountered by the poet in the present poem is to express his agonising circumstances. The main reason behind it is that it is often very challenging to express black man's pain in Whiteman's arguments. The poet is perplexed as he thinks whether he will be safeguarding the middle of his fellow Africans using colonialist language due to his protracted detachment from the African culture. In that sense, the poem is an honest expression of the struggle for identity that the poet is fighting. His name symbolises the culture of the colonizers, while his injured dark body allegorises their brutality.

In this way, this dilemma concerning his double identity continuous till the end of the poem as he finds himself perplexed whether to betray both ore to opt for one-Africa or England, but eventually his Love for Africa wins over his identification with the English and through rhetorical questions, he makes his clear alliance with Africa when he says:

> How can I face such slaughter and be cool?
> How can I turn from Africa and live? (12)

It reflects the poet's deep rooted affiliation and harmony as he is not able to tolerate the exploitation and maltreatment meted out to the Africans. Also, it delineates the poet's endless struggle with his attraction to advancement and technology inherited in the British culture coupled with his ironic longing for the African culture.

Conclusion

In this way, after making a close and incisive study of Derek Walcott's poem, *A Far Cry from Africa*, we can safely and rightly aver the fact that the poet identifies the characteristics of the culture that he admires the most. He desires the 'African terrain lifestyle and favours the English language and literary tradition.' According to the poet, both cultures have specific elements that attract him that prolongs the poem, and at the end, he has not found any solution to resolve his bewilderment. He opines that his divided loyalties troubles him and desires that he embraces the civilized British culture, however, he cannot confirm their cruelty towards the Africans.

Works cited:

1.Ashcroft, B Griffiths, G, & Tiffin, H. *The Post-colonial Studies Reader*. Which city: Taylor & Francis, 2006.
2.Birbalsingh, F. "The West Indies": The Commonwealth Novel Since 1960 . London: Palgrave Macmillan, 1991.
3.Chamberlin, J. E. *Come Back to Me My Language: Poetry and the West Indies*. Which city: University of Illinois Press, 1993.
4.Fanon, F. *The Wretched of the Earth*. NewYork: Grove, 1961.

Principal
Dyal Singh College
KARNAL

5.Walcott, Derek. "A Far Cry from Africa." *The Norton Anthology of Poetry*.
6.Margaret Ferguson, Mary Jo Salter, and Jon Stallworthy. New York: W.W. Norton & Company, 1996.
7.Margaret Ferguson, Mary Jo Salter, and Jon Stallworthy. New York: W.W. Norton & Company, 1996.
8. Walcott, Derek. *Collected Poems 1948-1984*. London: Faber and Faber, 1986.
9.Baugh, Edward. *Derek Walcott*. Cambridge: Cambridge University Press, 2006.
10.Cumber Dance, Daryl. *Fifty Caribbean Writers: A Bio- bibliographical Critical Sourcebook*. New York: Greenwood Press, 1986.
11.Walcott's Oevre", *Neruda, Walcott and Atwood Poets of The Americas, Ajanta Dutt*, Delhi: Worldview Publications, 2002.
12.Rei Terada. ""The Pain of History Words Contain": *Walcott and Creole Poetics", Neruda, Walcott and Atwood Poets of The Americas, Ajanta Dutt*. Delhi: Worldview Publications, 2002.

Principal
Dyal Singh College
KARNAL

Ad Litteram: An English Journal of International Literati
(A Peer-Reviewed Open Access Refereed Annual e-Journal)
December 2023: Volume 8 ISSN: 2456 6624

Reconsidering Feminism in Indian Cinema: A Critical Perspective

Dinesh Kumar
Associate Professor of English
Dyal Singh College, Karnal
Email. Id. Dineshkarnal1@gamail.com.

Abstract: In most of the societies, men are considered to be the bread winner of the family. On the other hand, the female is confined to the four walls of their houses-be there the walls of their family, parents, husband or somewhere else, they are marginalised and subjugated. They are supposed to play the role of bearing children and working for the welfare of the family. This image of women can be seen in a male chauvinistic world where strict patriarchal norms are followed by the conservative and stereotyped people. But, with the passage of time, the role of female has been changed drastically as the modernisation of the world has brought a sea-change in the traditional image of women all over the world. Cinema, like literature, is the reflection of society where we across the contemporary reality reflected through movies. Indian Cinema has also presented changes in the women's image from time to time.

Keywords: Feminism, Patriarchal, Domination, Transformation, Cinema.

It is commonly believed that the term feminism is used to propound social, political, cultural and economic movement at establishing gender, justice, equality and legal rights and protection for the vulnerable sections of society. Feminists around the world radically and strongly raised voice(s) and question against all kinds of oppression, exploitation and injustice. They have attempted to change and alter the pervasive order to create a healthy egalitarian and progressive environment for the betterment and holistic growth of men and women together.

Principal
Dyal Singh College
KARNAL

Feminism, on the whole, is all about the advocacy of women's rights on the ground of the equality of sexes.

Literature is the reflection of society, and so are the movies that play a significant role in exposing the contemporary reality as it is done by literature. In the recent years, there is a transformation in the role of women as projected by Indian cinema, but mostly the field of movies has been neglected by the society. In the contemporary and traditional movies, the females have been depicted as independent, confined, confident and career oriented. As films are the reflection of social milieu prevailing around us, so in the present paper, an attempt has been made to link the changing roles played by women in movies with the contemporary situation of women in India. There is no denying the fact that the Hindi movies are generally male centric. There is also a little space for females to grow as an independent character like males. Consequently, the role of female characters in Bollywood has been reduced to only spectacle with pretty faces objectified for their beauty. This change is a bit slow as we find the characters in Indian movies still playing their roles to attract the attention of accomplished males.

The most frequent examples of this notion can be witness in the movies *Singham*, *Dabaang*, *Gajini*, and Agneepath which are, more or less, male oriented and the female are merely the symbol of physical beauty and sensuality. No doubt, females are equally talented and full of merits, but they rules are restricted to in smaller and more respective roles. In English literature where the females' role is projected as inferior, the females in Hindi cinema, too, have been portrayed in uni-dimensional characters-either good or bad, white or black, but the audience does not find any in between shade. In Hindi cinema, we can witness the role of women according to patriarchal norms followed by different sections of the society. The women, who

Principal
Dyal Singh College
KARNAL

were given the status of goddesses in ancient period, are also the key-concerns of some of the movies in Hindi cinema. In Bollywood, we find that many films inspired to a large extent from religion and mythology whereby the female characters were witnessed as the epitome of virtue and values, those who could do no wrong.

The early focus of the Indian cinema was on mythological stories and great Epic such as Raja Harishchandra depicted by Dada Sahab Falke in his productions. During the Indian freedom struggle, the movies were based on to reflect anger and voice of the nationalist leaders and parties raising their voice for the freedom of India. After the independence, some movies have also projected the partition event to show how communal frenzy between the two nations was the root cause of displacement and migration of millions of people in India as well as Pakistan. It also reflected some of the contemporary social problems rampant in the society-poverty and hunger. We find that projection of the society was both desired and achievable through films.

The time period between 1950s and 1970s is generally hailed as the golden period in the history of Indian cinema when we come across the depiction of rural, but very rich and vibrant traditions of Indian society. Poverty was one of the significant issues and subject-matters of the movies which appealed the audience as it was their own state of existence depicted by the Indian cinema. In this regard, the movies like *Kagaj ke Phool, Mother India, Pakeeza, Padosan* and *Half-Ticket* are worthy of detailed consideration. But, at the same time, another aspect, the feministic concerns, also emerged in Indian cinema with the movie *Mother India* by Mehboob in 1957. During this phase of Bollywood, the women were playing a significant role in movies by taking responsibility on their shoulders for the promotion of movies in the market. That was the main reason why females were assigned equally dominated role along with male actors. In

Mother India, Mehboob has tried to synthesize socialistic aspects with the conventional ideals in the Indian society.

Mother India is a powerful castigation of feminine issues as it revolves around the character of Radha played by Nargis who is the wife of Shamoo (Rajkumar). When she comes to her in laws family, she finds that Sundar Chachi (Shamoo's mother) has pawned her family land in order to pay for wedding. Sukhi Lala, the money-lender, of the village, collects three-fourth of their produce as interest on the loan of 500 rupee. In this way, most of their crop goes into the hands of Sukhi Lala as an interest. The main reason behind it is that Sundar Chachi is not educated and she does not know how to read. Sukhi Lala takes her thumbprint on the papers which she does not know how to read. Shamoo, the only breadwinner of the family, gets one of the boulders rolls on his arm which had to amputate and very soon dies. Radha is all alone and the life for her is a big challenge after Shamoo's death, Sundar Chachi also dies. Later on, Radha's two out of four sons die in a flood, and, life becomes very hard and difficult for her. In these adverse circumstances, Radha reminds us of Rukmini, the central character of *Nectarina Sieve* who struggles against the heavy odds of life-first against the draught and then against flood. These natural calamities coupled with the loss of her husband and mother-in-law make Radha's life very challenging and hard.

Sukhi Lala wants to take undue advantage of Radha's present situation by offering food in return for sexual favour. Radha resists against these humiliations for a long time, but finding no alternate to solve the food problem and, ultimately, she decides to submit to Sukhi Lala's temptations as her family is starving. But internally she gets a divine signal that her husband is alive, she masters enough courage and stands up with a new hope and courage. She works in her

Principal
Dyal Singh College
KARNAL

fields to repay the money of Sukhi Lala.

In the next part of the film, Birjoo (Sunil Dutt) and Shamoo (Rajendra Kumar) are projected as Youngman. Shamoo has been delineated as a responsible person, whereas Birjoo does nothing and tries to show his resentment why Sukhi Lala was taking three fourth of their harvest and production. Birjoo has been portrayed as a person who does not have any control over his anger and finally, turns into a dacoit. He threatens to abduct Sukhi Lala's daughter when she is getting married to some other person. But Radha assures Sukhi Lala to protect his daughter's honour as it is the honour of the whole village and she shoots Birjoo dead when he tries to seduce Sukhi Lala's daughter. The film opens with Radha as an old woman who is asked to inaugurate a new canal in her village. The villagers do not want anyone else to inaugurate this canal. She has been presented as a supervisor and her love can be compared to divine love. Radha's ploughing in the fields with an expression of pain and concentration is an image of an Indian woman that still survives in the mind of every Indian. The song accompanying the scene nullifies the contradiction between the socialist working women and the traditional Indian women.

The movie also highlights how laaj is the only dharma of Indian women as depicted through Radha's character. This movie also throws light on the fact that a woman can carry these accepting beliefs as a part of her condition and can make use of them as a part of the positive ethic of fighting against adverse circumstances. In the 1980s, the role of women changed drastically in the Indian cinema as it was the beginning of a new era of changes in the concept of females' identity in Bollywood. During this period, the women were reduced to being a glamorous element of the film dancing away trees and kidnapped, raped and killed.

Principal
Dyal Singh College
KARNAL

Ketan Mehta's movie, *Mirch Masala* (1989) is a brilliant example of such cinematic productions. It reflects the change of role of females in Bollywood in which Sonabi, (Smita Patil) works in a chili factory during the pre-independence era in the Western part. Her husband leaves for city as he gets job in railway department. The Subedar (Naseeruddin Shah) arrives in the village to collect taxes and caught Sonabi's attention. He asks the village headman, the Mukhi, to bring her but the headman brings a wrong women. Sonabi, next day, is stopped by Subedar while she is passing by the Subedar's camp. She tries to free herself and runs towards the chilli factory where a Muslim watchman, Abu Miyan (Om Puri) protects her and giver her shelter as well. There is also a parallel track where Mukhi's wife, the Mukhiyan, is ill-treated by her husband. Subedar, along with the other people, reaches the factory and kills the watchman, but Sonabi throws bags of chili powder on his face to protect her. There are also a number of scenes in the movie that throw ample light on the glamorous role of female characters- their dancing and also looking lustful, Sonabi has been portrayed in different light.

Mirch Masala is not the only movie that reflects the idea how women were lagging behind. There are several other examples in Bollywood that reflect females in more dominant roles as well. In the past, we find that in Indian cinema, body became an essential part of success of an actress. It shows how they used to spend time in gym in workout. During 1980s it was witnessed that Sri-devi used to spend a considerable time in the makeup room. Like the hero, we find her fighting with villains in the movie, *Himmatwala* and defeat them. In some movies, the director used to cast two or three heroes to balance her role. Two male heroes would barely hold on their role on their when casted against her. In one of the newspapers, *ShowTime*, she has been declared as with the title 'Is Sridevi a hero?' This shows how there was a change in the attitude

Principal
Dyal Singh College
KARNAL

of the female in the society because movies, like literature, are also the reflection of social milieu. This is evident through the movie, *Joshila* released in 1990s (1989) where with Madhuri Dixit in *Hum Apke Hai Kaun*, we find the caring homemaker role of the women was back in trend. In this movie, she puts her own dreams ahead of the aspirations and desires of their family. In 1990s, more significant changes can be perceptible in Bollywood as far as the role of females in the movies is concerned. Several movies were released with a complete changed idea of females in 1994, when *Mohra* was released with Akshay Kumar (Amar Saxena) Raveena Tandon (Roma Singh) Sunil Shetty (Vishal Agnihotri) and Naseeruddin Shah (Mr. Jindal) Roma Singh, a journalist, is the central character in the movie who works for the newspaper called *Samadhan*. When she goes to jail in order to write an article on prisoners what type of problems they were facing in the prison, one of the prisoners tries to seduce her, but she is saved by Vishal Agnihotri who is accused of the murderers of his wife's rape due to which he was imprisoned. She fights for Vishal in order to get him released from the jail and is succeeded. Jindal kidnaps Roma and she is saved by the collaborated efforts of Amar and Vishal. In the whole movie, Roma establishes herself as a journalist only because of Mr. Jindal and at many places, she can be seen standing up to the editor by associating herself with Jindal, the owner of newspaper. If she is able to arrange vital meetings with top police officials, it is only because of Jindal's influence which is representative of gender-neutral sign of dealing what is common in any situation. Although she is presented as an incompetent and naïve, but her body language is that of liberated women as Monica Motwani says in this connection: the heroine may have metamorphosed over the years, but she still cannot break away from the shackles of certain norms followed by conservative people in Hindi cinema years ago.

Principal
Dyal Singh College
KARNAL

Among the 1990s movies, we can quote the examples of some movies in Bollywood where females have been depicted as a means of decoration. These movies do not portray the women as promising women who are conscious of their career. In this regard such females are a total failure. The role of women as a homemaker is the central concern the productions in the second half of the 1990s. In such movies, *Kuch Kuch Hota Hai, Biwi No.1* and *Dil to Pagal Hai* do not present the females as career oriented. Failing in love, females of these movies have been projected as to take up a career. This idea has been highlighted in *DiltoPagalHai* in which Karishma Kapoor as a dancer loses to Madhuri Dixit who is only interested in taking care of life her partner. Sushmita Sen has been delineated as a home breaker in Biwi *No. 1*, where she takes modelling as her profession in the beginning. But, very soon she realises the situation and turns out to be the forgiving home maker and, as a result of that, Karishma Kapoor wins at the end of the movie as a wife.

Dil Chahta Hai also captures the traditional role for its females directed by young director. The females in the movies do not have their identity of own rather having identities apart from their romantic ones. In the movie, only one female has been casted as passionate about her career, Dimple Kapadia, but she does not meet any happy ending. On the other side, Akshay Khanna finds the normal girlfriend in his life. The impact of Western life-style can be witness on some of the female in Bollywood movies. It is because some directors came across Western culture and lifestyle, but they have projected their female characters according to traditional Indian values and conservation in their movies. Recently the tradition of delineating the clear distinction between the heroine and the vamps, the good girl and the bad girl is another transformation in the roles assigned to women in Bollywood. It is perceptible in the movies like

Principal
Dyal Singh College
KARNAL

Purab and *Paschim* in which a foreign returned girl-Saira Banu, being a spoiled girl is taught a lesson by the hero. Vamp in the movie is shown smoking, bared flesh and one who gets punishment for her wicked deeds. On the other extreme, the good are always portrayed as the decent girls. The image of an ideal daughter or wife or daughter-in law is shown in different light and shades.

The movie, *Singh* (2007) is a beautiful castigation of the fact how the popular cinema shows its inclination on Indian mythology by sharing the interest and values of male prejudices as we find in the depiction of male fantasies of the females. Consequently, women are presented as an angel or as a monster. After 1990s, one finds the element of love disappearing between the vamp and heroine dressed as boldly and moved as provocatively as the bad girl of old times. Some think that it is the effect of globalisation and consumerism due to which a large number of people are demanding heroines to become more ornamental then real women. The heroine might be presented dancing in snow-covered environment of Switzerland or Austria, but basically following the concept of the ideal women that most of Indian males fantasise about which is being the home maker. The feminine aspect presented by Madhur Bhandarkar's movie, *Corporate*, Bipasha Basu (Nishigandha Gupta) in negative light. She has been presented as over confident who seeks to get rid of her past bad experiences. In the fits of passion to be successful by hook or by crook, she is even ready to indulge in industrial in a rival company. She is shown helpless and we cannot do anything, but to sympathize her in her adverse circumstances.

The changes in women's image painted by Indian cinema are not sudden, but have been witnessed gradually. The question that arises in our mind whether films are the reflection of life or life is presented through movies is very significant and important. But the fact remains that

Principal
Dyal Singh College
KARNAL

more or less, the movies are ignoring this reality in spite of the fact that there are a large number of females working in both sectors-urban and rural. In Bollywood, the presentation of women shows that time is not changed for them. It can be witnessed that the roles assigned to them are still traditional although characterization is more elaborated and detailed.

On the whole, the changes in the females' role cannot be counted all well. Initially started with myth, Indian cinema projected the women as ideal Indian women, an image that the audience was thrust upon. After the disappeared image of vamp in the 1950s and 1960s, some qualities were witnessed in Bollywood. The idea of poetic-justice in some of the movies is the main concern as it is propounded by William Shakespeare in his plays. It has been portrayed through some heroines who used to meet a tragic end after they took recourse to evil path. The changes the females' image underwent would not have been shown on the screen. We cannot say that the females were enjoying freedom or liberation, but it was only a means to draw the attention of audience.

Commercialization also affected the role of females in Bollywood as few directors think that movies are an art form, but most of them find it as a means to collect money by any method. We cannot blame that directors only are responsible, but also those females who want to attain name and fame in shorts span of time and for that can go to any extent and limits. Even by means of costumes and dress, the changes in the female's role have been reflected in Indian cinema vividly and clearly. There was a time during the 1970s when the entire body of the heroine was seen covered by means of traditional Indian dresses like saree as you find the role plays by Meena Kumari, but at present it, has been replaced their wearing bikini top as the choli as is presented through the role played by Priyanka Chopra in *Dostana*. It can be concluded that the

Principal
Dyal Singh College
KARNAL

ISSN: 2456-6624

earlier heroines would dress up for the hero, but now they dress up for the audience to leave permanent mark on the audience. Western clothes, the heroines generally neglect household works, but earlier the traditional heroines were more

Changes from Past to Present in Females' Image in Bollywood

From the early days of Bollywood to the projects released currently, women in Bollywood have been portrayed in stereotypes that promote inequality between the sexes. Despite the dilemma still persisting in modern-day culture, the most important question is, has the divide between men and women proved to become better or worse since the early days of the film industry. In the Golden Age of the Indian film industry, younger women in movies were divided into two categories: "The Vamp" and the "Damsel in Distress." Damsels in Distress were considered to be the heroines of a film, but had very little to do in the actual plot. Their purpose was to be a romantic foil for the heroes and be the object, which the hero would save in the end to show his bravery and manhood. Damsels in Distress were always the moral women, representing "proper" female roles in Indian culture. They believed in the husband as the "Godly" people in their lives, they respected their elders, they were quiet and kind, and they were fiercely loyal to tradition.

Vamps on the other hand, served an equally valued purpose as the Damsel in Distress (though that value is not a high one). The Vamps were the seductresses who would momentarily take the hero's mind off of the prize and inevitable victory. This would include women in item songs and/or women who have been hired by or are romantic interests for the villains. Vamps were temptresses that were usually scantily clad and performed acts (or dances) that left little to the imagination. At present, one important advantage women in Bollywood have today: The

Principal
Dyal Singh College
KARNAL

possibility of more power. Films like Rani Mukherji's "Mardaani" or Priyanka Chopra's upcoming "Mary Kom" biopic shows women are strong, fiercely moral, and determined individuals, who have fascinating stories to tell the world. Women should no longer sit idly in the corner while a hero goes around beating up bad guys single-handedly. But, this step forward also comes with a few steps back. Women might have more to do and say in some modern films, but in most, they are still treated like objects or trophies for the heroes, and they are more scantily clad than ever before. While being scantily clad is a choice that people should not necessarily judge or jump to any conclusions about, that is precisely what happens in films.

Why must a biopic like "Mary Kom" or a female-driven action movie be some of the only ways for women to be strong, fierce and likable in Bollywood films? Sure, there are other films like "Shuddh Desi Romance" that depict two great female romantic leads, but even in that film the story is concocted around a man who sees the love of two women. Isn't it about time audiences see more movies where the women in control are depicted as a positive characteristic? Isn't it about time Bollywood likes its women?

References:

Jain J, Rai S. Films and Feminism. New Delhi: Rawat Publications, 2002

Tabatabai Ra. Women and Their Portrayal in Indian Cinema, 2016.

Sibal. Stereotyping women in Indian Cinema. 2018.

Acharya DR, Bell JS, Simkhada P, Van Teijlingen ER, Regmi PR. Women's Autonomy in Household Decision-Making: A Demographic Study in Nepal. Reproduc Health 7 (2010):15.

Principal
Dyal Singh College
KARNAL

ISSN: 2456-6926

Beasley C. Gender and Sexuality. London: Sage Publications, 2005.

Singh I. Gender Relations and Cultural Ideology in Indian Cinema: A Study of Select Adaptations of Literary Texts, Deep & Deep Publication, 1982

Krishnaraj, M. and Desai, N. Women and Society in India. New Delhi: Ajanta Publications, 1987.

Vogt, W. P. Dictionary of Statistics & Methodology: A Nontechnical Guide for the Social Sciences. New Delhi: Sage Publications, 2005.

Principal
Dyal Singh College
KARNAL

Sudarshan Research Journal
Volume – 1, Issue - 6, October-2023
ISSN No: 2583-8792
Impact Factor: 3.179 (SJIF)

POETRY: THE HIGHEST CROWN OF LITERATURE

Dinesh Kumar[1], Iuliia Shamaieva[2]

[1]Assistant Professor of English, Dyal Singh College, Karnal, Haryana

[2] Ph.D. Associate Professor, Department of Foreign Languages, V.N. Karazin Kharkiv National University, Ukraine

ABSTRACT

It is an established fact that of all the literary genres, poetry is generally considered as the highest form of literature. It influences an individual's life the most as it manifests diverse hues and colours of human life. The historical context of poetry's elevated position is examined, tracing its origins from ancient epic narratives to the intricacies of Shakespearean sonnets. This historical perspective highlights the consistent and profound role that poetry has played in shaping the literary landscape over the centuries. Distinctive features that set poetry apart from other literary forms are also scrutinized, including its condensed and precise use of language, the incorporation of figurative devices, and its ability to evoke profound emotional and intellectual responses. Poetry's capacity to create an aesthetic experience through the careful manipulation of rhythm and sound further reinforces its unique position in literature. In fact, critics regard poetry as the most ancient art which is the product of humans' imagination. In comparison to fiction, prose and drama, poetry is the means through which the feeling of love, sorrow and anger can be expressed in a better way.

KEYWORDS: Form, Genre, Imagination, Literature, Mirror, Poetry.

I. INTRODUCTION

Poetry is, in fact, a constant, being produced by all non-civilizations from ancient to modern times. Throughout its extensive history, the individual art of high emotions sublimated into perfect language of poetry. It has approached a vast array of subject-matters including love, social issues, war and beauty of nature. That is why, W.H. Auden rightly and aptly remarks that poetry is clear expression of mixed feelings. As particular exercise of the mind and soul, and a unique way of apprehending reality, poetry is generally regarded as a self-sufficient universe that intensifies and

Principal
Dyal Singh College
KARNAL

enlarges life experiences. Pointing to inner knowledge rather than real circum
activates different layers of perception. By sweeping away human thoughts, poetry
and soothes suffering. The main function of poetry is to give pleasure or what
aesthetic pleasure. But, at the same time, poetry is also the art of uniting pleasure with
Dr. Samuel Johnson. No doubt, poetry also instructs as William Wordsworth has rightly
that poetry can teach us in a better way in comparison to a teacher and preacher. Robert
also right in saying when he asserts that a poem begins in delight, but end on wisdom. In
poetry serves the purpose of art for life's sake. So, a real poet will treat art of poetry
wine where only the pleasure values matter. Taking into consideration, the view point of
propounded by the classicists who opine that delight is chief, if not the only end of poesy.
Johnson says in this regard that the function of poetry is it to unable the readers better to enjoy
or to endure it.

Imagination is the hallmark of poetry writing. A poet, with his or her far-fetched imagination, can portray whatever he or he wants. There is a difference in the perception of a poet and of an ordinary man. For example, a poet will find ways of defining love in beautiful metaphors but they would not truly get it until they have felt it right to their very core. On the other hand, an ordinary man will define love on the apparent level. So, poetry is not written, it is just a flow of feelings like a stream unchecked with imagination playing at its best. According to Dryden, poetry gives pleasure only when generally and not perfectly understood. It is through the poetry of a poet when he is taking himself, but the reader sees himself instead. With the help of imagination, a poet can present things in a broadways as Jim Morrison says that if poetry aims to achieve anything, it is to deliver people from the limited ways in which they see, they feel. In fact, in nutshell, poetry is a painting of feelings with the colors of words.

In the same way, painting is a silent poetry, and poetry is painting of feelings, emotions and ideas that speak. During the Elizabethan period, there was a rich harvest of poetry creation. Love as the recurring theme can be seen as the subject-matter of the poets in this period. As literature is the most interesting and significant expression of humanity, so is the poetry that also depicts human nature in a vivid and graphic manner.

William Shakespeare' poetry is a powerful rendering of human nature in real sense of words. The intensity of passion and thoughts that is present in his sonnets, is really an exceptional quality that the readers come across. The statement of poetry given by Edgar Allan Poe that poetry elevates human's soul, is also applicable on Shakespeare's Poetry. In Shakespeare's poetry, one

Principal
Dyal Singh College
KARNAL

finds the ability to touch those things which are not present in reality. His poetry is not only melodious and lyrical by means of rhymes scheme imported by him, but it also touches somewhere where our hands could not. The Elizabethan poets practiced Romantic poetry. All of them, through their poetry, seem to sense romance in the air. Through their writings, their sharpened senses scent something that is different and rare. During the neo-classical period, the concept of poetry changed considerably. The neo-classical poetry is known as an artificial poetry or drawing room poetry because of heroic couplet as the metre used in it. Alexander Pope and John Dryden practiced satirical poetry imbued with realism of the society. But, like the Elizabethan poets, it was not lyrical and melodious.

Certain rules and conventions followed by neo-classical poets made their poetry as monotonous and mechanical. It was not as penetrating as the Elizabethan poetry. So, the neo-classical readers hardly experienced poetry in real sense of words because if a poem has not ripped apart your soul, you have not experienced poetry. Like other genres of literature, poetry too, is an exposition of reality. Albert Camus says the fiction is the lie through which we tell the truth. Poetry also serves the same function. The Romantics have a different conception of poetry. A poet is a man speaking to men who depicts human nature in true sense of words as says William Wordsworth. So is poetry written by a poet who depicts human attributes in a vivid manner. A poet also understands the mystery of life. After reading poetry, one can understand how to adjust to the time of life, the ups and downs of life. In this way, a poet renders great service for humanity by writing poetry whose ink will never run dry.

So, the ideas of a poet are based not on 'art for art's sake', rather 'art for life's sake'. So, poetry is not only a fancy way of giving you information, but it is also an incantation. It is actually a magic spell which changes things and changes us also. It is a means of bringing transformation. As feelings and emotions are the common attributes in human beings, so everyone among us is a poet as some of us are gifted enough to recollect those feelings and emotions and capture it in magical words. The same purpose is served by a poet.

William Wordsworth's idea of poetry that poetry is the breath and finer spirit of all knowledge; it is the impassioned expression is the countenance of all sciences, is highly philosophical. On the other hand, Keats' conception of poetry is highly Romantic when he says that poetry should surprise by a finer excess and not by singularity. It should strike the reader as a wording of his own highest thoughts, and appear almost a remembrance. As it is the case with fiction and drama through which one gives vent to his or her emotions and feelings, in the same

Principal
Dyal Singh College
KARNAL

way, poetry is also not throwing down words into the void to fill a page, it is all about writing tears of agony and rage. Various poets have explored diverse statements of poetry. William Wordsworth's poetry, for instance, is based on two important phrases: emotions recollected in tranquility', and 'spontaneous overflow of powerfully feelings'. Emotion recollected in tranquility means that a poet produces his or her best poetry in solitude and isolation.

This idea has also been illustrated by Pablo Neruda when he says that poetry in an act of peace. Peace goes into the making of a poet as flour goes into the making of bread. In other words, we can say that to a poet silence is an acceptable response, even a flattering one. So, poetry is all that based on tranquil souls of an emotional art and humanity works of thoughts and deal with the metaphysical writings. The best mood of writing poetry is loneliness. It gives all strength you desire and want while writing poetry. The main purpose of poetry is also to expose the hidden and mysterious things, whether human attributes or the reality about something. Poetry is a means to lift the veil from the hidden beauty of the world and makes unfamiliar objects as if they were not familiar. Wordsworth's poetry has the ability to present ordinary things as extraordinary. In this way, poetry is art, poetry is emotion, that captures the hidden beauty of the world through words.

In this way, poetry is not only the few written lines, but it serves as an important function. The main function of poetry is to inspire as well as to instruct. It is an initiation into the concealed order of the world. The intense gratification that one receives from poetry; its unrivalled authenticity and honesty; its appeal to human nature; and how it makes ultimate sense of the self, open for individuals new vistas to interaction and communication. Because of its expressive boundaries virtually unlimited, poetry ennobles, enlightens and entertains. Poetry goes beyond strict localization and cultural arbitrariness when it is translated from one language into another. In that situation, poetry generates a sense of spiritual compatibility and communion between the collective identities of world.

So, the above discussion leads to the tentative conclusion that poetry is the most precise form of literature. It is just the evidence of life. If your life is burning well, poetry is just the ash as remarks, Leonard Cohen. The best poetry is created when an emotion has found its thought and the thought as found words. In other words, poetry is simply the most beautiful impressive and widely mode of saying things. So, poetry mirrors which makes beautiful that which is distorted. But it has been witnessed that most poets tend to waste every sentence, every word and every punctuation in their poetry.

Principal
Dyal Singh College
KARNAL

Asia Pacific Association of Psychology

The purpose of this Psychological Association shall be to advance psychology as a science, as a profession and as a means of promoting the welfare of the people of Asia pacific region.
The Association will work toward achievement of its purpose by engaging in the following activities:
-Affiliating with Similar Professional Bodies in the region or worldwide;
-Promoting social and professional interaction with psychologists in the area;
-Supporting the professional development of future psychologists;
-Promoting public understanding of psychology;
-Assisting members in the understanding of the Ethical Standards;
-Promoting legislative and other actions that protect and enhance the profession of psychology.

FOUNDING MEMBERS

The Founding Members of this Association shall serve for a period of five years, subject renewal thereafter.

PRESIDENT : PROFESSOR EMERITUS JITENDRA MOHAN,
Email-jitendramohan74@gmail.com, +91 9876491321, INDIA

VICE PRESIDENTS : PROF.LAKSHMAN MADURASINGHE Neuroscience Centre, Sri Lanka
DR. MARIA LEVENTI - GREECE
PROFESSOR MEENA SEHGAL - INDIA
DR. IOR GUGLIERMI - ITALY

SECRETARY GENERAL - DR. H.R.S. KEERTHISINGHE - SRI LANKA

TREASURER - PROF. DAYA EDIRSINGHE - SRI LANKA
EXECUTIVE COUNCIL MEMBERS

(USA) DR.R.LIONEL MANDY
(AUSTRALIA) DR.MICHAEL JAMES IRELAND
(MALDIVES) DR.AISHNATH NAAZ
(NORWAY) DR.HAKON INGE STENMARK
(HONG KONG) DR.CHIU KOU TAI HERBERT
(GERMANY) PROF.HAROLD HOCHGRAFE
(NEPAL) DR.USHA KIRAN SUBHA
(GREECE) DR.ASPASIA PEPPA
(INDIA) SHRI RAVISHANKAR
(U.S.A.) DR. TERESA MISHLER
(INDIA) DR. TARNIJEE (PRESIDENT I.P.A)

Principal
Dyal Singh College
KARNAL

The real beauty of a poem does not depend upon what you are saying, but on how you are saying it. So, poetry is the highest form of literature that reflects life in different shades and colours.

II. WORKS CITED

I. Chatman, Seymour. *A Theory of Meter*. The Hague: Mouton, 1965.

II. Hawkes, Terence. *Metaphor*. London: Methuen, 1960.

III. Jones, Robert T. *Studying Poetry: An Introduction*. London: Arnold, 1966.

IV. Lakoff, George, and Mark Johnson. *Metaphors We Live By*. Chicago: University of Chicago Press, 1992.

V. Roberts, Philip Davies. *How Poetry Works*. Harmondsworth: Penguin, 1968.

VI. Attridge, Derek. *Poetic Rhythm: An Introduction*. Cambridge: CUP, 1995.

VII. Martí, M. C. S. (2018). Poetic Language in the Multilingual Crown of Aragon. *Tenso*, *33*(1), 67-91.

VIII. Watson, R., & Watson, R. (1984). The seventeenth century: crown and Covenant: the ballads. *The Literature of Scotland*, 114-160.

IX. CROWN, K. (1998). The Feminist Poetry Movement. *Contemporary Literature*, *39*(4), 644-645

Principal
Dyal Singh College
KARNAL

Indian Journal of Psychology
ISSN: 0019-5553 Book No.05 2023

EMERGENCE OF INDIAN DIASPORA: A CRITICAL ASSESSMENT

Dinesh Kumar Asstt. Prof. of English Dyal Singh College, Karnal (India) Email. Id. dineshkarnal1@gmail.com

Abstract

The term "Diaspora" generally refers to any people or ethnic population forced or induced to leave their traditional ethnic homelands; being dispersed throughout other parts of the world; and the ensuing developments in their dispersal and culture. In the beginning, the term Diaspora was coined by the ancient Greeks for the citizens of a grand city who migrated to a conquered land with the purpose of colonization to assimilate the territory into the empire. The original meaning was cut off from the present meaning when the Old Testament was translated into Greek, and the word 'Diaspora' was used to refer specifically to the populations of Jews exiled from Judea in 586 B.C. by the Babylonians, and from Jerusalem in 136 A.D. by the Roman Empire. This term is used interchangeably to refer to the historical movements of the dispersed ethnic population of Israel, the cultural development of that population, or the population itself.

As far writers of Indian Diaspora are concerned, we have a galaxy of eminent authors who have contributed a great deal to the development of this genre in which Amitav ghosh, Kamala Markandaya, Anita Desai, Bharati Mukherjee, Jhumpa Lahiri, Kiran Desai, Gita Mehta, Anjana Appachana, Abha Dawesar, Chitra Banerjee Divakaruni, Kavya Vishwanathan, Sujata Messey, Shani Muthoo, Marina Budhos, Rani Dharker, Meera Syal, and Anita Rao Badami are worthy of detailed consideration.

Key-words: Identity, migration, mobility, environment, nostalgia, feeling.

It is an established fact that nowadays the problem of displacement is entirely different from than it used to be earlier. In the present scenario, people are shifting from one place to another willingly for betterment and for the satisfaction of some personal ambitions. In the past, it was not migration rather it was transportation of third world people as labourers to a slave island. That is why, their adjustment in a different social, economic, political and religious environment is not as pathetic as it was the case with earlier migrants. In past, illiteracy of masses was the main factor behind their nostalgia. Moreover, the outer migration of different cultures and races was the main factor for creating cultural, linguistic as well as racial confusion due to which there was no formation of national integration.

One of the important aspects that has been dealt by Indian writers of Diaspora is that everyone wants to be accepted which is, indeed, a psychological as well as emotional problem as it is the concept of one's sense of belongingness. It is not necessary for one to take it for granted that the problem of identity takes place in one's life when he or she accepts migration and mobility. Being a psychological feeling, there are chances of its experience even within the native land.

It goes without saying that since the independence of India the Indian diasporic writers set new different and new trends in Indian literature. It is also a well known fact that this term attracted the readers the borders across the boundaries irrespective of language, literary forms, style and technique adopted in this ideology. Different perspectives included in Diasporic literature-magic realism, stream of consciousness technique, immigration, alienation or adaptability of a new lands and cultures and last, but not the least, nostalgia are the common traits that can be witnessed in the works of all Indian writers as the Indian Diaspora includes almost all parts of the world.

It is a wide known fact that a great deal of works in Indian Writing in English are produced not in the landscape of India, but in widely distributed geographical areas of indenture. In the present paper, the main focus will be on a few Indian Diasporic writers and their works which are worthy of detailed consideration.

Without any shadow of doubt, the theory of Diaspora with number of aspects associated with it, influenced considerably literature of every language of the world. Diasporic literature is also dubbed as expatriate literature which earned international recognition and admiration in the last couple of

Principal
Dyal Singh College
KARNAL

ABOUT SOCIETY

Academy for Humanities and Social Sciences **(AHSS)** aims at promoting the communication of scientific research in humanities and social sciences by focusing on fostering networking and collaboration among interest groups and professionals from different streams of science, policy makers, NGOs and industry and working in close collaboration with scientific organizations and the industry in development and implementation of innovative products & services. Prominent emphasis is on acting as a common guiding platform for prospective students and researchers by organizing field projects such as workshops, seminars and lectures on recent advancements in scientific research and development in different fields, disseminating knowledge by publishing brochures, periodicals, and journals, creating an exclusive web site for the society and regularly updating it with news of concerned fields, and navigate funds, endowments for the promotion of different scientific fields in our society. At broader level Society aspire be able to spearhead the development of appropriate clinical and industry policies and standards.

ABOUT THE JOURNAL

Humanities and Social Science Studies (HSSS) is a multi disciplinary, bi-annual & double blind peer-reviewed research journal, published by ***Academy for Humanities and Social Sciences*** **(AHSS),** that provides a publication outlet for empirical, conceptual and review papers of exceptional quality in the fields of humanities and social sciences. It is an interdisciplinary journal directed towards academics, research and application. Motivation for publishing this journal is to disseminate new ideas and research papers (with strong emphasis on realism of analysis, provision and use of empirical evidence) which have broad relevance to the working and development of various aspects of humanities and social sciences. Specific attention of the journal is to provide an intellectual platform for young researchers and fresher's to unleash their untapped potentials, and recognizing themselves at their embryonic stages, and to communicate scientific findings and interpretations relevant to pressing social issues in a non-technical manner but without the sacrifice of professional standards. **HSSS** aims to contribute for better understanding and wisdom to the all fields of social science and humanities.

Principal
Dyal Singh College
KARNAL

Humanities and Social Science Studies, Vol. 13, Issue 1, No. 19, January – June: 2024 ISSN 2319-829X

PICARESQUE ELEMENTS IN HENRY FIELDING'S *JOSEPH ANDREWS*

Dinesh Kumar Associate Professor of English Dyal Singh College, Karnal
Email. Id. dSineshkarnal1@gamail.com

The beginning of English novel can be traced back to the novels written by Daniel Defoe who wrote adventurous novels, but he did not start the novel in proper sense of words. In his novels the main drawback was the characterization as he only focused on the story. He is primarily known for his art of narration. Addison and Steele, the pioneer of Periodical Essays, gave a little bit importance to characterization. *Gulliver Travels*, a work based on adventurous spirit of the protagonist also cannot be classed under the heading of fiction.

After that, there was an emergence of four wheels of the novel in which Samuel Richardson was the first novelist, a spokesman of his age who provided a new tone and touch to English fiction. He is known as a leading and front-rank novelist who rendered meritorious services to English novel, but at the same time, some weaknesses can be witnessed in his works. He did not base his philosophy on wide observation or sound philosophy. In his works, he portrayed sentimental and pathetic scenes. Most of his defects were removed by Henry Fielding who wrote novel accidentally. Against the sentimentalism of Richardson, Fielding is known as a novelist who presented solid and plausible realism in his works. He presented life full of ills, abuses, foibles and weaknesses. In his works, he acted as a social reformer whose main purpose was to bring about social transformation in the society. Along with realistic details, the chief weapons used by him-irony, sarcasm, burlesque, satire and mockery are also the means to bring about social changes.

He wrote four novels-*Joseph Andrews, Jonathan Wild, Tom Jones*, and *Amelia*. In all these works, Fielding's realism is the key-concern of every work who had a deep interest in exposing the reality of the society. He describes ordinary life and unlike Richardson, he had also no heroes, rather his characters are the embodiment of weaknesses and demerits. In other words, Fielding presents a very comprehensive and realistic picture of life in his works along with the richness and variety, a whole vision of English life comes up before the readers' eyes. In other words, Fielding has presented a world of breathless activity ,prodigal of adventure and incident.

The life portrayed by Henry Fielding in his works is of contemporary social environment. His scenes in his works are the English scenes. In this connection, Walter Scott is right when he says: 'The person of the story live in England, travel in England, quarrel and fight in England". Another critic, Walter Raleigh, while paying a rich tribute to Fielding works, remarks: "Fielding's novels are, in general thoroughly his own: and they are thoroughly English. What they are most remarkable for, is neither, sentiment or imagination, nor wit nor even humour, though there is an immense deal of this last quality; but profound knowledge of human nature, and masterly pictures of characters of men as he saw them existing. As a painter of real life he was equal to Hogarth; as a mere observer of human nature, he was a little inferior to Shakespeare, though without ant genius and poetical qualities of his mind."

Henry fielding was interested in presenting the picture of society as he witnessed around him with all its pitfalls and demerits. He also aims to be a reformer and moralist and to remove the he ill rampant in the society. He had very deep interest in presenting the realistic picture of ordinary life of his times. Fielding, as a novelist, chooses to laugh at the ills of life rather than shed tears over them. As we read his novels, we come across a vast panorama of English social life. His knowledge of life brings before us cruel laws, bitter prosecution of innocent people, numerous ills abounding everywhere both in the countryside and in the urban surroundings.

Principal
Dyal Singh College
KARNAL

शोध–प्रभा (ISSN: 0974-8946)
(A REFERRED & PEER- REVIEWED QUARTERLY RESEARCH JOURNAL)

The Portrayal of American Society in Jack Kerouac's *On the Road*

Dr Ritu Sharma
Associate Professor, Department of English, Dyal Singh College Karnal
ritu_cs@rediffmail.com

Abstract

Unrest on both the political and social fronts characterised the middle of the twentieth century in the United States. The start of the Cold War sparked widespread fear among the people, and two of the most powerful movements - the Civil Rights Movement and feminist protests - came along with the mounting economic strain. In similar conditions, the Beats Movement emerged as a means of expression for the young authors and poets known as the Beats. Jack Kerouac emerged as a distinctive writer among this group of budding authors, and when his iconic book On the *Road* was released in 1957, it had a lasting impact on the next generation of young Americans. Jack Kerouac mentions both the contemporary political and social climate, which he disapproves of, as well as 1950s American society in his book *On the Road*. He discusses in detail the protest and an alternate way of living alongwith the general state of American culture. He takes satisfaction in the fact that he and his friends reject the commercial politics and mainstream culture that were just beginning to emerge in the 1950s. Kerouac emphasises criticism of 1950s American consumerism and conformity throughout his book, and succeeds in influencing the future generations in their perception of contemporary American society.

Key Words: Cold War, Civil Rights Movement, Beats Movement

One of the founders of the Beat Movement, which emerged in the United States in the 1950s, was Jack Kerouac. Following World War II, the United States had a number of revolutions and upheavals at that time in its history, including the Civil Rights Movement, the jazz era's explosive growth, feminist protests, and the start of the Cold War between the United States and Soviet Russia. The ensuing anti-communism, McCarthyism, and the Red Scare were the results. Kerouac authored his autobiographical book *On the Road* during this period, which chronicles his travels throughout the country with his companion Neal Cassady. The relationship between the 1950s society and Jack Kerouac's work *On the Road* will be covered in this essay. It will examine how Kerouac viewed American politics, the economy, society, and the nation as a whole during Sal and Dean's travels in the 1950s, voicing his disapproval of the country's consumerism, conformity, and American culture.

During this time, the literary movement known as the Beat Movement was established. The Beat Generation, also known as the Beat Movement, was a group of friends and authors that wrote poetry and prose, used drugs, travelled the country and experienced unusual forms of sexuality, and ultimately had a big impact on the growth of American literature. They experimented with literary and physical freedom and developed an interest in Eastern faiths. They objected to the materialism of the 1950s. Reno provides the following explanation of the Beats' 1950s standing:

Principal
Dyal Singh College
KARNAL

Following the devastation caused by the Great Depression and World War II, most Americans happily went back to the somewhat stable existence of the middle class, which by this time included the recently developed suburbs. The first rebellion against this broader trend came from The Beats. They deliberately chose to resist the post war trend toward normalcy by making ends meet through odd employment, G.I. benefits, and gifts from friends and family. Sixth (6)

According to Erik R. Mortensen, Jack Kerouac, who expressed disapproval of the expanding consumerism in America through his book *On the Road*, was one of those voices. One of the first books to critically examine America's burgeoning post-war economy is Jack Kerouac's (Mortensen 1-2).

Written in the legendary three weeks of April 1951, *On the Road* was written by Jack Kerouac. Contrary to popular belief, he worked at his mother's house using a typewriter that he had customized to hold a whole roll of Teletype paper since he was an extremely fast typist and found it annoying to continuously have to stand up and change the sheets. In addition, Kerouac's storytelling spontaneity necessitated a steady stream of paper to hold the deluge of words that, propelled by coffee and Joan's help, he penned over the course of three weeks. Even though he completed the entire novel in such a short period of time, Kerouac was a dedicated writer who carried a notebook and pen with him at all times and had a habit of scribbling down ideas for his future works. It's also likely that the material for *On the Road* changed over the years before 1951 while Kerouac travelled and lived on the road with Neal Cassady. Kerouac was able to publish his book six years after he first wrote it, but not before he made a number of alterations at his publisher's request. Fundamentally, *On the Road* is an autobiographical novel that takes place in 1947 and 1950 and revolves around the travels of author Jack Kerouac and his friend Neal Cassady through Mexico and the United States. The two primary protagonists in the book are Salvatore "Sal" Paradise, the narrator, and his companion Dean Moriarty. Con artist Dean Moriarty has a real American charm, but he's always searching for "the kicks" that only North America can provide—drug usage, crazy jazz nights out, transient relationships with women, and philosophical debates about the meaning of life and time. The character of Dean Moriarty was invented by Neal Cassady, a friend of Kerouac's at the time who also had writing aspirations and whose extraordinary life and character influenced many Beat writers. The book *On The Road* is structured into five sections, three of which track Sal and Dean as they set off on a journey that can be interpreted as a spiritual and physical search for their own meaning in life. Numerous significant themes and ideas are explored in the book, such as the pursuit of freedom and pleasure as well as a nuanced but pervasive critique of modern American politics, society, the economy, and the lifestyle that the media portrays as ideal. Kerouac describes his personal reasons for traveling in the book: "As a young writer, I wanted to go off. I knew that eventually I would get the pearl, and that along the way there would be girls and visions and other experiences (Kerouac 7). The novel had a big impact on young people in America.

His novels quickly gained the status as a classic because they were so brilliantly written about an alternative lifestyle when they were first published, contributing to the cultural revolution that swept over America and Europe in the late 1960s (American writers 809).

Though it soon became apparent that, despite the author's personal apoliticism throughout his life, the book nonetheless represented the rebellious spirit of Beatniks, hobos, and bohemians, not everyone in 1950s America was enamoured with Kerouac's adventure novel. Many saw the late 1940s actions of the protagonists in the book, which was released in 1957, as direct assaults on post-World War II American morals and conventions (Haslam 4).

Principal
Dyal Singh College
KARNAL

Throughout *On the Road*, we encounter numerous references to 1950s American society as Sal and Dean travel. It is clear from this statement that Kerouac aimed to portray not just the United States of America but also its people, who were essential to his travels: "He stares from the outside-in at Americans of all types and from right across the country." The book begins as prose poetry on the romanticism of the journey between the cowboys of the West and the intellectuals of the East (Skinazi 7). During their travels, Sal and Dean encountered people from all social classes and backgrounds, as well as American music and food, and they learned about the country's vast expanse and surrounding landscape. Sal traces the paths taken by the early settlers, tastes apple pie, smells the "raw flesh of America itself" in Mississippi 9, and meets along the way the people who make up America: truck drivers and mothers, students and gipsies, ranchers and cowboys (Skinazi 9). This allows Sal to travel halfway across his country. Sal and Dean get the opportunity to experience both the nice and friendly side of America as well as the less desirable side of a country that has just entered a dark chapter in its history, when fear and distrust are a big part of day-to-day existence. For example, after encountering the police in Sabinal, where he used to work, Sal asserts that "the American police are engaged in a psychological battle against those Americans who don't intimidate them with obtrusive paperwork and threats". It's a Victorian-era police force that can conduct crimes if it so chooses, peeks through musty windows, and wants to know everything (Kerouac 127). Spangler notes that Kerouac "brings out the portrayal of the forces of control- the police, highway troopers, and other authorities who engage with the hoboes, migrants, and other 'undesirables' whose societal place lay outside of the mainstream" in relation to this remark (Spangler 7). These problems were not unique to that era of American history, and during their journey, Sal and Dean never once claimed to be surprised by the relaxed demeanour and camaraderie of the Mexican police. Because "a climate of fear and mistrust generates unique issues and opportunities for the hegemonic forces that patrol the boundaries of citizenship and the associated agency such a phrase conveys" (Spangler 7), the circumstances in America are extremely different.

William Burroughs's invented character Old Bull Lee provides a vehicle for Kerouac's thoughts regarding the status of the American people today. According to Old Bull Lee, "the American leaders would rather make cheap goods, so everyone will have to continue working, punching timeclocks, organizing themselves into gloomy unions, and stumbling around while the big grab goes on in Washington and Moscow" (Kerouac 139). Sal's observation that "boys and girls in America have 10 different ways of being together" further illuminates Kerouac's views on American relationships.

Since sophistication demands them to consent to sex without having a suitable dialogue first, they are having a terrible time together. True conversation about souls, not flirtatious small talk, because life is precious and every minute is invaluable Refer to Kerouac, 52. It is clear that Kerouac believes modern American relationships to be overly cold and distant, maybe as a result of the overall distrust and anxiety that characterized the nation at the time. As a result, he encourages more intimate relationships between individuals. During his travels, Kerouac saw American employees in addition to hobgoblins. Though he feels that American workers are abused in society, he is nonetheless very respectful of them despite his reluctance to join them, which is especially shown in the opening section of the novel when he and Remi act as guards in a group of workers' shacks. "It can only be taken as satirical reflection on the postwar boom to portray the lifestyle of the nomadic worker as a desirable means of survival for any portion of the American people in the 1950s" (Spangler seven).

Principal
Dyal Singh College
KARNAL

Kerouac knows that most Americans lead lives best described as "hard-working and hard-spending," contributing to the enormous cog that is the American economy. "Just like after work in any town anyplace, all the men were driving home from work, wearing railroad hats, baseball caps, and all kinds of hats" (Kerouac twelve).

The Beats have a deep respect for the American working class, but they are scared of joining it since they would have to give in to the country's new way of life, which goes against all that Kerouac and they stand for. Mortensen connects this aversion to labour with the concept of time in *On the Road* as follows: "The first step requires revealing clock time for what it truly is — a tool for controlling the worker." Finding a "genuine" method to experience time cannot be done until this oppressive system is removed. Clearly, Sal and Dean have moved on from their day-to-day existence at work (Mortensen 6). Through the autobiographical character Sal, Jack Kerouac expresses his personal viewpoints, which conflict with his own beliefs about life, on the American working class and labour system. While traveling, Kerouac pays close attention to jazz, an American musical style from the 1950s. In addition to capturing the wild spirit of the time, he employed jazz to capture the essence of the American underground society, which enjoyed listening to jazz and wild parties on warm nights in New York, San Francisco, and other American cities. These people included some of Kerouac's friends, and during his travels across the country, he meets a variety of jazz musicians and fans who introduce him to the other, less conventional, side of American society. It's obvious that Kerouac prefers the more conservative classes to this group of free-spirited, accepting people who "live in the moment," of whom he sees himself as a member. Kerouac often recounts crazy jazz evenings in the book, stating, "Bop was going crazy all over America at this time, 1947." The guys at the Loop blew, if a little tiredly, because bop came between Charlie Parker's Ornithology era and another period that began with Miles Davis (11). Though he rarely does so on purpose, Kerouac occasionally shares his thoughts on the US government. For example, while traveling through Mexico, he said, "They didn't know that a bomb had come that could crack all our bridges and roads and reduce them to jumbles, and we would be as poor as they someday, and stretching out our hands in the same, same way" (Kerouac 298). At one point, Old Bull Lee also makes the caustic remark, "The bastards right now are only interested in seeing if they can."

Kerouac's sentence "Blow up the planet" (Kerouac 143) is a sombre commentary on the state of the Cold War during the period when the two opposing sides were vying to build nuclear weapons. Sal and Dean arrive in Washington at a pivotal moment: "We arrived in Washington at dawn. It was the day of the inauguration of Harry Truman's second term. Pennsylvania Avenue was lined with magnificent displays of military prowess, which we sailed past in our battered boat. There were B-29s, PT boats, artillery, and other military hardware scattered across the icy grass (Kerouac 126). As the trio drive past the President's inauguration in their ancient, broken-down vehicle, we witness—unlike everywhere else in the book—the collision between the Beat lifestyle and the modern American environment. Due to their ability to capture the dread that engulfed America at the time, the "displays of War" have enormous significance. Throughout *On the Road*, Sal and Dean's interactions with various segments of American society are evident. These segments include those who are confined by work schedules, cautious of lav

Principal
Dyal Singh College
KARNAL

and terrified of communist takeover, and those who have retained their carefree attitude, are inspired by jazz and rock music, and refuse to bow to the political constraints of the 1950s in America. By monitoring and "digging" both of these aspects of American culture, Sal and Dean hope to "collapse" the "social distances" generated by, among other things, geography, age, and class. It is true that Sal and Dean cross "paths of the most different people" (Haslam 6). In the end, Sal "realises that the world's material and social glories are nothing but barriers to perceiving life" (Mortensen 7).

Written in the legendary three weeks of April 1951, *On the Road* was written by Jack Kerouac. Contrary to popular belief, he worked at his mother's house using a typewriter that he had customized to hold a whole roll of Teletype paper since he was an extremely fast typist and found it annoying to continuously have to stand up and change the sheets. In addition, Kerouac's storytelling spontaneity necessitated a steady stream of paper to hold the deluge of words that, propelled by coffee and Joan's help, he penned over the course of three weeks. Even though he completed the entire novel in such a short period of time, Kerouac was a dedicated writer who carried a notebook and pen with him at all times and had a habit of scribbling down ideas for his future works. It's also likely that the material for *On the Road* changed over the years before 1951 while Kerouac travelled and lived on the road with Neal Cassady. Kerouac was eventually able to publish his book six years after he first wrote it, but not before he made a number of alterations at the request of his publisher, the Viking Press, including renaming every character and rewriting a significant portion of the story. Griffey notes that after Kerouac's book was finally published, it would be difficult to determine how many poets, criminals, filmmakers, musicians, hobos, professional outdoorsmen, social workers, painters, and general readers began their journeys with a copy of the book. Fundamentally, *On the Road* is an autobiographical novel that takes place in 1947 and 1950 and revolves around the travels of author Jack Kerouac and his friend Neal Cassady through Mexico and the United States. The two primary protagonists in the book are Salvatore "Sal" Paradise, the narrator, and his companion Dean Moriarty. A con guy with true American charm, Dean Moriarty is always searching for "the kicks" that only the North American continent can provide—drug usage, wild jazz evenings out, transient relationships with women, and philosophical conversations about life's meaning and their place in it. The character of Dean Moriarty was invented by Neal Cassady, a friend of Kerouac's at the time who also had writing aspirations and whose extraordinary life and character influenced many Beat writers. The book *On the Road* is structured into five sections, three of which track Sal and Dean as they set off on a journey that can be interpreted as a spiritual and physical search for their own meaning in life. Numerous significant themes and ideas are explored in the book, such as the pursuit of freedom and pleasure as well as a nuanced but pervasive critique of modern American politics, society, the economy, and the lifestyle that the media portrays as ideal. Kerouac describes his personal reasons for traveling in the book: "As a young writer, I wanted to go off. I knew that eventually I would get the pearl, and that along the way there would be girls and visions and other experiences (Kerouac 7). American youth were greatly inspired by the novel, as we have already mentioned.

His novels quickly gained the status as a classic because they were so brilliantly written about an alternative lifestyle when they were first published, contributing to the cultural revolution that swept over America and Europe in the late 1960s (American writers 809). But not everybody in the 1950s Since it soon became apparent that Kerouac's adventure novel still contained the rebellious spirit of

Principal
Dyal Singh College
KARNAL

hobos, and bohemians, despite the author's personal apoliticism throughout his life, America was enthralled with the book. Many saw the late 1940s actions of the protagonists in the book, which was released in 1957, as direct assaults on post-World War II American morals and conventions (Haslam 4).

Works Cited

Griffey, Adam. "On the Road: Fifty Years Later." EBSCO. 10 April 2012. Web. 29 June 2012.

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=72f6420f-cbe6-486b-813d-15d1a090c372%40sessionmgr114&vid=2&hid=119>

Haslam, Jason. "It Was My Dream That Screwed Up : The Relativity of Transcendence in On the Road." EBSCO. 10 April 2012. Web. 29 June 2012

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=fd80d01a-8429-49f6-a368-98b4664466b6%40sessionmgr115&vid=2&hid=119>

Kerouac, Jack. On the Road. New York: Penguin Books, 1999.
Menand, Louis. Drive, He Wrote. EBSCO. 8 May 2012. Web. 29 June 2012

<http://web.ebscohost.com/ehost/detail?sid=bd9a49f5-cdbc-4e6b-bb5f-445b311f6403%40sessionmgr115&vid=2&hid=13&bdata=Jmxhbmc9aHImc2l0ZT1laG9zdC1saXZl#db=a9h&AN=26868559>

Mortensen, Erik R. "Beating Time: Configurations of Temporality." EBSCO. 15 May 2012. Web. 29 June 2012

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=a23bcc2a-1f72-4364-82a0-79dbd5bfb6ef%40sessionmgr114&vid=2&hid=108>

Nicolet, Todd. "A Guide to Jack Kerouac: The Influences and History Behind His Literature." EBSCO. 15 May 2012. Web. 29 June 2012.

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=10982008-1dd4-41fc-8550-06e41280c4de%40sessionmgr4&vid=5&hid=19>

Reno, R.R. " he End of the Road." EBSCO. 16 May 2012. Web. 29 June 2012 <http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=e35d8ad6-

05de-4a3c-b178-59997ce3bdef%40sessionmgr113&vid=2&hid=13>

Skinazi

Journey into the Meaning of America." EBSCO. 17 May 2012. Web. 29 June 2012

Principal
Dyal Singh College
KARNAL

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=cc6d5b7a-5c81-4052-a7ac-44cad3d4441f%40sessionmgr112&vid=2&hid=108>

Spangler, Jason. "We're on a Road to Nowhere: Steinbeck, Kerouac, and the Legacy of the Great Depression." EBSCO. 17 May 2012. Web. 29 June 2012.

<http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=7148502e-6739-4521-8ddc-9ea4985a446b%40sessionmgr114&vid=2&hid=108>

Unger, Leonard, and A. Walton Litz, eds. American Writers: Selected Authors. New York: Charles Scribner's Sons, 1998. Print.

Principal
Dyal Singh College
KARNAL

शोध-प्रभा

ज्ञान-विज्ञान विमुक्तये
UGC
University Grants Commission

CERTIFICATE OF PUBLICATION

This is to certified that the article entitled

The Portrayal of American Society in Jack Kerouac's *On the Road*

Principal
Dyal Singh College
KARNAL

Authored By

Dr Ritu Sharma
Associate Professor, Department of English, Dyal Singh College Karnal

Published in Vol. 51, Issue: 1, October- December 2023
SHODHA PRABHA (ISSN: 0974-8946)
UGC-CARE List Group I

Impact Factor: 6.1

Editor-in-Chief

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

Patterning Various Personal Efforts : A Special Reference to Amitav Ghosh's *The Circle of Reason*

Dr Ritu Sharma
Associate Professor. Dept of English
Dyal Singh College, Karnal (Haryana)

Ghosh's first novel The Circle of Reason (1986) is considered totally different from the traditional themes of Indian English novels.The Circle of Reason is about the quest necessary for motivation and survival of the artist in every soul in an inherently deadening, hostile and uncertain environment. A life of constant movement and violence has incessantly serrated our roots. The novel combines within itself an uncompromising restlessness with a poise and control that suggests peace rather than longing.The Circle of Reason offers nothing, which we normally call home. Initially located in a refugee village, the story refers back toBangladesh and Calcutta and finally moves to Middle East via Kerala,where it reaches its denouncement in a desert of shifting sand dunes.And it travels through an environment, which is never entirely rural orurban. Nor do its ideas present a stable attitude. Each idea evolves froma story posing a challenge to the proceeding and is itself qualified bysucceeding understanding, Pradip Datta rightly remarks:"The Circle of Reason is an epic of restlessness. And yet thecalm....."[1]

But, for G.S.V. Prasad, "The Circle of Reason is not merelycircular but a finely patterned novel and when seen as a whole displaysthe intricate butiwork of a master weaver in the making". [2]The journey from 'Satwa' through 'Rajas' to 'Tamas' the threeparts of the novel is not a straight forward narrative but one full ofreasons hankering back and forth like an unfolding raga circling andrepeating notes and sequences of notes each contextually different. Andlike a singer Amitav Ghosh points to the expert's appreciation of thesubtle variations, the resonance and hence, the whole narrative structure.In a sense, like other contemporary metafictional texts, The Circle ofReason is about narration itself. The book is about patterning the variouspersonal efforts at imposition of order in a chaotic world in order tocome to terms with it, in order just to live. Realistic fiction andchronological narrative have been discarded, as being insufficient toconvey the vastness and complexities of experience and life. Allegory,symbols, fantasy magical realism, narrative fluctuating backward andforward in time, the compelling use of narrator, fluency in storytellingand unveiling of layers and layers of meaning have all become a modeof writing. Novy Kapadia is very apt when she says: "Slickcraftsmanship and continuous experimentation with narrative andpossibilities for Indian novel in English".[3]

Principal
Dyal Singh College
KARNAL

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

Thus, the most striking feature of the novel is the author's selfassuredstyle of narration. Science, philosophy, history, politics, culture,art, language, the art of living, the despair of repeated loss– these areonly some of the strands which make the scope of this novel fairlyformidable. The novel provides not one, but many stories, each equallyappealing and important. There are always fresh disclosure and subtleconnections between the numerous stories. Almost all the majorcharacters in The Circle of Reason try to understand and constitute theworld, hence, motivate their actions through patterning of some kind.Basically, there are three stories knitted around characters, namely,Balaram, Alu and Mrs. Verma.

In the first section 'Satwa: Reason', the story of Balaram theidealist entranced by the 'Life of Pasteur' and his entanglement with thecongressman Bhudeb Roy get unfurled. Balaram is an idealistic withoutlimits and this very obsessive trait of nationalism leads him to treatpeople as object either of observation or of change. As he says to Gopal:

"You ought to be preserved in methylated spirit, you've adiscovery. You are the only person alive with phegmatic organ."[4] (TCR:13)

This very obsession of Balaram leads to his destruction. He isobsessed with the science of phrenology of disinfectant, and this to berational to the extent where even science fails to go. Later on, in this partBalaram gets entangled with Bhudeb, a congressman who, thoughmotivated by cynical considerations, looks at the people in the same wayas Balaram. And this fight of Balaram, with his alter ego Bhudebultimately culminates in the death of Balaram and destruction of hisfamily. Only Alu, his nephew survives to face the hard realities of life.Alu searching for shelter ultimately reaches Mariamma, the big boat ofZindi sailing towards al-Ghazira. The sail highlights the absurd and uglyside of Indian society enticing its people to leave for other countries forshelter and food and this journey to al-Ghazira takes us to second part ofthe novel. 'Rajas: Passion' which revolves around Zindi, the earlypractical zestful trader whose presence brings together a community ofIndians in the Middle East and Alu, the only survivor of Balaram'sfamily. The very presence of Zindi makes their life less miserable, asthey are scolded by their masters, so money is the only thing that mattersfor most of them. Now, the story moves through Alu, the only life savedfrom Balaram's destructive obsession. The Circle of Reason fails everytime in the novel where there is crisis. Here too, Alu makes attempts tocreate co-operative community, which tries to dispense with money andtrade. All this leads to nothing but death. Again Alu with Zindi andKulfi survives and they are made to run for life from one place toanother till they reach El-qued on the North Eastern edge of AlgerianSahara. From here we are moved into the third part of the story 'Tamas:Death' where we are acquainted with Mrs. Verma, who in defiance ofall rational skepticism, creates in the desert an oasis of Indiancommunity life.

Principal
Dyal Singh College
KARNAL

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

The main source of continuity in the novel is the storyof Alu, Jyoti Das and the police officer who is ordered to keep track ofAlu. Alu is declared an extremist by his boss. The D.I.G. Jyoti Das startsthe chase of Alu in the first part of the novel, but he catches him only atEl-Qued at Mrs. Verma's house. He finds surprisingly Alu as innocentas expected. Himself caught up in officialdom, he leaves for anunknown destination away from Mrs. Verma, Ali and his desert: "so heturned to face and land before him, now grown so real, the dizzy withexultation he prepared to step into a new world".(TSR:423) The story ofAlu and Jyoti Das is the main source of continuity. Thus, the scope ofnovel is formidable but Amitav Ghosh's narrative technique is an indication of development in Indo-Anglican fiction.The story of Alu starts from Lalpukur and Das sustains theinterest of readers from the very beginning because it is thrilling and italso exposes the corruption and inefficiency of police and its oppressivenature. Officially Jyoti Das is in charge of sedition case against Alu andis on duty in pursuit of guilty. But personally, he is in pursuit of birds.The bird man is migrating to begin a new life and for him as for Alu,'Hope is the beginning'.(TCR:166) The Circle of Reason appropriatelyends with a new beginning, the renewed search for contexts andpersonal readings and the novel holds out hope for the success of theseaesthetic quest.

Thus, we find all the characters in The Circle of Reason try tounderstand and constitute the world and hence motivate their actionsthrough patterning of some kind. The author invests in his characters–flesh and blood, dreams and defeats, which root them firmly and makethem recognizable. The major characters in their various attempts ofreading reality create and float in the sea of metaphors. The majorcharacters include Alu, Alu's aunt Toru Debi, Balaram, Shombhu,Debnath, Jyoti Das and Zindi.The Circle of Reason begins with an eight year old Alu, so namedbecause his head resembles a potato. 'It's an 'Alu' a potato, a hugefreshly dug, lumpy potato.' (TCR:3)Orphaned Alu comes to live with his aunt and uncle Toru Debiand Balaram in Lalpukur, a village in West Bengal. The village is"nothing but a dumping ground from the refuge from tyrant's frenzies"(TCR: 18) a village "damned to hell and longing" for whose inhabitantsonly passion is memory.Alu's aunt Toru Debi is recognized by her singer sewing machineand her mission in life is to perfect the petticoat and blouse. Balaram isthe local schoolmaster. Perpetually, armed with the claws, a menacinginstrument to measure people's skull. Balaram seeks to understand manand his motives. Alu's skull arouses his curiosity as he puts it, "Thearray of bumps and protuberances grew cheerfully all over his head andshowed no signs at all of dividing into distinct and recognizable organs.It was all very confusing and very exciting." (TCR:18)

Principal
Dyal Singh College
KARNAL

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

He has been a crusader, an inspired individual, organizingcampaign after campaign with a missionary zeal. In the PresidencyCollege, Calcutta as head of the Rationalistic Association, he campaignsagainst dirty underwear, at Lalpukur he launches a drive to rid thevillage of germs through bucketful of carbolic acid.Then there is Shombhu Debnath, master weaver, restless,unpredictable and fond of heights, who spends most of his time atoptoddy trees thundering Bairavi, who reletantly takes Alu on asapprentice. In Lalpukur Ghosh recreates a village which is distinctly apart of Bengal and at the same time universal. These people's life isnever dull, never still for a moment. Events gallop past strangeseemingly inexplicable events, mysterious happening, nothing is quitewhat it is. Events rapidly crescendo and Alu's world goes up in flames.He flies to Calcutta, to Kerala and finally to al-Ghazira the mythicalland of opportunities.At al-Ghazira, we meet a 'number of characters who travel insearch of material wealth and more opportunities.'[5]

Here all thecharacters are in motion, they cross borders 'with almost the biologicalnecessity if not always the ease and nonchalance of migratory birds'.[6] Jyoti Das, Rakesh, Professor Samuel, Kulfi and Chuni and enormous jetblack Zindi all meet here in their own quest of life.As in Lalpukur, Ghosh deftly and unerringly brings Al-Ghazira to lifethrough the small dreams and tragedies. The victories and defeats of men andwomen who have flocked there, thrown together by destiny to live out a shared,near bizarre history.Alu, Kulfi and Zindi abandon al-Ghazira heading westward to theland of sewing machines. They land eventually in El-Qued in the middleof the Sahara desert in the home of Balaram's friend Mrs. Verma, whereAlu comes face to face with exhausted Birdman Jyoti Das.

Thus, between death on one hand and hope on other, events fallinto some kind of place and answers tentatively emerge. Ghosh hasgiven his own impression and has expressed reactions against theexisting norms of society. The problem of human survival has becomedependent on finding the connections between a full conception ofrelationships and of social change. The problems of our country are alsowhat we share with the rest of the world. Driven by poverty, hunger,starvation people dream of a world where they can get a lot of moneyand impelled by that desire they move to Middle East or many otherplaces leaving their roots.

Published in 1996, The Calcutta Chromosome is considered to bea novel of 'fever, delirium and discovery'. Even many critics havecalled it a mystery full of thrillers. Like Ghosh's other novels this verynovel is also a multilayered novel swinging on the phases of time andplace. Even critics have commented on the narrator that he has tried toconvey the sense of interpretation of past and present and all time andspace. Meenakshi Mukherjee points out that time and space are sodeliberately jumbled in the novel that "The discon [illegible] meaningful".[7]

Principal
Dyal Singh College
KARNAL

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

The novel is a science fiction and having mysterious elements init. To exaggerate human understanding and recognition the novelist 'hascontrived to introduce a maze of ideas criss-crossing each other toproject the profound meaning of life through a visible insignificantfaçade of a 'spine chiller that negates the rational view of science andthe universe'.[8]To excavate the novel one must 'read the novel a secondtime and also read between lines'.[9]

Works Cited

1. Pradip Dutta, "A Voice among Bullet Holes: Amitav Ghosh's "TheCircle of Reason", Common Wealth Fiction ed. R.K. Dhawan(New Delhi: Classical Publishing Company, Vol.2, 1988), 71.

2. G.J.V. Prasad, "The Unfolding of a Raga: Narrative Structure inThe Circle of Reason", The New Indian Novel in English: TheStudy of 1980s ed. Vijay Kirpal (New Delhi: Allied PublishersLtd., 1990), 101.

3. Novy Kapadia, "Narrative Techniques in the New Indian Novel",The New Indian Novel in English: A Study of 1980s ed. VineyKirpal (New Delhi: Allied Publishers Ltd., 1990), 250.

4. Amitav Ghosh, The Circle of Reason (New Delhi: Ravi DayalPublisher 1986), 13.

(Note: All textual citations in this chapter are from this edition andare followed by the page numbers and abbreviations inparenthesis.)

5. K. Damopdar Rao, "Magic and Irony as Principles of Structures: Areading of the Circle of Reason", The Novels of Amitav Ghosh, ed.R.K. Dhawan (New Delhi: Prestige Books, 1999), 3-7

6. G.J.V. Prasad, "Really Imagined" (Seminar, 384 August 1991), 23.

7. Meenakshi Mukharjee, "Spine Chiller", India Today (May 15,1996), 163.

8. Ibid. 163.

9. Madhu Malti Adhikari, "The Continuity of Life, Mission andMystery in the Calcutta Chromosome", The Novels of AmitavGhosh, ed. R.K. Dhawan (New Delhi: Prestige Books), 228.

Principal
Dyal Singh College
KARNAL

JIMR

"INTERNATIONAL"

JOURNAL OF INTERDISCIPLINARY AND MULTIDISCIPLINARY RESEARCH

E-ISSN:1936-6264| Impact Factor: 6.886| UGC APPROVED 42887

CERTIFICATE OF PUBLICATION

This is to certify that the paper entitled

Patterning Various Personal Efforts : A Special Reference to Amitav Ghosh's *The Circle of Reason*

Authored by

Dr Ritu Sharma
Associate Professor. Dept of English
Dyal Singh College, Karnal (Haryana)

Has been published in

Volume 19, Issue 01 Jan 2024

www.jimrjournal.com

Principal
Dyal Singh College
KARNAL

FRANCIS J. KEEFE
EDITIOR IN CHEIF

Double-Blind Peer Reviewed Refereed Open Access and UGC Approved International Journal

Journal of Interdisciplinary and Multidisciplinary Research (JIMR)
E-ISSN:1936-6264| Impact Factor: 8.886|
Vol. 19 Issue 01, January- 2024
Available online at: https://www.jimrjournal.com/
(An open access scholarly, peer-reviewed, interdisciplinary, monthly, and fully refereed journal.)

Populism in Contemporary Politics: A Comprehensive Review

Dr. Anita Agarwal
Department of Political Science
Dyal Singh College, Karnal

Abstract:

This review article provides a comprehensive analysis of the phenomenon of populism in contemporary politics, examining its origins, manifestations, and impact on democratic institutions globally. Populism has emerged as a significant force in recent years, reshaping political landscapes and challenging established norms. This review synthesizes existing literature, offering insights into the defining characteristics of populist movements, the factors contributing to their rise, and the consequences for democratic governance. The surge of populism in contemporary politics has undeniably become a focal point of scholarly examination, and this review article provides a comprehensive analysis of this phenomenon. Populism, as observed in recent years, has evolved into a potent force that reshapes political landscapes and questions established norms, leaving a lasting impact on democratic institutions worldwide.

Furthermore, the analysis scrutinizes the factors contributing to the rise of populism. Economic inequality, social discontent, and a perceived loss of cultural identity emerge as significant drivers, fostering an environment conducive to the flourishing of populist sentiments. The review not only identifies these factors but also evaluates their interplay and dynamic relationships, offering a holistic perspective on the complex web of influences.

In sum, this review article provides a thorough and insightful analysis of populism in contemporary politics, contributing valuable insights into its origins, manifestations, and profound implications for democratic institutions globally

Key words – populism, politics, democratic institutions

Introduction:

The introduction provides an overview of the rise of populism in contemporary politics, highlighting its prevalence across diverse regions and ideological spectrums. The section sets the stage for the review by emphasizing the need to understand the driving forces and implications of this political trend. Populism, as a political phenomenon, has become a defining feature of contemporary politics, transcending geographical and ideological boundaries. Over the past

Principal
Dyal Singh College
KARNAL

ISSN: 2319 - 829X

Humanities and Social Science Studies

A Bi-annual Interdisciplinary journal

Vol. 13, Issue 1, No. 11, January – June: 2024

UGC Approved (CARE List) Journal

Principal
Dyal Singh College
KARNAL

ISSN : 2319-829X

HUMANITIES AND SOCIAL SCIENCE STUDIES

Peer-Reviewed, Bi-annual, Interdisciplinary UGC CARE List Journal
2023 Volume : 13 Issue :01, Book No: 11

CONTENTS

S.No	Title	Page No.
1	A STUDY ON CONSUMER PERCEPTION TOWARDS ELECTRIC VEHICLES WITH REFERENCE TO COIMBATORE CITY	1
2	CONSUMER PERCEPTION TOWARDS ONLINE SHOPPING OF HOUSEHOLD PRODUCTS	5
3	A STUDY ON THE PERSPECTIVE OF YOUTH TOWARDS DIGITAL CURRENCY WITH SPECIAL REFERENCE TO SMALL SCALE INDUTRIES	10
4	A STUDY ON CONSUMER EXPECTATION & SATISFACTION LEVEL OF HANDICRAFT PRODUCTS IN COIMBATORE CITY	13
5	THE IMPACT OF NATIONAL EDUCATION POLICY	18
6	EMPLOYMENT OF WOMEN	22
7	THE SOCIAL TRANSFORMATION IN TAMIL NADU: MAPPING THROUGH THE LEADESHIP OF E.V.R PERIYAR	32
9	CONSUMER PROBLEMS IN ONLINE SHOPPING IN THENI DISTRICT	44
10	A STUDY ON POTENTIAL OPPORTUNITIES AND CHALLENGES FOR SUSTAINABALE FASHION MARKET IN INDIz	50
11	'COLLECTIVE ECOLOGICAL MEMORY' AND 'SOLASTALGIA' IN CONTEMPORARY INDIAN WRITING IN TRANSLATION: A SELECT STUDY	54
12	PARTITION AS A PERNICIOUS MIGRATION IN KHUSWANT SINGH'S TRAIN TO PAKISTAN	61
13	NEW SPACES WITHIN THE OLD DISCOURSE IN VOLGA'S THE LIBERATION OF SITA	63
14	"THE JOUISSANCE OF TRANSGRESSION": A VOYAGE OF URSULA'S PLEASURE PRINCIPLE TOWARDS JOUISSANCE IN D. H. LAWRENCE'S THE RAINBOW	67
15	A SYNOPTIC STUDY OF JEAN ARASANAYAGAM'S FEAR: MEDITATION IN A CAMP	71
16	SUFFERINGS AND TRAUMAS OF FARMERS BY THE POLITICS OF THE INDIAN SOCIETY: KOTA NEELIMA'S SHOES OF THE DEAD	74
17	SOCIAL STRUCTURE AND CASTE SYSTEM OF THE CONTEMPORARY AMBIVALENT INDIAN SOCIETY DISCUSSED IN ARAVIND ADIGA'S NOVEL THE WHITE TIGER	77

Principal
Dyal Singh College
KARNAL

18	DISPOSAL OF THE COLONIAL SYSTEM IN LIFE AND TIMES OF MICHAEL K	81
19	SOCIO-POLITICAL UNREST IN ASIF CURRIMBHOY'S PLAYS	84
20	MEASURING FOOD SECURITY IN NORTH-EAST INDIA: A STATE-WISE ANALYSIS	88
21	REVOLUTIONIZING LANGUAGE LEARNING: AI AS A PARADIGM SHIFT IN ELT	98
22	AN HISTORICAL PERSPECTIVE ON WESTERN LIBERALISM AND THE REFORMIST IMPULSES OF COLONIAL INDIA	102
23	EMBARKING ON A JOURNEY OF SELF-DISCOVERY : A STUDY OF CHITRA BANERJEE'S THE MISTRESS OF SPICES	109
24	ISOLATED SLEEP PARALYSIS IN ADULTS: A QUALITATIVE INQUIRY	113
25	EMPOWERING RURAL WOMEN THROUGH RURAL LIVELIHOOD PROJECT "JEEVIKA": AN EMPIRICAL STUDY OF TEKARI & MAINATAD BLOCK OF BIHAR.	139
26	CONSUMER SATISFACTION ON USING THE ONLINE MODE OF PAYMENT.	149
27	THE IMPRESSIVE AND AWE-INSPIRING VIEWS THAT FASCINATED EUROPEAN TRAVELLERS IN INDIA DURING THE MUGHAL PERIOD	154
28	SHAREHOLDER'S VALUE CREATION THROUGH MERGERS AND ACQUISITIONS	161
29	UZAHAVAR SANTHAI: A STUDY ON SOCIAL, AGRO-ECONOMIC AND FINANCIAL BENEFITS EXPERIENCED BY FARMERS.	173
30	A STUDY ON PROBLEMS FACED BY WOMEN ENTREPRENEURS IN DAVANGERE DISTRICT	180

Principal
Dyal Singh College
KARNAL

ISSN 2319-829X
Humanities and Social Science Studies, Vol. 13, Issue 1, No. 11, January – June: 2024

EMBARKING ON A JOURNEY OF SELF-DISCOVERY : A STUDY OF CHITRA BANERJEE'S *THE MISTRESS OF SPICES*

Aastha Bhatia Assistant Professor of English Dyal Singh College, Karnal
Dr. Poonam Verma Assistant Professor of English D.A.V. P.G. College, Karnal

Abstract
Literature is the mirror of society. The modern times, with their complexities and difficulties, find a reflection in literature. The works written by Indian immigrant authors, particularly reflect the dilemmas, frustrations and hopes of the Indian immigrants living in various parts of the world. Chitra Banerjee Divakaruni's novel *The Mistress of Spices* is one such work that delineates the innermost thoughts of the Indian expatriates living in Amer
ica. The present paper attempts to study the social and psychological journey of the characters in this novel, finally culminating into a sense of self-discovery.

The world today has come down to be a global village. Globalisation has had its far-reaching impact not only on the social and economic spheres but also with regard to literature. With people migrating to various other countries in search of greener pastures, life for them brings new challenges every day. And literature, being the mirror of society, incorporates all these changes in the best possible manner. India is a country with a multitude of people from different regions, speaking different languages, following different religions, but still living as one nation. The sense of belongingness to a particular country is what makes us going. However, with the increasing globalisation and materialism, immigration to other countries has become the order of the day. Thousands of Indians migrate to the United States, Canada, Australia, New Zealand and other countries every year. They go there carrying hopes of a rosy future. But their journey is not a cake walk. They have their own share of problems, difficulties and challenges as they try to create a space for themselves. Living on the edge of two worlds is not an easy thing to do. It requires a lot of grit and resilience to keep going in an alien land. Chitra Banerjee Divakaruni has tried to capture the essence of this struggle in her works.

Born in 1956, Chitra Banerjee Divakaruni is an Indian-American writer of novels, short stories and poetry. Winner of a number of awards and recognitions including the American Book Award, Divakaruni gives voice to the problems faced by South Asian immigrants. Her debut novel *The Mistress of Spices* was published in 1997 and has also been adapted into a film of the same name. Her other works include a short story collection titled *Arranged Marriage*, novels *Sister of my Heart*, *The Palace of Illusions, One Amazing Thing, The Conch Bearer, The Mirror of Fire and Dreaming* and *Independence.*

The Mistress of Spices has as its protagonist a woman named Tilo (Tilottama) .Born to poor parents in South India, Tilo was initially named 'Nayan Tara' and was considered a burden by her parents : "Wrap in her old cloth, lay her face down on the floor. What does she bring to the family except a dowry debt. " (Divakaruni 7) Her parents do not bother about her and she wanders in the countryside, unattended and uncared for. It is not long before she discovers her special gift of foreseeing the future. As she helps various villagers in distress and predicts natural calamities like floods, her fame spreads far and wide. In fact, the very name 'Nayan Tara' has symbolic significance and hints towards the prophetic stature of the girl. However, her happiness in this phase of life is short-lived and she is kidnapped by the pirates who want to use her gift for their material benefits. They give her the name "Bhagyavati" meaning harbinger of good luck. Thus, she is separated from her family and displaced from her homeland only to become the queen of pirates who, with the help of sea snakes, escapes the ship and finds herself on the island of spices. It is here that she gets solace, comfort and a sense of belonging. In fact she feels at home in the protection of the First Mother or the Old One who guides her and other girls in the art of using spices to heal others. She even experiences a new sense of self and attainment of a new identity on the island: "Who was I? I could

Principal
Dyal Singh College
KARNAL

not say. Already my name had faded in the rising sun, like a star from a night that has pa away…." (33)

Thus begins a new phase in her journey of life as she is trained to be the mistress of spices—a s healer who would try to solve the problems and conflicts of people through the magic of sp Divakaruni here uses magical realism as she endows Tilo with supernatural powers used smoothening the entanglements of the reality of lives around her. The name Tilo signifies a identity .It is derived from Til or seesame seeds used as a restorer of health and life. As she cho her name, she says : " I will be Tilottama, the essence of til, life-giver, restorer of health hope."(42) As Tilo passes through the Shampati fire, she sheds not only her old identity but also body. Though she has a youthful heart, it lives in the body of an old arthritic woman who ha focus only on her work and nothing else. There are three rules that a mistress of spices has to kee mind: First, never to leave the spice store; second, never to use the power of spices for her benefit and third, never to touch the skin of any other human being. The Old one says: "You'll tempted. You especially with your lava hands that want so much from the world. Your lava h flying too easily to hate, to envy, to love-passion. Remember why you were given your power."(Thus, it is an austere kind of life that is expected from Tilo. She chooses Oakland as her place service.

Thus begins another phase in Tilo's journey—as mistress of spices in a foreign, alien land. He Tilo receives a number of customers in her store named 'Spice Bazaar' and while solving th problems, she herself grows. As she cannot leave her store, she forms an idea of the world a society of America through her customers' eyes only. The Spice Bazaar becomes a microcosm of t South Asian, particularly Indian immigrant community with their hopes, desires, frustratio ambitions, conflicts and dilemmas. It is here that the novel emerges as a diasporic text that captu the essence of the lives of Indian immigrants in America and their challenging journey of trying find a home in an alien land.

One of these customers is Lalita, a housewife, often referred to as "Ahuja's wife", as she has almc no identity of her own. She is a victim of domestic violence and is a typical example of a subalte who does not speak—a woman who is a victim of the discriminatory attitude of the patriarch society. Thus, she is doubly marginalised—as an immigrant and as a woman. To make matte worse, her husband tries to rape her, robbing their relationship of all possibilities of dignity, respe and a healthy future. Lalita shares her agony with Tilo: "*I can still hear the ripping sound, like it w my life.*"(270?) Though she approaches Tilo to find solace through the world of spices, the fact is th anything would work only if she gathers courage and takes a stand for herself. And when she realise this, she does take a stand. "I deserve dignity, I deserve happiness."(272), she says. Thus, from pitiable and pathetic figure, Lalita transforms herself into a resilient woman full of self-esteem an determination to live life on her own terms.

The immigrants have to face yet another problem, that is, the problem of racial discrimination. S deep-rooted and humiliating is this problem, that even after many years, the scars seem fresh in th hearts of its victims. Jagjit in this novel is one such figure—a shy, Punjabi boy trying to find hi place in the American cosmopolitan society. He is badly bullied at school and is even beaten u mercilessly by his white classmates for no fault of his, just because he is brown-skinned. The constantly use abusive language against him: "Talk English son of a bitch. Speak up nigger wetback asshole" (39) Infact, Chitra Banerjee herself had been a victim of racial attack. Uma Girish records:

> It happened in 1976 when Chitra Banerjee Divakaruni was all of 19.Walking down a Chicago street with some relatives she was appalled when a few white teenagers yelled "nigger" and hurled slash at her. The incident, deeply shaming, was never discussed, but it stayed and played in her mind and acted as the spur to kick start her writing. And then one evening, her five-year-old son Abhay returned from school and tried hard to wash off the 'dirt' colour of his skin. It's little wonder that much of Divakaruni's writing resonates with the Indian-American immigrant experience. 'Writing was a way to go beyond the silence', she offers. And even as

Principal
Dyal Singh College
KARNAL

she tried to adjust to the reality of life in an alien culture, her other life, the real one, was dimming inside her head (Girish np)

Throwing light on the plight and dilemma of the immigrants, Ashutosh Dubey says: " The immigrant experience is complicated as a sensitive immigrant finds himself or herself perpetually at a transit station fraught with memories of the original home which are struggling with the realities of the new world" (Dubey 22).

Thus, though Jagjit tries to find solace in the memories of his original homeland, he cannot avoid the bitter reality of his new home. He feels secluded, alienated and out of place to such a great extent that he finally rejects his native Punjabi culture and way of dressing up, and adopts a totally Western one. Thus, Jagjit's journey ends on a note of giving up to the hostile tendencies of the Western world towards the immigrants.

Another significant character from this point of view is Haroun. His roots go back to Kashmir where his ancestors used to row shikaras for the tourists. Unfortunately, they had to flee from there owing to terrorism and moved to America. Haroun is a Muslim Indian who struggles to find his place in the modern American society, but ends up being alienated and dislocated. He takes up the job of a cab driver in America but finds it difficult to avoid racial discrimination. He, however, is not somebody to be easily cowed down; and shows exemplary resilience in preserving his identity. Taking help from Tilo, he does fight back and pursue his dream of fulfilling the Great American Dream. He finds love in her neighbour Hameeda and tries to create meaning out of his difficult life in America. His is a journey full of obstacles. However, he leaves no stone unturned in overcoming them.

Another perspective on the journey towards self-exploration can be seen through the character of Geeta, a third generation immigrant. Born and brought up in America, Geeta wears western clothes, leads a western way of life and works outside. But all this does not go well with her grandfather who wants her to adopt an Indian way of life. He despises her working with male colleagues and going out with male friends. Though Geeta is living in America, she is still tied to the shackles of the traditional Bengali culture and the corresponding behaviour expected of her. She yearns for independence in a male-dominated world and blames her grandfather for all the problems in her life : "He's the one who turned them against me with all that shit about good women and family shame. They never would have behaved so prehistorically otherwise...." (134)

Geeta is in love with an American named Juan and knows that her family would never accept him. However, she cannot gather enough courage to go against her family as her Indian roots prick her conscience. She is thus caught in a dilemma between her desires and her family expectations. Clara Nubile remarks about this plight of women in The Danger of Gender:

> "to be entrapped into inescapable cage of being a woman-wife-mother....A woman cannot exist outside the boundaries of married life and motherhood, otherwise she is perceived as useless and unworthy according to traditional Indian views....Indian women do not appear to have their independent role in society. Moreover, they must become a male appendix in order to have a role. Indian women are thus linked by male definitions, sex- segregation patterns....Female individual space is unacceptable and inconceivable."(Nubile 12)

Tilo, through the magic of her spices, tries to bring about a reconciliation between Geeta and her family. However, Geeta's journey is a typical example of a woman trying to create a space and identity for herself in a fiercely male-dominated world.

Tilo herself faces an acute dilemma. It is the dilemma between duty and love. As she falls in love with Raven, an American man, she knows that she is forbidden to enter this territory because of her role as a mistress of spices, lest the spices should turn their powers against her. She , however, experiences such a passionate love for him that finally she ends her dilemma by choosing her heart over her duty. Tilo tries to shed her identity as the mistress of spices by burning herself in the spice store. However, she wakes up to find that the store has been destroyed by an earthquake. She and Raven together make a resolution to restore the store to its original state together.

Principal
Dyal Singh College
KARNAL

Raven himself embarks on a journey of self- discovery as he learns that he is a native Am the maternal side. However, his mother has snapped all ties with her native American fam to become a part of the mainstream Americans. When Raven learns this, he is so distur distances himself from his mother and identifies himself with his native American r loneliness is a prominent cause of their closeness. As Tilo remarks: "[I]t is a surprise. I di that Mistress could feel so lonely" (69).

Thus, Tilo's decision to choose Raven over the spices is an indication to the fact that ther parts of our identity that we can never forego. Thus she attains a balance between he mistress of spices and her love for Raven.

Chitra Banerjee Divakaruni , thus, portrays the journey of various characters on the pa discovery in an alien land, trying to establish themselves and find their identity.

WORKS CITED

Divakaruni, Chitra Banerjee. *The Mistress of Spices*. London: Black Swan, 1997.

Dubey, Ashutosh. Immigrant Experience in Jhumpa Lahiri's "Interpreter of Maladies". *Indian Writings in English*. 30.2(2002): 22-6.

Girish, Uma. "An Interview with Chitra Divakaruni."np. 22 Septembe http://calitreview.com/58

Nubile, Clara. *The Danger of Gender Caste Class and Gender in Contemporary Indian Writing*. New Delhi: Sarup Book Publishers Pvt. Ltd., 2003.

Principal
Dyal Singh College
KARNAL

Monthly Baraheen ISSN:2395-3640

UGC CARE Group 1

www.monthlybaraheen.com

IMPACT FACTOR 7.817

CERTIFICATE OF PUBLICATION

This is to certify that the article entitled

Maurya Kalin Samajik Vyavastha: Ek Adhyayan

Authored By

Dr. Parveen Kumar

Assistant Professor, Department of History

Dyal Singh College, Karnal

Principal
Dyal Singh College
KARNAL

Published in

Monthly Baraheen, ISSN: 2395-3640

Vol.15, IssueNo.177, Sep2023, Impact Factor: 7.817

ज्ञान-विज्ञान विमुक्तये

ManagingEditor

≡ UGC-CARE List

UGC-CARE List

Principal
Dyal Singh College
KARNAL

You searched for "Monthly baraheen". Total Journals : 1

Search:

Sr.No.	Journal Title	Publisher	ISSN	E-ISSN	UGC-CARE coverage years	Details
1	Monthly Baraheen (print only)	Shah Waliullah Institute	2395-3640	NA	from January-2022 to October- 2023	Discontinued from Oct. 2023

Showing 1 to 1 of 1 entries

Previous 1 Next

Monthlybaraheen Publication

Logout



1830-1847 ×

Search

No results found.

Principal
Dyal Singh College
KARNAL

8:44 pm

मौर्य कालीन सामाजिक व्यवस्था : एक अध्ययन

डॉ. प्रवीन कुमार,
सहायक प्राध्यापक, इतिहास विभाग,
दयाल सिंह कॉलेज, करनाल

सारांश

मौर्ययुगीन समाज अत्यन्त सुखी एवं सम्पन्न था। उत्कृष्ट आर्थिक समृद्धि में ही समाज का सांस्कृतिक स्वरूप प्रस्फुटित होता है। समृद्ध मौर्य समाज पूर्णतः संगठित व व्यवस्थित था। सुखी एवं सम्पन्न सामाजिक स्थिति होने के कारण ही मौर्य काल में साहित्य का अनुपम सृजन हुआ एवं दर्शन व कला का विस्तार हुआ। मौर्य काल तक आते-आते वर्णाश्रम व्यवस्था को एक निश्चित आधार प्राप्त हो चुका था। वर्ण कठोर होकर जाति के रूप में बदल गए, जिसका आधार जन्म था। कोई भी व्यक्ति न तो अपनी जाति के बाहर विवाह कर सकता था और न ही भिन्न पेशा अपना सकता था। परन्तु दार्शनिक इसके अपवाद थे और वे किसी भी वर्ग से हो सकते थे।[1]

परिवार में स्त्रियों की स्थिति स्मृति काल की अपेक्षा अधिक सुरक्षित थी, किन्तु उन्हें पुनर्विवाह तथा नियोग की अनुमति थी, किन्तु फिर भी मौर्य काल में स्त्रियों की स्थिति को अधिक उन्नत नहीं कहा जा सकता।[2]ग्रीक विवरणों के अनुसार भारत में दास प्रथा की सत्ता नहीं थी, पर कौटिल्य अर्थशास्त्र से ज्ञात

Principal
Dyal Singh College
KARNAL

होता है कि मौर्य युग में दास प्रथा विद्यमान थी। संभवत: जिस ढंग की दास प्रथा प्राचीन काल के ग्रीस तथा रोम में थी, वैसी भारत में नहीं थी।[3] वहीं अशोक ने दासों एवं सेवकों के साथ अच्छा व्यवहार करने का आदेश अपने कर्मचारियों को दिया था, ऐसा उल्लेख मिलता है।[4]

यूनानी लेखकों ने लिखा है कि भारतीय सादा जीवन बिताते और शान्ति से रहते थे। झूठ व चोरी का नाम न था। वे अधिकतर चावल खाते और केवल यज्ञों के समय ही मदिरा पीते थे। धरोहर आदि के कोई मुकदमें नहीं होते थे। उनके मकान और संपत्ति बिना चौकीदारी के भी सुरक्षित थे।[5]ब्रह्मा और पशुपति शिव के उपलक्ष्य में समाजों का आयोजन किया जाता था। इन समाजों में मनुष्यों और हाथियों के युद्ध, रथों की दौड़ आदि होती थी। जुआ और शतरंज जैसे खेल भी खेले जाते थे।[6]

मुख्य बिन्दु:-

वर्ण व्यवस्था, दास प्रथा, स्त्रियों की स्थिति, आमोद-प्रमोद के साधन, खानपान व पहनावा और रीति-रिवाज व स्वभाव

जाति एवं वर्ण व्यवस्था:

कौटिल्य अर्थशास्त्र में समाज को चार वर्णों में विभक्त किया गया है - ब्राह्मण, क्षत्रिय, वैश्य और शूद्र। ब्राह्मण के 'स्वधर्म' (कार्य) अध्ययन, अध्यापन,

Principal
Dyal Singh College
KARNAL

यज्ञन (यज्ञ करना) और प्रतिग्रह (दान ग्रहण करना) कहे गए हैं। क्षत्रिय का स्वधर्म अध्ययन, याजन (यज्ञ कराना), दान, शस्त्रजीव (शस्त्र द्वारा आजीविका प्राप्त करना या सैनिक सेवा) और भूतरक्षण (प्राणियों की रक्षा) है। वैश्य का स्वधर्म अध्ययन, याजन, दान, कृषि, पशुपालन और वाणिज्य है। शूद्र का स्वधर्म द्विजातियों (ब्राह्मण, क्षत्रिय और वैश्य) की सेवा करना, कारूकर्म (शिल्पी या कारीगर का कार्य) और कुशीलव कर्म (नट आदि के कार्य) हैं।[7]

मौर्य युग में अनेक ऐसी जातियों का भी विकास हो चुका था, जिसका आधार कोई विशेष शिल्प या पेशा था। तन्तुवाय (जुलाहे), रजक (धोनी), तुन्नवाय (दर्जी), सुवर्णकार (सुनार), चर्मकार (चमार), कर्मार (लुहार), कुदाक (बढ़ई) आदि।[8]

मेगस्थनीज द्वारा भारतीय समाज को सात जातियों अथवा वर्गों में विभाजन किया है। उसके द्वारा उल्लिखित सात जातियाँ हैं - 1 दार्शनिक, 2. कृषक, 3. ग्वाले या आखेटक, 4. कारीगर व व्यापारी, 5. युद्धकर्मी (सैनिक), 6. निरीक्षक या ओवरसियर तथा 7. काउन्सिलर्स या मन्त्री और सचिव अथवा अमात्य।[9]

मेगस्थनीज के अनुसार -दार्शनिक समाज का बुद्धिजीवी वर्ग है। उसका राजदरबार व समाज में बड़ा सम्मान है। यद्यपि संख्या की दृष्टि से अन्य जातियों से कम है, तथापि प्रतिष्ठा में उन सबसे श्रेष्ठ है। दार्शनिक लोग सब

Principal
Dyal Singh College
KARNAL

सार्वजनिक कर्त्तव्यों से मुक्त हैं, इसलिए न तो किसी के दास और न किसी के स्वामी हैं। गृहस्थ लोगों के द्वारा ये बलि प्रदान करने व मृतकों का श्राद्ध करने के लिए नियुक्त किए जाते हैं, क्योंकि लोगों का विश्वास है कि ये देवताओं के बहुत प्रिय हैं और परलोक संबंधी बातों में बहुत निपुण हैं। इन क्रियाओं के बदले ये बहुमूल्य दान पाते हैं। भारत के लोगों को इनसे बहुत लाभ पहुंचता है। साल के आरम्भ में ही ये लोग जब एकत्र होते हैं, तो अनावृष्टि, शीत, आँधी,रोग आदि की सूचना पहले ही दे देते हैं।[10]

दूसरी जाति में किसान लोग हैं, जो दूसरों से संख्या में बहुत अधिक हैं। वे राजा को भूमिकर देते हैं। किसान लोग स्वयं अपनी स्त्रियों और बच्चों के साथ देहात में रहते हैं और नगरों में जाने से बिल्कुल डरते हैं।[11]

तृतीय वर्ग ग्वालों व आखेटकों का था, जो यायावर जीवन व्यतीत करते थे। इस वर्ग के लोग जयंती पशुओं का नाश करते थे तथा फसल को क्षति पहुंचाने वाली चिड़ियों से भूमि को मुक्त रखने में सहायक होते थे। ये लोग राजा को कर रूप में पशु देते थे और सेवा के बदले अनाज पाते थे।[12]

चतुर्थ वर्ग कारीगर लोगों का था। इसमें कुछ कवच बनाने वाले और कुछ उन विविध उपकरणों को बनाते हैं, जिनका किसान व अन्य व्यवसायी लोग उपयोग करते हैं। पाँचवी जाति सैनिकों की है। यह भलीभाँति संगठित

Principal
Dyal Singh College
KARNAL

तथा युद्ध के लिए सुसज्जित रहती है। संख्या में इसका दूसरा स्थान है। शान्ति के समय यह आलस्य और आमोद-प्रमोद में मस्त रहती है। सारी सेना, योद्धा सैनिक, युद्ध के घोड़े-हाथी सबका राजकीय खर्च से पालन होता है।[13]

छठे वर्ग में विभिन्न राजकीय विभागों के निरीक्षण हेतु नियुक्त पदाधिकारी सम्मिलित थे। इसके अतिरिक्त इस वर्ग में अनगिनत जासूस भी आते थे। ये जासूस महत्वपूर्ण बातों तथा प्रजा के विषय में गुप्त जानकारी प्राप्त करके राजा को निरंतर सूचना देते रहते थे।[14]सातवीं जाति सभासदों तथा अन्य शासनकर्ताओं की है। ये लोग राज्य कार्य की देखभाल करते हैं। संख्या की दृष्टि से यह जाति सबसे छोटी है, पर अपने चरित्र व बुद्धि के कारण सबसे प्रतिष्ठित है। इसी जाति से राज्य के मंत्रीगण, राज्य के कोषाध्यक्ष और न्यायकर्ता लिए जाते हैं। सेना के नायक व मुख्य शासक लोग प्रायः इस जाति से होते हैं।[15]

दासप्रथा:

मौर्यकालीन भारत में दास-प्रथा प्रचलित थी या नहीं - यह एक विवादास्पद प्रश्न है। मेगस्थनीज हमें बतलाता है कि भारत में दास नहीं थे। लेकिन अर्थशास्त्र में दास प्रथा और दास्य-मुक्ति से संबंधित विस्तृत नियमों को सूत्रबद्ध किया गया है।[16] उन दिनों दास थे इसमें कोई संदेह नहीं है। अशोक ने

Principal
Dyal Singh College
KARNAL

अपने नवें शिलालेख के प्रज्ञापन में दासों एवं नौकरों की स्पष्ट चर्चा की है। कौटिल्य के अर्थशास्त्र में दासों की महत्त्वपूर्ण व्यवस्थाओं के विषय में वर्णन है।[17] कौटिल्य ने कई प्रकार के दासों का वर्णन किया है, यथा ध्वजाहृत (युद्ध में बन्दी), आत्मविक्रयी (अपने को बेचने वाला), उदरदास (गर्भदास, जो दास द्वारा दासी से उत्पन्न हो), आहितिक (ऋण के कारण बना हुआ), दण्डप्राणित (राजदण्ड के कारण) और आत्मधाता (अपने आपको दास के रूप में धनी व्यक्ति के पास बन्धक रखने वाला)।[18] अशोक के लेखों में दासों का उल्लेख है। इसके विपरित मैगस्थनीज के अनुसार समस्त भारतवासी स्वतंत्र है। उनमें कोई भी दास नहीं है। भारतीय विदेशियों तक को दास नहीं बनाते, अपने देशवासियों की तो बात ही क्या है। परन्तु इस विवरण के बावजूद अर्थशास्त्र के प्रमाण के आधार पर यह कहा जा सकता है कि भारत में दास प्रथा विद्यमान थी। किन्तु यहाँ दासों की स्थिति प्राचीन रोम व यूनान के दासों की अपेक्षा बहुत अच्छी थी। उनके प्रति मानवीय आचरण किये जाते थे। अशोक अपने अभिलेखों में दासों व सेवकों के प्रति उचित व्यवहार किये जाने का आदेश देता है। लगता है इसी कारण यूनानी लेखकों को यहाँ दास प्रथा दिखाई नहीं दी।[19]

Principal
Dyal Singh College
KARNAL

स्त्रियों की स्थिति:

परिवार में स्त्रियों की स्थिति स्मृतिकाल की अपेक्षा मौर्य काल में अधिक सुरक्षित थी। उन्हें पुनर्विवाह तथा नियोग की अनुमति थी। किन्तु फिर भी स्त्रियों की स्थिति को अधिक उन्नत नहीं कहा जा सकता। उन्हें बाहर जाने की स्वतंत्रता नहीं थी और पति की इच्छा के विरूद्ध वो कोई कार्य नहीं कर सकती थी। संभ्रांत घर की स्त्रियाँ प्राय: घर के अन्दर ही रहती थी।[20] मौर्यकाल में कुशल तीरन्दाज तथा खड्ग विद्या में प्रशिक्षित स्त्रियों को चन्द्रगुप्त मौर्य द्वारा अंगरक्षिकाओं के रूप में नियुक्ति मौर्यकालीन स्त्री दशा का प्रतिनिधत्व करती है। सुविधा प्राप्त वर्ग की श्रेणी में निम्नवर्ग की स्त्रियों को स्थान पाने का सुअवसर दिखाई देता है।[21]

स्मृतियों में वर्णित आठों प्रकार के विवाह इस समय समाज में प्रचलित थे। तलाक की प्रथा भी प्रचलित थी। पति के बहुत समय तक विदेश में रहने या उसके शरीर में दोष होने पर पत्नी उसका त्याग कर सकती थी। इसी प्रकार पत्नी के व्याभिचारिणी होने या बान्ध्या होने जैसी दशाओं में पति उसका परित्याग करने का अधिकारी था। पति की मृत्यु हो जाने पर स्त्री अपना पुनर्विवाह करने के लिए स्वतंत्र थी। विवाहिता स्त्री के उपहार तथा आभूषण उसकी अपनी संपत्ति होती थी। पति के अत्याचारों के विरूद्ध पत्नी न्यायालय में

Principal
Dyal Singh College
KARNAL

जा सकती थी। स्त्रियों के साथ अन्याय अथवा अत्याचार करने वाले राज्य की ओर से दण्डित किए जाते थे।[22]

राजमहल में नियुक्त स्त्रियाँ या तो अन्त:पुर में काम करती थी या वे राजा की देखभाल का कार्य करती थी। राजा के निजी सेवकों में स्त्रियाँ भी थी। अर्थशास्त्र में इसकी पुष्टि होती है। अन्त:पुर की स्त्रियों को बाहर जाने की आज्ञा जल्दी नहीं मिलती थी। दुराचारिणी पत्नियों के लिए अत्याधिक कठोर दण्ड निर्धारित थे। बुनाई विभाग के अध्यक्ष को राजकीय आदेश था कि राजकीय बुनाई विभाग में उन निर्धन स्त्रियों को नियुक्त किया जाए, जिसमें विधवा, अपाहिज, अनाथ, भिखारिन अर्थदण्ड देने में असमर्थ रहने वाली स्त्रियाँ, वेश्याएँ एवं उच्च वर्णों की कोई कष्ट ग्रस्त स्त्री हों।[23] इस युग में भी बहुत-सीस्त्रियाँ ऐसी थी जो विवाह द्वारा पारिवारिक जीवन न बिताकर गणिका या वेश्या के रूप में जीवन यापन करती थी। वे अनेक प्रकार से राजा का मनोरंजन करती थी। स्वतंत्र रूप से वेश्यावृति करने वाली स्त्रियाँ 'रूपजीवा' कहलाती थी। इनसे राज्य को आय होती थी। इनके कार्यों का निरीक्षण गणिकाध्यक्ष तथा एक राजपुरुष करता था। बहुत-सी गणिकाएँ गुप्तचर विभाग में भी कार्य करती थी।[24]इस युग में कुछ स्त्रियाँ राजकीय कार्यों में भी भाग लेती थी। प्रयाग लघु स्तम्भ लेख के अनुसार अशोक की द्वितीय पत्नी तीवर की माता कारवाकी के द्वारा दान दिए जाने का वर्णन है। अशोक की पत्नी

Principal
Dyal Singh College
KARNAL

तिष्यरक्षिता को चिकित्सा के क्षेत्र में काफी जानकारी थी। उसने बीमार अशोक की जान बचाई थी और पुरस्कारस्वरूप सात दिनों के लिए मौर्य सम्राज्ञी बनी थी।[25]

मनोरंजन के साधनः

मौर्य काल में लोग अनेक साधनों द्वारा अपना मनोरंजन करते थे। रथ-दौड़, घुड़-दौड़, साँड-युद्ध, हस्ति-युद्ध आदि मनोविनोद के साधन थे।[26] अर्थशास्त्र के अनुशीलन से ज्ञात होता है कि मौर्यकाल में बहुत से ऐसे लोग भी थे, जिनका पेशा लोगों का आमोद-प्रमाद करना तथा तमाशे दिखाना होता था। ये लोग एक स्थान से दूसरे स्थान पर तमाशे दिखाते हुए घुमते रहते थे। अर्थशास्त्र में ऐसे नट, नर्तक, गायक, वादक, वाग्जीवक (तरह-तरह की बोलियां बोलकर आजीविका कमाने वाले), कुशीलक, सबक (रस्सी पर नाचने वाले)सौभिक (मदारी) और चारणों का उल्लेख किया गया है। ये सब शहर या गाँव के बाहर तमाशे दिखाया करते थे। तमाशा के लिए इन्हें लाईसैंस लेना पड़ता था। इसके लिए राज्य को कर के रूप में पाँच पण दिए जाते थे। अनेक बार तमाशे का प्रबंध ग्राम की तरफ से भी होता था। इस दशा में ग्राम के लोग अपनी तरफ से हिस्सा डालते थे। जो हिस्सा न डाले, उसे तमाशे में शामिल होने का अधिकार नहीं होता था।[27]

Principal
Dyal Singh College
KARNAL

कौटिल्य के अनुसार ये नट, नर्तक, वादक आदि जनता के कार्य में विघ्न डालने वाले होते हैं। अत: ऐसी व्यवस्था की जानी चाहिए जिससे कि ये कार्य विघ्न न कर सकें, क्योंकि ग्राम प्राय: निराश्रय होते हैं और निजी खेती पर ही अपनी आजीविका के लिए आश्रित रहते हैं। अत: नट, नर्तक आदि को ग्रामों में जाकर लोगों के कार्य में विघ्न नहीं डालने देना चाहिए।[28]

शिकार खेलने का उस समय रिवाज था। मैगस्थनीज के अनुसार 'जब राजा शिकार के लिए राजप्रसाद से निकलता है, तो स्त्रियों की भीड़ उसे घेरे रहती है। उनके घेरे के बाहर बरछे वाले रहते हैं। मार्ग का चिह्न रस्सों से डाला जाता है। इन रस्सों के भीतर जाना स्त्री या पुरुष सब के लिए मृत्यु को निमन्त्रण देना है। ढोल और झाँझ लेकर आदमी इस दल के आगे-आगे चलते हैं। राजा घेरे के भीतर से शिकार खेलता है और चबूतरे से तीर चलाता है। उसके बगल में दो या तीन हथियारबंद स्त्रियाँ खड़ी रहती थी। यदि वह खुले मैदान में शिकार करता है, तो वह हाथी की पीठ से तीर चलाता है। स्त्रियों में कुछ तो रथ के भीतर रहती हैं, कुछ घोड़ों पर कुछ हाथियों पर। वे हर प्रकार के शस्त्रों से सुसज्जित रहती है, मानों वे किसी चढाई पर जा रही हों।' केवल आमोद-प्रमोद के लिए मौर्य सम्राट जो शिकार यात्रा करते थे, यह उसी का वर्णन है। उस युग में शिकार के लिए पृथक रूप से वन सुरक्षित रखे जाते थे। राजा के विहार के लिए ऐसे जंगल भी

Principal
Dyal Singh College
KARNAL

होते थे, जिसके चारों ओर खाई खुदी रहती थी और इनमें प्रवेश के लिए एक ही द्वार होता था इसमें शिकार के लिए पशु पाले जाते थे, राजा इसमें स्वछंद रूप से शिकार खेल सकता था।[29] ब्रह्मा और पशपुति शिव के उपलक्ष्य में समाजों का आयोजन किया जाता था। इन समाजों में मनुष्य और हाथियों के युद्ध, रथों की दौड़ आदि होती थी। अशोक ने मनुष्यों और पशुओं के युद्ध बन्द कर दिए, क्योंकि उनमें व्यर्थ रक्तपात होता था। पतंजलि ने नाटकों के अभिनय का वर्णन किया है। जुआ और शतरंज जैसे खेल भी खेले जाते थे।[30]

खानपान व पहनावा

यूनानी लेखकों के अनुसार भारतीय सादा जीवन बिताते और शान्ति से रहते थे।[31] उनके भोजन में अन्न, फल, दूध मांस शामिल थे। अन्नों में गेहूँ, चावल तथा जौ का प्रयोग होता था। मेगस्थनीज ने भारतीयों के खाने के ढंग का वर्णन इस प्रकार किया है - ''जब वे खाने बैठते हैं तो उनके सामने तिपाई के आकार की एक मेज रख दी जाती है। उसके ऊपर एक सोने का एक प्याला रखा जाता है। इसमें सर्वप्रथम चावल डाला जाता है। इसके बाद भोजन के अन्य पकवान एवं पदार्थ परोसे जाते हैं, जो भारतीय विधि द्वारा तैयार किए जाते हैं।''[32]एक अन्य स्थान पर यूनानी यात्री ने लिखा है - ''वे सदैव अकेले में भोजन करते हैं। वे कोई ऐसा नियत समय नहीं रखते, जबकि इकट्ठे मिलकर भोजन किया जाए। जिस समय उनकी इच्छा होती है, [illegible]

Principal
Dyal Singh College
KARNAL

भोजन कर लेता है।[33] यद्यपि सामान्य रूप से भारतीय चावल व सूप का भोजन के रूप में प्रयोग करते थे, पर कौटिल्य अर्थशास्त्र में अन्य भी अनेक अन्नों, सब्जियों और मांस आदि का भोजन के रूप में उल्लेख हैं।[34]

उस युग में बहुत से पशु, पक्षी, मछली आदि जन्तुओं को भोजन के लिए मारा व बेचा जाता था। मांस को सुखाकर भी रखा जाता था। अशोक के प्रयत्नों से प्राचीन भारत में मांस का उपयोग कुछ कम अवश्य हुआ, पर बौद्ध-धर्म स्वीकार करने के बाद भी अशोक के महानस (रसोई) में मांस बनना और उसके लिए पशु हत्या जारी रही थी।[35] प्रथम वृहत शिलालेख के अनुसार ''पहले देवताओं के प्रियदर्शी राजा की पाठशाला में प्रतिदिन कई हजार जीव सूप (शोरबा) बनाने के लिए मारे जाते थे, पर अब जबकि यह धर्मलेख लिखा जा रहा है, केवल तीन ही जीव प्रतिदिन मारे जाते हैं, दो मोर और एक मृग, पर मृग का मारा जाना निश्चित नहीं है। भविष्य में ये तीनों प्राणी भी नहीं मारे जाएंगे।''[36]

शराब का प्रचार भी मौर्य काल में बहुत था। शराब के बेचने तथा पीने के लिए बड़ी-बड़ी दुकानें होती थी, जिनमें अलग-अलग कमरे बने होते थे। प्रत्येक कमरे में सोने के लिए अलग-अलग बिस्तरे बिछे होते थे। इन सुन्दर सुसज्जित कमरों में विदेशी तथा भारतीय लोग शराब का आनन्द लेते थे। शराब केवल शराबखानों में ही पी जा सकती थी। बाहर जाकर उसे पीने की

Principal
Dyal Singh College
KARNAL

अनुमति नहीं थी। शराब का सेवन भारत में बहुत मर्यादित था। इसी कारण मेगस्थनीज यह लिख सका था कि भारतीय लोग मदिरा नहीं पीते। उनके अनुसार मदिरा का सेवन केवल यज्ञों में ही होता था।।[37]

मौर्य युग में वस्त्र-व्यवसाय, बहुत उन्नत था। ऊन, रेशम, सन, कपास और विविध वृक्षों व वनस्पतियों के रेशों के नानाविध वस्त्र उस युग में तैयार किए जाते थे। कौटिल्य अर्थशास्त्र में तुन्नवाय (दर्जी) शब्द का प्रयोग हुआ है। दर्जी कैसे कपड़े सीते थे, और मौर्यो के शासन काल में संपन्न व सर्वसाधारण लोग किस ढंग के कपड़े पहनते थे, इसे जानने को अभी हमारे पास कोई साधन नहीं है। हमें मैगस्थनीज के विवरण से ही संतुष्ट रहना पड़ता हैं, जिसमें कि उसने सिर पर धारण की जाने वाली पगड़ी और मलमल के महीन वस्त्रों का जिक्र किया है।[38] चीन भूमि के कौशेय (रेशमी वस्त्र) तथा नेपाल के कम्बल का उल्लेख मिलता है। चर्म उद्योग भी उन्नति पर था। एरियन ने भारतीयों द्वारा श्वेत चमड़े के जूते पहने जाने का उल्लेख किया है जो काफी सुन्दर होते थे।[39]

रीति-रिवाज व स्वभावः

मेगस्थनीज ने भारतवासियों के चरित्र व व्यक्तित्व की बड़ी प्रशंसा की है। भारतीय सत्य बोलने वाले व गुणी है। आचरण में वे सरल मितव्ययी है।

Principal
Dyal Singh College
KARNAL

अच्छे नियमों का पालन करते है। अपनी सम्पत्ति को वे बहुधा आरक्षित अवस्था में ही छोड़ जाते हैं। वे न्यायलयों की शरण यदा-कदा लेते है। भारतवासियों पर मिथ्या भाषण का आरोप नहीं लगाया जा सकता। वे सन के सघन बुने हुए कपड़ों पर पत्र लिखते है। पेड़ों की छाल लिखने के काम आती है। सत्य और गुण का आदर भारत में होता है।[40] उनमें व्यायाम करने की सर्वप्रिय रीति संघर्षण है। यह कई प्रकार से किया जाता है, पर संघर्षण प्राय: चिकने आबनूस के बेलनों का त्वचा पर फेर कर होता है।[41]

निष्कर्ष: इस प्रकार मौर्य काल में यूनानी व भारतीय साक्ष्यों के अनुसार भारतीय एक अन्य आदर्श जीवन जीते थे। यूनानी लेखकों के अनुसार भारतीय मितव्ययी व सादा जीवन जीने वाले थे अनेक साधनों द्वारा अपना मनोरंजन करते थे। समाज चार वर्णों में बंटा हुआ था। मेगस्थनीज भारतीय समाज का सात वर्णों में बंटा बताता है। सूत्रकाल की अपेक्षा महिलाओं की दशा इस समय अच्छी कही जा सकती है। सम्राट चन्द्रगुप्त की अंगरक्षिकाएँ महिलाएं थी। इस समय लोग शाकाहारी भोजन करते थे लेकिन यूनानी लेखकों के अनुसार समारोहों व उत्सवों के समय मांसाहार व मदिरापान भी किया जाता था। भारतीय सत्य व गुणों का आदर करते थे। इस प्रकार इस समय भारत के लोग एक अच्छा जीवन यापन कर रहे थे व समाज में शान्ति व भाईचारे का वातावरण था।

Principal
Dyal Singh College
KARNAL

ग्रन्थ संदर्भ सूची:

1. श्रीवास्तव, के.सी. : ''प्राचीन भारत का इतिहास एवं संस्कृति'', यूनाइटेड बुक डिपो, इलाहाबाद 1991, पृ. 265
2. झा, द्विजेन्द्र नारायण, श्रीमाली, कृष्णमोहन : ''प्राचीन भारत का इतिहास'', दिल्ली विश्वविद्यालय, दिल्ली, 1981, पृ. 198
3. विद्यालंकार, सत्यकेतु : ''मौर्य साम्राज्य का इतिहास'', श्री सरस्वती सदन, मसूरी, 1970, पृ. 367
4. कुमार, रंजन : ''भारत की कला एवं संस्कृति के विकास में मगध का योगदान'', आर्यवर्त शोध विकास पत्रिका, वॉल्यूम-13, इश्यु-17, सितम्बर 2020, पृ. 60
5. ओमप्रकाश : ''प्राचीन भारत का इतिहास'', विकास पब्लिकेशन्स दिल्ली, 1971, पृ. 144
6. वही : पृ. 145
7. अर्थशास्त्र : 1/3
8. विद्यालंकार, सत्यकेतु : पूर्वोक्त, पृ. 384

Principal
Dyal Singh College
KARNAL

9. गोयल, श्रीराम : ''नन्द-मौर्य साम्राज्य का इतिहास'', कुसुमांजलि प्रकाशन, मेरठ, 1988, पृ. 211

10. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'', हिन्दुस्तानी एकेडेमी, इलाहाबाद, 1949, पृ. 305

11. वही : पृ. 306

12. गोयल, श्रीराम : पूर्वोक्त, पृ. 212

13. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'',पूर्वोक्त, पृ. 306-07

14. गोयल श्रीराम : पूर्वोक्त, पृ. 212-13

15. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'',पूर्वोक्त, पृ. 307

16. झा, डी.एन. : ''प्राचीन भारत : एक रूपरेखा'', पीपुल्स पब्लिशिंग हाउस, नई दिल्ली, 1980, पृ. 72

17. प्रसाद, ओमप्रकाश, गौरव, प्रशान्त : ''प्राचीन भारत का सामाजिक एवं आर्थिक इतिहास'', राजकमल प्रकाशन, नई दिल्ली, 2006, पृ. 72-73

18. श्रीवास्तव, के.सी. : पूर्वोक्त, पृ. 157-58

19. वही : पृ. 157

Principal
Dyal Singh College
KARNAL

20. झा, द्विजेन्द्र नारायण, श्रीमाली, कृष्ण मोहन : पूर्वोक्त, पृ. 208

21. प्रसाद, ओमप्रकाश, गौरव, प्रशान्त : पूर्वोक्त, पृ. 86

22. श्रीवास्तव, के.सी. : पूर्वोक्त, पृ. 266-67

23. प्रसाद, ओमप्रकाश, गौरव, प्रशान्त : पूर्वोक्त, पृ. 86

24. झा, द्विजेन्द्र नारायण, श्रीमाली, कृष्ण मोहन : पूर्वोक्त, पृ. 199

25. प्रसाद, ओमप्रकाश, गौरव, प्रशान्त : पूर्वोक्त, पृ. 86

26. श्रीवास्तव, के.सी. : पूर्वोक्त, पृ. 267

27. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'',पूर्वोक्त, पृ. 327

28. अर्थशास्त्र : 2/2, कांगले, आर.पी. द्वारा संपादित, बम्बई, 1968

29. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'',पूर्वोक्त, पृ. 327-328

30. ओमप्रकाश : ''प्राचीन भारत का इतिहास'', विकास पब्लिकेशन्स, दिल्ली, 1971, पृ. 145

31. वही : पृ. 144

32. श्रीवास्तव, के.सी. : पूर्वोक्त, पृ. 267

Principal
Dyal Singh College
KARNAL

33. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'', पूर्वोक्त, पृ. 314

34. विद्यालंकार, सत्यकेतु : ''मौर्य साम्राज्य का इतिहास'', पूर्वोक्त, पृ. 401

35. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'', पूर्वोक्त, पृ. 315

36. भट्ट, जनार्दन : ''अशोक के धर्म लेख'', पब्लिकेशन डिवीजन, दिल्ली, 1957, पृ. 56

37. विद्यालंकार, सत्यकेतु : ''पाटलीपुत्र की कथा'', पूर्वोक्त, पृ. 326

38. विद्यालंकार, सत्यकेतु : ''मौर्य साम्राज्य का इतिहास'', पूर्वोक्त, पृ. 408

39. श्रीवास्तव, के.सी. : पूर्वोक्त, पृ. 268

40. यादव, रजनी : ''प्राचीन भारत का इतिहास'', डिस्कवरी पब्लिशिंग हाऊस प्राईवेट लिमिटेड, नई दिल्ली, 2010, पृ. 147

41. विद्यालंकार सत्यकेतु : ''पाटलीपुत्र की कथा'', पूर्वोक्त, पृ. 316



Principal
Dyal Singh College
KARNAL

IMPACT FACTOR : 5.25

ISSN 2250-0561

GLIMPSES

(A Peer-Reviewed Bi-Annual Refereed International Journal of Multi Disciplinary Research)

Abstracted & Indexed at- Ulrich, U.S.A

Vol. 13, No. 1 | DECEMBER, 2023

ICI WORLD of JOURNALS

UGC Approved Journal
UGC
Jr.No. 48755

COSMOS IMPACT FACTOR

GLIMPSES Vol. 13, No. 1 DECEMBER, 2023

ISSN 2250-0561

Editor-in-Chief :
Prof. (Dr.) Ram Sharma

Rumination Literary and Cultural Society (Regd.)
C-26, Shradhapuri Phase-2, Meerut (U.P.) India

Principal
Dyal Singh College
KARNAL

CONTENT

1. मानव मूल्य और शान्ति : एक अध्ययन 25
   – **अतर सिंह**

2. Corporate Finance 36
   – **Dr. Rahul Kumar**

3. Employee Development and Training 49
   – **Dr. Neelima Kumari**

4. इक्कीसवीं सदी में महिला सशक्तिकरण 62
   – **डॉ. प्रिया सिंह**

5. Female Sufferings in the Selected Novels of Shashi Deshpande 71
   – **Dr. Narendra Singh**

6. The Cross-Cultural Experience of Women Protagonists: A Study of Bharati Mukherjee's Selected Fictional Works 79
   – **Dr. K. Prabakar, Dr. R. Krishnaveni**

7. मेरी माटी मेरा देश 89
   – **कुमुद दूबे**

8. आधुनिक पर्यावरण चिंतनः एक वैदिक दृष्टिकोण 92
   – **डॉ. कुसुमलता**

9. Environmental Sustainability through Gandhian Lens: A Study of Ecological Wisdom in Today's Context 100
   – **Dr. Parveen Kumar, Dr. Vijay Chauhan**

Principal
Dyal Singh College
KARNAL

10. भारत-अमेरिका संबंध : एक विश्लेषणात्मक अध्ययन 110
– **डॉ. रचना सैनी**

11. India's Northeast and South East Asia: Historical and Civilisational Linkages 117
– **Dr. Anand Aran**

12. वैदिक साहित्य में जीवन मूल्य एवं मानवाधिकार 127
– **डॉ. पुष्पा देवी**

13. भारतीय बैंकिंग क्षेत्र-चुनौतियाँ एवं अवसर 138
– **डॉ. बबली चन्द्रा**

14. Importance of Animal Husbandry in Rural Economy of Rajasthan 149
– **Dr. Shravan Raj**

Principal
Dyal Singh College
KARNAL

ENVIRONMENTAL SUSTAINABILITY THROUGH GANDHIAN LENS: A STUDY OF ECOLOGICAL WISDOM IN TODAY'S CONTEXT

DR. PARVEEN KUMAR
Assistant Professor, Department of History,
Dyal Singh College, Karnal
DR. VIJAY CHAUHAN
Assistant Professor, Department of Political Science,
M.P.N College, Mullana (Ambala)

ABSTRACT

Mahatma Gandhi, a towering figure in the realms of political and social philosophy, left behind a rich legacy that extends beyond the realms of political independence. Gandhi's ideology, deeply rooted in principles of simplicity, self-sufficiency, and non-violence, finds a surprisingly contemporary resonance when applied to the pressing issue of environmental sustainability. As our world grapples with unprecedented ecological challenges, ranging from climate change and biodiversity loss to pervasive pollution, the need for alternative perspectives and sustainable solutions becomes increasingly evident. In this study, we delve into Gandhian ecological wisdom, exploring how his principles offer a profound lens through which to address the complex environmental issues

Principal
Dyal Singh College
KARNAL

of our time. Gandhi's reverence for nature, manifested in his respect for all living beings, lays the foundation for a holistic understanding of environmental well-being. His advocacy for self-reliance, minimalism, and sustainable living emerges as a prescient prescription for a world in need of ecological balance. The concept of "Sarvodaya," or welfare for all, takes on new significance when applied to the interconnected web of life on Earth. This research endeavors to unravel the timeless relevance of Gandhian principles and their potential to inform and inspire contemporary approaches to environmental sustainability. By delving into the intricacies of Gandhi's ecological philosophy, we seek to illuminate pathways that lead towards a more harmonious coexistence between humanity and the natural world.

INTRODUCTION

Individuals around the world have various ideas on what development is. While some view it as an economic activity, others see it as merely necessary for a person's or a community's socio-cultural and personal well-being. Everywhere we look, the phrase "development" is relative. The actual issue is that there are differences in how persons are conceptualized. The idea of development has helped humanity come to new insights, breaking down old and conservative boundaries in the process. But given the current circumstances, it is imperative that the concept of development be reexamined and that a fresh interpretation of it be created. The enormous "Cognitive Revolution" that occurred in the homo sapiens species is a hallmark of the arrival of man. Our species has been able to adapt and organize itself into the intricate socio-political and geographical domains because of this. It has also been elevated to

Principal
Dyal Singh College
KARNAL

a new level by the concepts of identity and nationality.[1] Our understanding of the developmental idea as a whole has been significantly impacted by the emergence of the idea of the nation state. Humans are inherently superior, and this is constantly reinforced by the genetic code. Human DNA has been evolving into ever-more-advanced combinations in order to enhance adaptive capacities. The fact that the human species has survived and is continuing surviving in harsh environments makes this especially clear. Given that the developmental notion has been the driving force behind the enormous advancements made by mankind in the name of development and progress, the current trend makes it abundantly clear that the entire process depends upon it.

The current rate at which the world is changing makes it clearly a concern since many things are at stake.[2] The environment has been a great concern in today's world hence the idea of sustainability has been in vogue. The sustainable view of development aims for a balanced approach so that progress cannot be at the cost of the environment and hence this new idea has been the reason for a positive change in the world. The industrial revolution has brought about a great change in the lifestyles of the people but the results have been devastating for people and communities around the world. Gandhi has been a great inspiration for millions of people around the world and his ideas have been instrumental in shaping billions of lives.[3] The idea of Gandhi was simple and unique in the same time While the world around him was talking of fast paced progress a the name of development, Gandhi was of the view that development was not only about personal or material benefits but it had to liberate the people from the shackles of penury and servitude This has been the aim of every welfare state that has been active in its pursuit of this goal.

Principal
Dyal Singh College
KARNAL

WHAT IS SUSTAINABLE DEVELOPMENT?

A method of human growth known as "sustainable development" strives to meet human needs while protecting the environment so that these needs can be satisfied for both the present and future generations. The 1987 study "Our Common Future" by the Brundtland Commission popularized the phrase. Sustainable development, according to the report, is development that "meets the present without compromising the ability of future generations to meet their own needs."Sustainable development involves finding a balance between economic, social, and environmental considerations. It recognizes the interconnectedness of these aspects and seeks to create a harmonious and lasting development path. Sustainable development goals often include poverty reduction, social inclusion, environmental protection, and economic prosperity.[4] The United Nations has established Sustainable Development Goals (SDGs) as a universal call to action to address various global challenges and work toward a more sustainable future by 2030.

Among the fundamental ideas of sustainable development are:

Environmental Sustainability: Ensuring that natural resources be used in a way that does not eventually deplete or harm them is known as environmental sustainability. This entails actions that lessen pollution and encourage conservation.

Social Equity: Social equity is the promotion of social cohesion and the guarantee that progress benefits every member of society without the exclusion or detriment of any particular group.

Economic Viability: Supporting long-term, financially feasible economic growth and development without draining resources or creating economic instability is known as economic viability.

Inter-generational Equity: Intergenerational equity is making decisions that do not jeopardise the ability of future generations to

Principal
Dyal Singh College
KARNAL

meet their own requirements by taking their wants and interests into account.

Gandhian Idea of Environmental Sustainability: Gandhi believed that the earth was a living thing. He used the Law of Species and Cosmic Law, two fundamental laws, to explain his points of view. According to Cosmic Law, the universe is one single entity. Beyond the threshold boundaries incorporated into the grand system, which encompasses both living and non-living phenomena, nothing could malfunction. He believed that "the universe was structured and informed by the cosmic spirit, that all men, all life and indeed all creation were one." He wrote: "I believe in the Advaita (non-duality), I believe in the essential unity of man and for that matter, of all that lives. Therefore, I believe that if one man gains spiritually, the world gains with him, and if one man fails, the whole world fails to that extent."Gandhi held that evolution is impossible without the collaboration of both non-human and human species, according to the rule of species. As sane humans, we should respect the rights of all living things and value diversity because we are the stewards of the rest of creation. This is the reason why taking more resources than necessary is considered theft. Gandhi's study and comprehension of many religious systems, including Islam, Christianity, Jainism, and Hinduism, helped him to formulate these ideas.[5] His conceptions of politics, economy, and society were based on the assumption that everything in the cosmos is interdependent.In the contemporary sense, Gandhi was not an environmentalist. He did not write poetry about the natural world or develop a green philosophy, but he is frequently referred to as a "apostle of applied human ecology."Although there were not many environmental issues during Gandhi's lifetime, renowned environmental writers such as Ramachandra Guha regard Gandhi as an early environmentalist.[6] His articles contain a variety

Principal
Dyal Singh College
KARNAL

of opinions about nature. His views on development, simplicity of living, and Satyagraha—which is founded on truth and non-violence—show how sustainable growth is achievable without endangering the environment or other living things. His belief that "nature has enough to satisfy everyone's needs, but not to satisfy anybody's greed" served as the foundation for contemporary environmentalism's ethical platform.

Gandhi's Ethical Approaches to Save Our Home Planet Earth: Regarding the preservation of our planet Earth and its resources for future generations, Gandhi's revolutionary ideas, his practice of a yogic-centered way of life, his spiritual understanding of self-realization, his moral value of non-violence, and the sustainable development of society, all represent a comprehensive approach.[7] The 'Autobiography' of Gandhi shows that he was indeed a practicing ecological yogi. Although he himself did not say anything about his yoga practice of yogas. In simple words, Yoga means discipline and control over body and mind through two types of practices. One is Hat yoga, and the other is Raj yoga. There are eight formal disciplines in the practice of Raja yoga, and the first two are 'Yamas and Niyamas.' These two are pertained to human-earth relationship and ethics of resource use. These were practiced and preached by Mahâtmâ Gandhi.

The 'Yamas' are ethical commandments or principles that regulate the behavior of humans toward other human beings, non-human creatures, and non-living materials. The five Yamas, according to Yogashastra are, the first is non-violence that approaches toward sentient and non-sentient beings.[8] The other is Truth, the source of everything. He pervades all there is on the earth, nothing belongs to humans as their property, and they can only use them as a trustee.[9] Since God is the master of everything which human beings possess. The third is non-stealing, avoiding destruction or damage. The fourth

Principal
Dyal Singh College
KARNAL

is celibacy, to live in spiritual manner and avoid sexual relations to control growing population otherwise demand on resources will increase.[10] The last is non-possession means not desiring or amassing materials and wealth beyond requirement. The use of resources is based on Gandhi's philosophy of 'need' base not for 'luxury' base.The evolution of Gandhi's thought and philosophy is marked by its diversified dimension.

Mahatma Gandhi wished to see a society to be based on non-violent social order and peace which should extend ultimately to the whole world. This he begins to test in no other land rather than in his own country. He believes that poverty and exploitation was rampant in all societies whether it is east or west, south or north, this he himself witnessed in England, South Africa as well as in his own country.[11] Moreover he experiences the ills of industry, the bad condition of labour, the profit motive of the capitalist class and mill owners, the military might and so on. His main venture is to establish a society of class collaboration based on equality so that everyone should earn his livelihood according to his need. His socio-political as well as moral philosophy is intertwined to his economic thought in such a way that where the interest of everyone is protected whether man or nature, whether living or non-living and more particularly his philosophy provides a clue to resolve many of our present day problems like environmental issues, conflict resolution etc.

The Sustainable Development Goals (SDGs) goals are a big thing in the current world and hence this is a big achievement for the people of the world that the Millennium Development Goals (MDGs) have now been given a new lease of life through the same. The MDGs were more specific or rather concentrated on the efforts of the developed world and hence it presented a halfway to the goal of eradicating hunger and poverty. The SDGs however have a more

Principal
Dyal Singh College
KARNAL

inclusive approach of educating and empowering people and communities of the world so that their lives can change for the betterment of their condition. The concept of sustainability is increasingly discredited as a useful concept by itself, it appears to be serving some purpose when preceded by a delineating modifier like "ecological" or "agricultural" or "economic." Efforts have been made by members of various professions to give meaning to the term within the context of those respective professions.Callicott and Mumford, for example, develop the meaning of the term "ecological sustainability" as a useful concept for conservation biologists; In "Ecological Sustainability as a Conservation Concept," these authors advance an ecological definition of sustainability that connects human needs and ecosystem services: "meeting human needs without compromising the health of ecosystems." They propose this concept as a guiding principle for areas where human activities take place. Mahatma Gandhi dedicated his entire life to upholding the principles and ideals he held dear because he was a ray of hope for millions of people worldwide.[12] The SDGs, which were put forth by eminent scholars worldwide, had a striking resemblance to Gandhi's philosophy of freedom. Gandhi's primary goals were village republics and character development, and he worked very hard to achieve both. Leaders worldwide have always aimed to eradicate poverty and hunger, and initiatives have been designed for the same in various roles. The globe has been a major obstacle to the same. has been overly preoccupied with pursuing financial success.The single biggest factor contributing to the industrial and technological revolutions—which specifically brought about advances in the fields of communications, transportation, health, and technology—was the rise of capitalism. The quest for immortality has intensified due to the arrival of the IT revolution and nanotechnology. The average lifespan

Principal
Dyal Singh College
KARNAL

has grown, diseases like the black plaque have been understood, and medications have given billions of people worldwide a fresh start. Newborns are born healthier, and food production has reached entirely new heights. Vegetables and fruits are available everywhere.

CONCLUSION

It also calls for intense self-control, soul-force development, and training." Gandhiji felt that the best and most efficient way to achieve Sarvodaya is spiritually via the practice of Satyagraha, or holding fast to the Truth and Nonviolence even at the expense of great personal pain or even death. Gandhian Satyagraha is frequently used as a method of resolving disputes. "Self-giving, self-control, and self-suffering are prime requisites" for achieving Sarvodaya, according to Gandhiji. Gandhi is not primarily significant as an environmentalist because of his vision and accurate assessment of the interdependence of man and nature. He tried sincerely to apply his perceptions to the real world. The perception of informed people and the general public in society has been surveyed for the current study.

REFERENCES

1. Barua A. 2015 Towards a Philosophy of Sustainability: The Gandhian Way. Sociology and Anthropology.; 3(2): 136–143.
2. Bhikhu Parekh, 1989 Gandhi's Political Philosophy; A Critical Examination (London: Macmillan), p.72.
3. Gandhi, M. K., 1938. Hind Swaraj, Navajivan Publishing House, Ahmedabad, p.21
4. T. N. Khoshoo, Mahatma Gandhi and the Environment: Analysing Gandhian Environmental Thought.
5. M. K. Gandhi, The Essence of Hinduism, 150–51.
6. M. K. Gandhi, "Hind Swaraj or Indian Home Rule," in On Violence (United States: Duke University Press, 2020), p.110–26.

Principal
Dyal Singh College
KARNAL

7. Gandhi, M. K., 1954. Nature Cure, Navajivan Publishing House, Ahmedabad.p.31
8. Guha R. How Much Should A Person Consume? Permanent Black: The University of California Press, Berkeley; 2006.p.43
9. Kumar, S B., Environmental Problems and Gandhian Solutions, Deep and Deep Publications, New Delhi, 2002, p.21
10. Bhikhu, Parekh. 1997. Past Masters: Gandhi, Oxford New York.p.55
11. Haigh, "Deep Ecology Education: Learning from Its Vaisnava,"p. 50.
12. Arne. Naess, Self-Realization: An Ecological Approach to Being in the World (Murdoch: Murdoch University, 1984), 43.

❖❖❖❖

Principal
Dyal Singh College
KARNAL

Glimpses : A Bi-Annual International Journal of Multi Discipline research. It has been started to meet a long felt need of factual analysis and intensive research in multi disciplines.

Research Papers are welcome, these should be written in 2000 or 3000 words, prepared according to the latest MLA Handbook (9th ed.) style. Author's name should appear on the cover page only. Research Papers should be submitted in two hard copies along with a soft-copy, double-spaced throughout and accompanied by duly signed along with a self-addressed envelope. All papers submitted for publication will be evaluated by the journal's referees. For book reviews, two copies of the book should be sent to the Editor. For any enquiry, please feel free to call the following number:

Rumination Literary and Cultural Society (Regd.)

Prof. (Dr.) Ram Sharma

C-26, Shradhapuri Phase-2,
Kankerkhera, Meerut, U.P., India
Cell: +91-9219710874

E-mail: dr.ramsharma786@gmail.com
glimpsesjournal@gmail.com

Website: ruminationssociety.com

Subscription Charges of the Journal

	For Ind.	For Inst.
• For 5 years	Rs. 5,000/-	10,000/-
• For 3 years	Rs. 3,000/-	6,000/-
• Annual	Rs. 1,200/-	2,400/-

GLIMPSES Vol. 13, No. 1 DECEMBER, 2023

IMPACT FACTOR : 5.25

ISSN 2250-0561

GLIMPSES

(A Peer-Reviewed Bi-Annual Refereed International Journal of Multi Disciplinary Research)

Abstracted & Indexed at- Ulrich, U.S.A

Vol. 13, No. 1 | DECEMBER, 2023

ICI WORLD OF JOURNALS

UGC Approved Journal UGC Jr.No. 48755

COSMOS IMPACT FACTOR

ISSN 2250-0561

Editor-in-Chief :

Prof. (Dr.) Ram Sharma

Rumination Literary and Cultural Society (Regd.)

C-26, Shradhapuri Phase-2, Meerut (U.P.) India

Principal
Dyal Singh College
KARNAL

Our Journals

GLIMPSES

&

RUMINATIONS

have been Indexed by

I.A.O., Houston, U.S.A.

It's proud moment for us. Our Journals Ruminations and Glimpses have got Certificate of Accreditation from International Accreditation Organization, Houston (U.S.A.)



IAO

Certificate of Accreditation

This is to certify that

Dr. Ram Sharma

is accredited and recognized by the IAO complying with all the established professional and educational standards and criteria.

IAO confirms that Dr. Ram Sharma meets his/her quality of education responsibility to the students and to the education profession.

IAO

Accreditation Committee

GLIMPSES

ISSN 2250-0561

Guidelines for Contributors

Research Papers are welcomed. These should be written between 2000-3000 words, prepared according to the latest MLA Handbook (8th ed.) style. Author's name should appear on the cover page only. Research Papers should be submitted in two hard copies along with soft copy, double-spaced throughout and accompanied by duly signed along with a self-addressed envelope. All papers submitted for publication will be evaluated by the journal's referees. For book reviews, two copies of the book should be sent to the Editor.

Copyright © Dr. Ram Sharma

The Editor-in-chief reserves right to reprint/reproduce the papers/submission in any form.

The views expressed by the authors in their research papers, reviews etc. in this issue are their own. The Editor/Publisher is not responsible for them. All disputes concerning the journal shall be settled in the Court at Meerut, U.P., India.

DISCLAIMER

Papers published in this journal do not reflect the views or policies of the Editors. Respective authors are responsible for the originality of their views expressed in their papers.

Editors

Owned, Printed and Published by : Dr. Ram Sharma for Rumination Literary and Cultural Society (Regd.), C-26, Shradhapuri Phase-2, Kankerkhera, Meerut, U.P., India
Printed at : Sahil Printers, Meerut
Typesetting by : Shubham Computers, Meerut

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

Unveiling the Social Media Effect on Consumer Purchasing Decisions: Navigating the Digital Marketplace

Dr. Vandana Sabharwal
Assistant Professor, Dept of Commerce, Dyal Singh College, Karnal

Abstract:
In the digital age, the pervasive influence of social media platforms has transformed the landscape of consumer behaviour. This abstract delves into the multifaceted relationship between social media and consumer purchasing decisions, shedding light on the intricate dynamics that shape contemporary market interactions. Social media platforms serve as powerful tools for information dissemination, social interaction, and consumer engagement. With the ability to reach vast audiences in real-time, social media has become an integral component of modern marketing strategies. From brand awareness to product reviews, social media channels offer consumers a wealth of information and avenues for exploration. One of the most significant impacts of social media on consumer buying behaviour is its ability to shape perceptions and influence purchasing decisions. Through targeted advertisements, influencer endorsements, and user-generated content, social media platforms exert a profound influence on consumer preferences and product perceptions.

The prevalence of peer recommendations and social validation further amplifies the impact of social media on consumer choices, as individuals seek affirmation and validation from their social networks. Moreover, social media platforms facilitate seamless integration between online and offline shopping experiences, blurring the lines between physical and digital commerce. The rise of e-commerce platforms and social shopping features has transformed the way consumers discover, evaluate, and purchase products, creating new opportunities for brands to engage with their target audiences.

Keywords: social media, consumer behaviour, brand awareness

Research Objective

1. To identify the various social media websites which affect the consumer buying behaviour.
2. To identify the usage level of various social media websites in buying decision making process.

Introduction

In today's interconnected world, social media platforms have become pervasive in shaping various aspects of human interaction, including consumer purchasing behaviour. The influence of social media on consumer decisions has become a subject of intense scrutiny and interest among marketers, researchers, and businesses alike. As we delve into the complex relationship between social media and consumer purchasing decisions, it becomes evident that understanding this dynamic is essential for navigating the modern digital marketplace effectively.

"Unveiling the Social Media Effect on Consumer Purchasing Decisions: Navigating the Digital Marketplace" aims to explore the multifaceted impact of social media on consumer behaviour and its implications for businesses operating in an increasingly digital landscape. This study seeks to unravel the mechanisms through which social media platforms shape consumer preferences, influence product perceptions, and ultimately drive purchasing decisions. The proliferation of social media platforms has fundamentally transformed the way individuals discover, evaluate, and purchase products and services. From Facebook and Instagram to Twitter and TikTok, these platforms serve as hubs of information, social interaction, and commerce, offering consumers a vast array of content and opportunities for engagement. As such, businesses are compelled to understand and harness the power of social media to effectively reach and engage with their target audiences.

However, the impact of social media on consumer purchasing decisions is not uniform or straight
While social media platforms offer unprecedented opportunities for businesses to connect with co

Principal
Dyal Singh College
KARNAL

they also present unique challenges and complexities. Issues such as information overload, privacy concerns, and the spread of misinformation can undermine consumer trust and confidence in the digital marketplace, complicating the path to purchase. Moreover, the rise of influencer marketing, user-generated content, and algorithmic curation further complicates the relationship between social media and consumer behaviour. The influence of peer recommendations, social validation, and personalized content algorithms can significantly shape consumer preferences and perceptions, often in ways that are difficult to predict or control.

Literature Review

Increasing concentration on global development and the expansive use of technology in marketing, advertising and promotion have led to shifts in the way in which companies focus on consumers (Quelch & Jocz, 2008). Researchers have recognized that technology has become a major component in expanding markets and have defined entire marketing strategies around global access to technology. Cyberspace and computer-generated groups have renovated consumers, societies, and corporations with wide spread access to information, better social networking and enhanced communication abilities (Kucuk and Krishnamurthy, 2007). Social media are the websites which link millions of users from all over the world with same interests, views and hobbies. Blogs, YouTube, MySpace, Facebook are examples of social media that are popular among all level of consumers (Sin, et al., 2012). The inimitable aspects of social media and its enormous popularity have transformed marketing practices such as advertising and promotion (Hanna, Rohn and Crittenden, 2011). Social media and their impact on buying behaviour of consumer from information search stage to post purchase behaviour such as dissatisfaction statements or behaviours about a product or a company (Mangold and Faulds, 2009).

Social media sites such as Facebook, Instagram and Twitter enable users to maintain great connections among themselves as well with others (Ellison et al., 2007) by achieving more than one task and facilitating the way of communication and sharing different information (comments, thoughts, videos and images) (Kietzmann et al., 2011). Social media is playing substantial roles in different aspects of our lives. Social media is that it supports users in several sectors, such as, business, marketing, advertising and education (Hennig-Thurau et al., 2010). From business perspective, businesses and buyers can interact directly by social media with each other, and thereby find whatever products and services are looking for (Parson, 2013). Consumers today are increasingly using technology and particularly social media as an effective tool in their online shopping process. This process can be defined as is an electronic process that allows consumers to deal with business people and meet their purchases needs. (Hennig-Thurau et al., 2010). A study showed that social media enable 25% of all consumers to post links about products and services information in their retail sites to update other users about the purchase process (Pookulangara and Koesler, 2011). Another study stated that social marketing has made very important role in persuading consumers to buy online. He found that 70% of consumers are visiting social media to get useful information, 49% of them made the decision to buy certain product and 60% of consumers prefer to share their information about the products with others online. However, the actual transactions of purchasing processes occur for only 7% of consumers (Miller and Lammas, 2010).

Types of Social Media Websites used by consumers to purchase their products.

Facebook has more than 6 million consumers who registered to buy and share information about products (Scott, 2013). A study revealed that 60% of Facebook users say that they are more able to recommend a product or service to their friends after following that brand on social media (Parson, 2013). Facebook has reached 51% of users who buy different products through it (Kunkel, 2013).

Twitter has documented 800,000 followers who showed their appreciation to the provided services about the products. The same study has indicated that written blogs has increased from 54% to 77% in two years, and watching several videos related to different products has increased from 32% in 2006 to 83% in 2008 (Miller and Lammas, 2010). Another study indicated that 79% of Twitter users say they are more able to recommend a product or service to their friends after following that brand on social; media (Parson, 201

Principal
Dyal Singh College
KARNAL

Also, 64% of users use Twitter to buy different products (Kunkel, 2013).

Instagram is spreading widely in the recent two years because of active users who share and upload different kind of photos. Based on the activities provided by users who use Instagram, the results showed more than 16 billion photos were shared among users (Krieger, 2012). Phil Gonzalez, the founder of Instagrammers (Instagram users) was interviewed to recognize the increasing of Instagram users. He stated in the interview that number of users who login into Instagram increased in less than two years to 100 million users in more than 60 countries around the world. (Gonzalez, 2013). Because of the new adoption of Instagram, there is a lack of information about the use of Instagram as a tool in online purchasing.

Among the three social media websites acknowledged by companies to support marketing and branding (i.e. Twitter, YouTube and Facebook), In the Facebook setup, advertisers present their information about specific brands and products, Facebook users provide comments or "Like" content (showing approval of specific content), and this then drives additional similar content (Nelson-Field, Riebe, & Sharp, 2012; Shen & Bissell, 2013). The more consumers engage in behaviours around product advertising or comment on Facebook about specific products, the more content they will be provided that has similar products or brands (Shen & Bissell, 2013). Social media, then, has a significant impact on how marketers design their strategic approach, how they deliver brand information, and how they scale advertising to enhance consumer engagement.

Social networking sites like Facebook have provided a new way of introducing brand-related content and creating exchanges with consumers by generating consumer interactions (Shen & Bissell, 2013). The value of this approach is based on the shift in the way in which the Internet is being used, and social venues are progressing. Just a decade ago, the number one online activity was pornography, but just a decade later, this has shifted to social networking (Shen & Bissell, 2013). As a result, about 93% of businesses use some form of social networking for marketing and branding (Shen & Bissell, 2013). In their 2013 study, Shen and Bissell maintained that in any given year, there are more than 200 million active online users in the United States who spend more than 29 hours spent on online browsing, product assessment and networking. Of this large amount of social networking use, Facebook is the leader, with the most time spent on this social network leader (over 7 hours per person per week) (Shen & Bissell, 2013). Brand loyalty becomes an increasing focus when companies consider the use of social media. Facebook, for example, has more than 955 million active users, most of whom log on at least once each month (Laroche, Habibi, & Richard, 2013). About half of Facebook users access their accounts on a daily basis, either via the internet-based platform or through their mobile application (Laroche, Habibi, & Richard, 2013). As a result of this widespread use, advertisers view Facebook and other social media platforms as the most beneficial technology to introduce brand-related content and promote band associations. Online advertising is a powerful marketing tool for building brands and increasing traffic for firms to achieve success (Song, 2001). Social media marketing has claimed around 80% of the online marketers stated that social media influencers are reliable endorsers who support their businesses into higher levels (Dhanesh & Duthler, 2019). Social media is discharging the role of an important facilitator in establishing strong relationships with the customers making social media a sound beneficial case for organizations to adopt and implement (Tedeschi, 2006). Social media serves as a comprehensive communication channel with buyers for realizing three highly sought after objectives namely customer interaction, customer engagement and trust (Behravan & Rahman, 2012). Social media provides opportunities to salespeople to interact and engage with customers while deriving values for both organizations as well as for customers resulting in a mutually beneficial relationship (Jones, Busch, & Dacin 2003).

Conclusion:

Social media platforms have become influential channels for consumers to discover, research, and purchase products or services. They provide a space for brands to engage directly with consumers, influenc purchasing decisions through targeted advertisements, influencer endorsements, and user-generated

Principal
Dyal Singh College
KARNAL

Consumers rely on social media for product information, reviews, and recommendations from peers and influencers. The accessibility of user-generated content allows consumers to gather insights and make informed decisions before making a purchase. Social media enables brands to build relationships with their audience, fostering brand loyalty and advocacy. Through consistent engagement, brands can establish trust and credibility, leading to repeat purchases and positive word-of-mouth marketing.

Social media platforms utilize algorithms to personalize content and advertisements based on user preferences and behaviours. This targeted approach allows brands to reach specific segments of their audience with relevant messaging, increasing the likelihood of conversion. Social media has reshaped the traditional purchase journey, with consumers moving seamlessly between awareness, consideration, and purchase stages. From initial discovery to post-purchase interactions, social media plays a crucial role in shaping consumer perceptions and behaviours throughout the buying process. In conclusion, social media has transformed the way consumers engage with brands and make purchasing decisions. Its influence is pervasive across all stages of the consumer journey, making it essential for brands to adapt their marketing strategies to effectively leverage these platforms and meet the evolving needs and expectations of their audience.

References

1. Ellison, N. B., Steninfield, C. & Lampe, C. 2007. The benefits of Facebook “friends:” Social capital and college students’ use of online social network sites. Journal of Computer-Mediated Communication, 12, 1143-1168.
2. Gonzalez, P. 2013. Interview to Phil Gonzalez, founder of Instagrammers @igers [Online]. Mobile World Capital Available: http://mobileworldcapital.com/en/article/161 [Accessed on 22/3/2024].
3. Hanna, R., Rohm, A. & Crittenden, V., (2011). We’re all connected: The power of the social media ecosystem, Business Horizons, 54, 265-273.
4. Kietzmann, J. H., Hermkens, K., Mccarthy, I. P. & Silvestre, B. S. 2011. Social media? Get serious! Understanding the functional building blocks of social media. Business Horizons, 54, 241-251.
5. Kunkel, E. R. 2013. Social Media Statistics That Every Business Needs to Know [Online]. YAHOO! SMALL BUSINESS. Available: http://smallbusiness.yahoo.com/advisor/15-social-media-statistics-every-business-needsknow-001509118.html [Accessed on 28/2/2024]
6. Kuruk K., (2007). An analysis of consumer power on the Internet, Technovation, 27(1–2), 47–56.
7. Mangold G. and Faulds D., (2009). Social media: The new hybrid element of the promotion mix, Business Horizons, 52, 357-365.
8. Miller, R. & Lammas, N. 2010. Social media and its implications for viral marketing. Asia Pacific Public Relations Journal, 11, 1-9.
9. Parson, A. 2013. How Does Social Media Influence the Buying Behavior of Consumers? [Online]. BUSINESS & ENTREPRENEURSHIP. Available: http://yourbusiness.azcentral.com/social-media-influence-buying-behavior-consumers17017.html.
10. Pookulangara, S. & Koesler, K. 2011. Cultural influence on consumers' usage of social networks and its' impact on online purchase intentions. Journal of Retailing and Consumer Services, 18, 348-354.
11. Quelch, J. A., & Jocz, K. E. (2008). Milestones in marketing. Business History Review, 82 (4), 827-838.
12. Scott, M. 2013. Surprising Social Media Statistics for 2013 [Online]. Social media today website. Available: http://socialmediatoday.com/docmarkting/1818611/five-surprising-socialmedia-statistics-2013 [Accessed on 25/3/2024]
13. Sin S., Nor K. M. & Al-Agaga A. M., (2012). Factors Affecting Malaysian young consumers’ online purchase intention in social media websites, Procedia - Social and Behavioural Sciences, 40, Pag[illegible] 326-333.

Principal
Dyal Singh College
KARNAL

14. Thurau, E T., Malthouse, E. C., Friege, C., Gensler, S., Lobschat, L., Rangaswamy, A. & Skiera, B. 2010. The impact of new media on customer relationships. Journal of Service Research, 13, 311-330.
15. Nelson-Field, K., Riebe, E., & Sharp, B. (2012). What's not to 'Like'? Can a Facebook fan base give a brand the advertising reach it needs? Journal of Advertising Research, 52(2), 262-269.
16. Shen, B., & Bissell, K. (2013). Social media, social me: A content analysis of beauty companies' use of Facebook, in marketing and branding. Journal of Promotion Management, 19, 629–651. DOI: 10.1080/10496491.2013.829160
17. Laroche, M., Habibi, M., Richard, M., & Sankaranarayanan, R. (2012). The effects of social media-based brand communities on brand community markers, value creation practices, brand trust and brand loyalty. Computers in Human Behaviour, 28(5), 1755–1767.
18. Song YB, 2001, Proof That Online Advertising Works, Atlas Institute, Seattle, WA, Digital Marketing Insight.
19. Dhanesh, G. S., & Duthler, G. (2019). Relationship management through social media influencers: Effects of followers' awareness of paid endorsement. Public Relations Review, 45(3), 101765.
20. Tedeschi, B. (2006). Like Shopping? Social Networking? Try Social Shopping, Retrieved from www.nytimes.com/2006/ 09/11/technology/11ecom.html?_r=1&scp=1&sq=tedeschi%2C +bob&st=nyt .
21. Behravan, N., & Rahman, M.S. (2012). Customer relationship management constructs under social networks towards customers' retention, Australian Journal of Basic and Applied Sciences, 6(7), 271-282. Beinhocker, E., Davis, I. & Mendon.
22. Jones, E., Busch, P., & Dacin, P. (2003). Firm Market Orientation and Salesperson Customer Orientation: Interpersonal and Intrapersonal Influences on Customer Service and Retention in Business-to-Business Buyer–Seller Relationships, Journal of Business Research, 56 (4), 323–340.

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA

রবীন্দ্র ভারতী পত্রিকা

Unveiling the Social Media Effect on Consumer Purchasing Decisions: Navigating the Digital Marketplace

Authored By

Dr. Vandana Sabharwal
Assistant Professor, Dept of Commerce, Dyal Singh College, Karnal

Published in

Rabindra Bharati Patrika: Rabindra Bharati University

ISSN No: 0937-0037
Impact Factor: 6.4

Vol.: XXVII, No. : 7, January 2024

UGC CARE, Peer Reviewed and Refereed Journal

Principal
Dyal Singh College
KARNAL

ज्ञान-विज्ञान विमुक्तये

Rabindra Bharati Patrika ISSN No: 0937-0037

Editor
Rabindra Bharati Patrika

Indian J Med Res 158, October 2023, pp 1-10
DOI: 10.4103/ijmr.IJMR_4608_20

Quick Response Code:

Downloaded from http://journals.lww.com/ijmr by IeJYX11TtbwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKImAveo49fIxRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6ArJd0rTMxOoiU= on 11/11/2023

Serum anti-Müllerian hormone: A potential biomarker for polycystic ovary syndrome

Ashutosh Halder[1], Hemant Kumar[1], Mona Sharma[1], Manish Jain[1], Amanpreet Kaur Kalsi[1,†] & Shivam Pandey[2]

Departments of [1]Reproductive Biology & [2]Biostatistics, AIIMS, New Delhi, India

Received November 28, 2020

***Background & objectives*: Polycystic ovary syndrome (PCOS) is characterized by chronic ovulatory dysfunction, hyperandrogenism and polycystic ovary morphology (PCOM). Although hyperandrogenism is one of the major features of PCOS, it is rarely observed in southeast Asia. Recently, however, there has been growing evidence on association of anti-Müllerian hormone (AMH) with PCOS. The objective of this study was to investigate the diagnostic potentials of AMH in PCOS individuals.**

***Methods*: This case-control study included a total of 131 women with PCOS and 49 healthy controls who were enrolled after the exclusion of secondary causes of PCOS. Serum AMH was measured using an ultra-sensitive AMH ELISA kit in addition to other diagnostic biomarkers. Statistical analyses was carried out using the Student's t test, Wilcoxon rank-sum test, receiver operating characteristic (ROC) curve analysis, Spearman's rank correlation test and multivariable binary logistic regression analysis.**

***Results*: The median AMH values were 8.5 ng/ml and 2.5 ng/ml in the study group and controls, respectively (*P*<0.001). The normal cutoff value of 4.1 ng/ml for AMH was derived from ROC curve analysis. With a 4.1 ng/ml cut-off value, high levels of AMH was found in about 84 per cent of PCOS cases. However, no significant difference in AMH level was noted between age groups (<20 *vs.* ≥20 yr), body mass index (BMI) (<25 *vs.* ≥25 kg/m^2) and PCOM types. The area under the ROC curve (AUC) for AMH yielded diagnostic range values. In total PCOS cases, AUC was 0.93 (95% CI: 0.88 and 0.96), and in phenotype A PCOS cases, AUC was 0.96 (95% CI: 0.91 and 0.98). The correlation test also showed no association with BMI, the FG score, PCOM, free androgen index, androstenedione, dehydroepiandrosterone sulphate and luteinizing hormone. However, a weak correlation was observed with testosterone in total PCOS cases and with DHT as well as age in phenotype A PCOS cases. The prediction model for PCOS using multivariable binary logistic regression analysis showed AMH as the best marker.**

***Interpretation & conclusions*: The results of this study suggest that AMH can be considered as the most promising biomarker in PCOS women, particularly with phenotype A and phenotype D.**

Key words AMH - biomarker - body mass index - dihydrotestosterone - free androgen index - phenotypes and testosterone - PCOS

Polycystic ovary syndrome (PCOS) is the most common reproductive endocrine disorder in women of reproductive age with a prevalence between four and 22.5 per cent depending on the population

[†]Present address: *Department of Zoology, Dyal Singh College, Karnal, Haryana, India*

© 2023 Indian Journal of Medical Research, published by Wolters Kluwer - Medknow for Director-General, Indian Council of

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKImAveo49fIxRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6ArJd0rTMxOoiU= on 11/11/2023

studied and the diagnostic criteria used[1,2]. PCOS is a complex reproductive syndrome characterized by hyperandrogenism (clinical and/or biochemical), ovulatory dysfunction (oligo- and/or anovulation) and polycystic ovary morphology (PCOM) (polycystic and/or enlarged)[3]. Currently, Rotterdam criteria with phenotypic classification is followed to diagnose PCOS[4,5]. Hyperandrogenaemia, a cardinal criteria of PCOS, is rarely seen in southeast Asians[6-8]. The Endocrine Society advises mass spectrometry (MS) based assay for testosterone estimation due to less sensitivity and specificity of direct immunoassay methods[9]. However, MS-based assay is not readily available and requires a high-end laboratory setup. Hence, there is a need to find a better marker.

Anti-Müllerian hormone (AMH) is a glycoprotein and a member of the transforming growth factor family. It is produced by the granulosa cells of developing ovarian follicles, mainly preantral and small antral follicles[10]. AMH level does not alter much during phases of a menstrual cycle or with exogenous oestrogen which is an important advantage of AMH as a biomarker[11]. In the last few years, there is accumulating evidence on the association of AMH and PCOS[12,13]. Several studies have reported a high level of AMH, in particular with phenotype A and D PCOS[14,15], and suggested incorporating it in the diagnosis[16-18]. There is heterogeneity in AMH levels in different PCOS phenotypes with higher levels in phenotypes A and D[15]. However, the cut-off value of AMH for PCOS diagnosis was variable across studies[18,19]. Some investigators reported a level of 4.7 ng/ml or more serum AMH as a strong predictor of PCOS[20,21], whereas others reported >5 ng/ml[18]. Ethnic diversity is another factor associated with variations in AMH levels; generally, Asian women have lower AMH than Caucasians[22].

Prior experience on this subject suggests poor association of PCOS and androgens in addition to other biomarkers[6-8]. Therefore, it is important to investigate PCOS cases to find a potential diagnostic biomarker. The primary objective of this study was to evaluate the accuracy, diagnostic cut-off value and power of prediction of AMH in north Indian women with PCOS.

Material & Methods

This study was conducted in the department of Reproductive Biology, All India Institute of Medical Sciences, New Delhi, India, from January 2016 to December 2019 after obtaining approval by the Institutional Ethics Committee. Informed consent was obtained from all the participants included in the study.

All suspected PCOS cases underwent clinical and basic investigations before inclusion in the study. Women with PCOS cases were selected for the study after the evaluation of reproductive and menstrual history, hirsutism, testosterone level and targeted ovarian ultrasonography. A menstrual cycle length of 42 days/more (instead of 35 days) was considered as oligomenorrhoea and at least 182 days for amenorrhoea. Hyperandrogenism was defined as Ferriman–Gallwey (FG) score ≥9 (hirsutism/clinical hyperandrogenism)[23] and/or testosterone levels >0.6 ng/ml (laboratory cutoff level/biochemical hyperandrogenism). PCOM was considered when targeted ovarian ultrasonography showed follicle size of 2-9 mm and count was ≥12 in one or both ovaries with ovarian size 10 ml or more (one/both ovaries).

Inclusion criteria: All cases were also evaluated for cortisol, prolactin, TSH, oestradiol (E2), progesterone (P4), FSH, luteinizing hormone (LH), dehydroepiandrosterone sulphate (DHEAS), testosterone, *etc*. (using Abbott Inc. autoanalyzer; IL, USA) to exclude secondary causes and/or for the diagnosis of PCOS. The 17-hydroxyprogesterone along with other androgens (dihydrotestosterone and androstenedione) and sex hormone-binding globulin (SHBG) was measured using commercial enzyme-linked immunosorbent assay (ELISA) kits[24]. In some cases, chromosome analysis was also carried out to exclude rare secondary causes such as the disorder of sex development/sex reversal. After preliminary evaluation, 131 cases were found as primary PCOS and included in the study (after exclusion of secondary causes such as congenital adrenal hyperplasia (CAH), premature ovarian failure, hyperprolactinaemia, androgen-producing tumours and the disorder of sex development).

Study participants were segregated into four groups such as phenotype A (hyperandrogenism, ovulatory dysfunction and PCOM), phenotype B (hyperandrogenism and ovulatory dysfunction), phenotype C (hyperandrogenism and PCOM) and phenotype D (ovulatory dysfunction and PCOM). 49 women with normal menstrual cycle and fertility were included as controls for the comparison. About 50 per cent of control samples were collected from PHC near Ranchi from normal fertile (at least 2 children, last childbirth >2 yr ago; some lactating but resumed menstruation) tribal women <30 yr.

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKlmAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6AxJd0rTMxOoiU= on 11/11/2023

Exclusion criteria: Before the inclusion as PCOS, every case was evaluated for ovarian neoplasm, CAH, adrenal neoplasm, Cushing's syndrome, thecoma, drug-induced hyperandrogenism, hypothyroidism, hyperprolactinaemia or premature ovarian failure and excluded from the study.

Sample size: Sample size for the study was computed for comparing testosterone level between PCOS and control based on the following assumptions: mean [standard deviation (SD)] in PCOS as 1.5 (0.5) nmol/l and in controls as 1 (0.5) nmol/l with 95 per cent confidence level, 90 per cent power and control: PCOS as 1:2 allocation ratio[24]. The minimum sample size required was 44 controls and 88 cases.

Statistical analysis: Data were recorded on a pre designed proforma and managed on an Excel spreadsheet. All the entries were checked for any possible keyboard error. Quantitative variables were assessed for approximate normality. Variables following approximate normal distribution were summarized by mean and SD. Non-normal variables were summarized by a median with the minimum and maximum values. Student's t test was used to compare the mean between two independent groups, while Wilcoxon rank-sum test was used to compare the median between the two groups. Spearman's rank correlation was used to compute the correlation coefficient. The receiver operating characteristic (ROC) curve was used to determine the appropriate cut-off value and its predictive value for each of the potential biomarkers of PCOS (total PCOS and phenotype A PCOS cases). All the potential biomarkers were simultaneously considered in a stepwise multivariable binary logistic regression model to determine the weightage/score for predicting PCOS. Using ROC analysis, a cut-off value of the score was determined for the combination of biomarkers for predicting PCOS. Sensitivity, specificity and its 95 per cent confidence interval were computed. In this study, a *P* value less than 0.05 were considered significant. STATA 15.0 software (Stata Corp. TX, USA) was used for data analysis.

Results

A total of 131 women with PCOS and 49 healthy women were enrolled for this study. Of the 131 PCOS women, 87 were phenotype A, 23 were phenotype B, 8 were phenotype C, and 13 were phenotype D. The mean age of the PCOS group was 23.5 yr and 26.2 yr in control group; the difference between groups being significant ($P<0.001$). The mean age was lower in the PCOS group, more so with phenotype D (Table I).

High BMI (≥25 kg/m^2) was observed in about 50 per cent of PCOS cases. Clinical hyperandrogenism, *i.e*., FG score of 9 or more, was observed in overall 74 per cent (97/131) total PCOS cases and 77 per cent (67/87) with phenotype A PCOS cases (Table I). Ultrasonographic PCOM of type 1 (ovarian volume 11-15 ml and /or follicle count 12-15 of 2-9 mm size in one/both ovaries) was observed in most (about 71%) of the PCOS cases, whereas type 3 PCOM (ovarian volume >20 ml and/or follicle count >20 of 2-9 mm size in one/both ovary) was seen in about seven per cent of total PCOS cases. Table I summarizes each biomarker analysed. As compared to controls all biomarkers in PCOS group were significantly different.

Table II shows AMH level comparison between age groups (<20 *vs.* ≥20 yr), BMI groups (<25 *vs.* ≥25 kg/m^2), and PCOM types (type 1/ ovarian volume 11-15 ml and /or follicle count 12-15 of 2-9 mm size in one/both ovaries *vs.* type 2/ovarian volume 16-20 ml and/or follicle count 16-20 of 2-9 mm size in one/both ovaries). No significant differences were found in AMH levels across age groups, BMI groups, or PCOM types. Spearman's correlation study of AMH concentration with clinical and biochemical variables of total PCOS and phenotype A PCOS cases found no significant correlations except with androgens (Table III). ROC curve analysis (Table IV) was performed for AMH, T, FAI, DHT, androstenedione, DHEAS, and LH in total PCOS and phenotype A PCOS cases. The area under the ROC curve (AUC) of >0.9 (promising biomarker) was observed with AMH and testosterone. The prediction model for PCOS diagnosis using multivariable binary logistic regression analysis of the biomarkers studied are shown in Table V and Figure. Phenotypes B, C, and D were excluded from analysis due to the small number of cases.

Anti- Müllerian hormone (AMH): The median serum levels of AMH was 8.5 ng/ml in the PCOS group and 2.4 ng/ml in the control group (Table I). Phenotype wise median AMH values were 8.4 ng/ml in phenotype A, 8.9 mg/ml in phenotype B, 5.6 ng/ml in phenotype C and 10.2 ng/ml in phenotype D. Significant difference was found between controls and total ($P<0.001$) and phenotype A ($P<0.05$) PCOS cases, respectively. A weak correlation with AMH levels was observed with testosterone in total PCOS cases and DHT, as well as age in phenotype A PCOS cases. However, we found no

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by ieJYX11TbBwRWyjAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwiIg1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKlmAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4ulaqHq6ArJd0rTMxOoiU= on 11/11/2023

Table I. Comparison of demographic characteristics and investigation details of polycystic ovary syndrome (PCOS) cases

Parameters	PhA (87; 66.4%)	PhB (23; 17.6%)	PhC (8; 6.1%)	PhD (13; 9.9%)	Total (131; 100%)	Control (49; 100%)
Age (yr), mean (SD)	23.9 (5.1)***	23.9 (4.9)	23.5 (3)	20.2 (3.8)	23.5 (4.9)***	26.2 (4.4)
<20 yr, n (%)	19 (22)	6 (26)	0 (0)	7 (54)	32 (24)	4 (8)
BMI (kg/m^2), mean (SD)	26.1 (5.2)***	25.3 (5.9)	22.9 (2.9)	22.3 (3.8)	25.4 (5.2)**	22.6 (3.4)
≥25 (high), n (%)	47 (54)	12 (52.2)	2 (25)	3 (23)	64 (49)	11 (22.4)
FG score, mean (SD)	12.3 (5.8)	14.6 (5.2)	18.2 (8.4)	5.1 (1.6)	12.4 (6.3)	None c/o hirsutism
≥9 (hirsute), n (%)	67 (77)	22 (95.7)	8 (100)	0 (0)	97 (74)	0 (0)
USG PCOM, n	87	0	8	13	108	None investigated
Type 1: n (%)	62 (71.2)	NA	6 (75)	9 (69.3)	77 (71.3)	
Type 2: n (%)	18 (20.8)	NA	2 (25)	3 (23)	23 (21.3)	
Type 3: n (%)	7 (8)	NA	0 (0)	1 (7.7)	8 (7.4)	
Testosterone (ng/ml), mean±SD	0.54 (0.24)*	0.47 (0.24)	0.56 (0.36)	0.25 (0.1)	0.5 (0.25)*	0.23 (0.11)
DHT (pg/ml), mean±SD	627 (328.6)*	423.8 (199)	376.2 (110)	375 (163.4)	561 (309)**	257.15 (102.3)
DHEAS (µg/dl), mean±SD	224.3 (98.4)*	213.4 (92.6)	248.8 (92.1)	143.4 (57.8)	216.3 (96.2)***	152.2 (78.5)
FAI, median (mini-max)	4.1 (0.3-26)***	2 (0.4-11.5)	3.3 (1.2-13.5)	1.6 (0.4-2.2)	3 (0.3-26)***	0.97 (0.1-4.1)
Androstenedione (ng/ml), median (mini-max)	1.6 (0.4-8.5)***	1.5 (0.6-1.1)	0.7 (0.6-0.9)	0.7 (0.5-1.2)	1.1 (0.4-8.5)*	0.9 (0.4-2.5)
LH (mIU/ml), median (min-max)	7.3 (0.8-25.8)***	4.7 (0.3-19.1)	3.5 (1.3-10.6)	6.3 (1.1-13.8)	4.6 (0.3-25.8)*	4.2 (0.7-11.5)
AMH (ng/ml), median (min-max)	8.4 (1.5-24)*	8.9 (1.3-18.7)	5.6 (1.5-22)	10.2 (3.1-20.3)	8.5 (1.3-24)***	2.4 (0.5-6.6)

Student t test and Wilcoxon rank-sum test were used for statistical analysis. *P**<0/05,**<0.001,***<0.001. Ph, phenotype; BMI, body mass index; FG, Ferriman–Gallwey; USG PCOM, ultrasonographic polycystic ovary morphology; NA, not applicable; SD, standard deviation; DHT, dihydrotestosterone; DHEAS, dehydroepiandrosterone sulphate; FAI, free androgen index; LH, luteinizing hormone; AMH, anti-Müllerian hormone

correlation between AMH level with BMI, FG score, and PCOM (Table III). The area under the ROC curve (AUC) for the AMH assay yielded a highly satisfactory result. The AUC for AMH was 0.93 [95% confidence interval (CI): 0.88, 0.96] in total PCOS cases and 0.96 (95% CI: 0.91, 0.98) for phenotype A PCOS cases. A high level of AMH was observed in 84 per cent of the total (cut-off level >4.1 ng/ml) and 87.4 per cent of the phenotype A (cut-off value 5.17 ng/ml) PCOS cases (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects AMH as the best marker (P<0.001) with the highest weighted score of 27.3 and a cut-off score for prediction of PCOS as ≥39.51 (Table V; Figure).

Testosterone: The mean testosterone was 0.5 ng/ml in the study group, whereas in the control group, it was 0.23 ng/ml (Table I). A significant (P<0.05) difference was observed between the controls with total and phenotype A PCOS cases (phenotypes B, C, and D were excluded from analysis due to the small number of cases). A weak correlation between testosterone and AMH was also observed in total PCOS cases. The AUC for testosterone yielded satisfactory results in total (0.87; 95% CI: 0.81, 0.91) and phenotype A (0.92; 95% CI: 0.87, 0.96) PCOS cases (Table IV). A high testosterone level was observed in 80.8 per cent of the total PCOS cases with a cut-off value of 0.3 ng/ml and in 83.7 per cent of the phenotype A PCOS cases with a cut-off value of 0.35 ng/ml (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects testosterone as the second-best (next to AMH) marker (P<0.001) with the highest weighted score of 24.3 (Table V; Figure).

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKImAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6AxJd0rTMxOoiU= on 11/11/2023

Table II. Comparison of anti-Müllerian hormone in relation to age (<20 *vs*. ≥20 yr), body mass index (≤25 *vs*. >25 kg/m^2) and polycystic ovary morphology (type 1 *vs*. type 2) in total and phenotype A PCOS cases

Parameters	n	AMH (ng/ml), median (range)	*P*
Total PCOS			
<20 yr	32	8.84 (2.5-23.8)	0.8
≥20 yr	99	8.47 (1.29-24)	
PhA PCOS			
<20 yr	19	8.84 (3.59-23.8)	0.7
≥20 yr	68	8.39 (1.49-24)	
Total PCOS			
<25 BMI	67	8.0 (1.19-24)	0.8
≥25 BMI	64	8.3 (1.49-23.8)	
PhA PCOS			
<25 BMI	40	8.2 (3.4-24)	0.5
≥25 BMI	47	8.34 (1.49-23.8)	
Total PCOS			
Type 1 PCOM	77	8.2 (1.5-24)	0.2
Type 2 PCOM	23	9.6 (3-22)	
PhA PCOS			
Type 1 PCOM	68	8.25 (1.5-24)	0.4
Type 2 PCOM	18	9.55 (3.6-19.5)	

P values were derived using Wilcoxon rank-sum test

Table III. Spearman's correlation of anti-Müllerian hormone (ng/ml) concentration with clinical and biochemical variables of total and phenotype A polycystic ovary syndrome (PCOS) cases

Variable(s)	Spearman's rho	
	Total PCOS cases (n=131)	PhA PCOS cases (n=87)
Age (yr)	−0.049	−0.174*
BMI (kg/m^2)	0.066	−0.083
FG score (cut-off 9)	−0.088	−0.153
PCOM		
Type 1	0.019	0.133
Type 2	0.072	0.089
Type 3	−0.599	−0.132
Testosterone (ng/ml)	0.173[a]	−0.129
DHT (pg/ml)	−0.015	−0.176*
Androstenedione (ng/ml)	−0.077	−0.149
DHEAS (µg/ml)	−0.053	−0.076
FAI (ratio)	0.037	0.026
LH (mIU/ml)	0.162	−0.068

*P**<0.05

Dihydrotestosterone (DHT): The mean DHT value was 561 pg/ml in the study group, whereas, it was significantly low in the control group at 257 pg/ml. A weak correlation between DHT and AMH was observed in phenotype A PCOS cases. The AUC for DHT yielded satisfactory results in total (0.87; 95% CI: 0.81, 0.92) and phenotype A (0.91; 95% CI: 0.84, 0.95) PCOS cases (Table IV). A high level of DHT was observed in about 80 per cent of PCOS cases with a cut-off value of 360 pg/ml for total and 370 pg/ml for phenotype A PCOS cases (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects DHT as a good marker (*P*<0.007) with the highest weighted score of 11.2 and a cut-off score for the prediction of PCOS as ≥39.51 (Table V; Figure).

Androstenedione: The median androstenedione was 1.1 ng/ml in the study group, whereas in the control group, it was 0.9 ng/ml (*P*<0.05). No correlation between AMH level and androstenedione was observed. The AUC for androstenedione was 0.77 in total and 0.74 in phenotype A PCOS cases. A high level of androstenedione was observed in about 62 per cent of PCOS cases, with a cut-off value of 1 ng/ml for total and phenotype A PCOS cases (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects androstenedione as a marker with the highest weighted score of 12.2 and a cut-off score for prediction of PCOS as ≥39.51 (Table V; Figure).

Dehydroepiandrosterone sulphate (DHEAS): The mean DHEAS was 216 µg/dl in the study group, whereas in the control group, it was 152 µg/dl. No correlation between AMH level and DHEAS was observed. The AUC for DHEAS was 0.72 in total and 0.7 in phenotype A PCOS cases. A high level of DHEAS was observed in about 62 per cent of total PCOS cases with a cut-off value of 164 µg/dl and in about 58 per cent of phenotype A PCOS cases with a cut-off value of 166 µg/dl (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects androstenedione as a marker (*P*<0.018) with the highest weighted score of 10 and a cut-off score for prediction of PCOS as ≥39.51 (Table V; Figure).

Free androgen index (FAI): The median FAI was 2 in the study group, whereas in the control

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWy/AfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWl+pjl2pzKlmAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6ArJd0rTMxOoiU= on 11/11/2023

Table IV. Receiver operating characteristic curve analysis of anti-Müllerian hormone and other biomarkers for total PCOS and phenotype A cases

Characteristics	Parameters						
	AMH	Testosterone	DHT	Androstenedione	DHEAS	FAI	LH
Total PCOS cases *vs*. controls							
AUC	0.93	0.87	0.87	0.77	0.72	0.84	0.72
95% CI	0.88-0.96	0.81-0.91	0.81-0.92	0.64-0.82	0.63-0.81	0.77-0.9	0.68-0.86
SE	0.018	0.029	0.029	0.109	0.721	0.034	0.031
Cut-off value	4.1	0.3	360	1.01	164	2.2	4.6
Per cent sensitivity	84	80.8	77.8	62.5	62.4	70.6	84.6
Per cent specificity	87.8	81.3	84.1	87.7	87.9	82.1	87.7
PhA PCOS cases *vs*. controls							
AUC	0.96	0.92	0.91	0.74	0.7	0.86	0.74
95% CI	0.91-0.98	0.87-0.96	0.84-0.95	0.66-0.83	0.66-0.83	0.79-0.95	0.65-0.83
SE	0.016	0.024	0.025	0.109	0.762	0.033	0.031
Cut-off value	5.17	0.35	370	1.08	166	2.9	4.3
Per cent sensitivity	87.4	83.7	81.4	62.4	58.6	70.2	84.7
Per cent specificity	89.8	85.4	84.1	87.7	84.9	84.3	87.8

0.97 (P<0.001). No correlation between AMH level and FAI was observed. The AUC for FAI was 0.84 in total and 0.86 in phenotype A PCOS cases. A high level of FAI was observed in about 70 per cent of PCOS cases with a cut-off value of 2.2 for total and 2.9 for phenotype A PCOS case (Table IV). The prediction model for PCOS using multivariable binary logistic regression detects no significance with FAI for the prediction of PCOS.

Luteinizing hormone (LH): The median LH was 4.6 mIU/ml in the study group, whereas in the control group, it was 4.2, which is insignificant. The phenotype wise median LH value was 7.3 mIU/ml in phenotype A (P<0.001), 4.7 mIU/ml in phenotype B, 3.5 mIU/ml in phenotype C and 6.3 mIU/ml in phenotype D. No correlation between AMH level and LH was observed. The AUC for LH was 0.72 in total and 0.74 in phenotype A PCOS cases. A high level of LH was observed in about 84 per cent of PCOS cases, with a cut-off value of 4.6 for total and 4.3 for phenotype A PCOS cases (Table I). The prediction model for PCOS using multivariable binary logistic regression detected no significance value for LH as a predictor of PCOS.

Discussion

PCOS is a complex reproductive endocrine disorder characterized by hyperandrogenism (clinical and/or biochemical), chronic ovulatory dysfunction (oligo and/or anovulation), and PCOM (polycystic and/or enlarged ovary). The first scientific description of PCOS was published in 1935 by Stein and Levanthal[25]. Since then, many efforts have been made for the precise diagnosis; however, unfortunately till date, there is no promising biomarker (sensitive and specific) and no definite etiologic factors detectable in primary PCOS. Serum testosterone and/or FAI is commonly used as hyperandrogenaemia markers[26]; however, high values are rarely observed in women with PCOS from southeast Asian countries, including India[6-8]. Similarly, other androgens, such as androstenedione and DHEAS, are weakly correlated with PCOS. There is no other biochemical marker linked to PCOS until recently. In recent years, several studies have reported the diagnostic value of AMH in PCOS patients[14-18,27]. The most common PCOS phenotype in our study was phenotype A (all three features, *i.e.* classical PCOS), about 66 per cent and similar to most western countries[28]. However, there are more PCOS cases with phenotype D[6,7].

This study reports the reference range of AMH for diagnosing PCOS in the north Indian population. It also compares the diagnostic value of each biomarker of PCOS, such as testosterone, FAI, DHT, androstenedione, DHEAS, and LH. In this study, we have found a median AMH value of 2.4 n

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWy/AfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54fKEWI+pjl2pzKImAveo49fIXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6AxJd0rTMxOoiU= on 11/11/2023

Table V. Prediction model for PCOS using stepwise multivariable binary logistic regression model to predict power of each biomarker

Variable(s)	Estimated regression coefficients (SE)	$Weighted score
AMH (ng/ml), (≥4.1)	4.60 (0.98)***	27.27
Testosterone (ng/ml), (≥0.3)	4.18 (1.13)***	24.73
DHT (pg/ml), (≥360)	1.90 (0.71)**	11.24
Androstenedione (ng/ml), (≥1)	2.08 (0.8)**	12.24
DHEAS (µg/dl), (≥165)	1.69 (0.72)*	10

*P**<0.05, **<0.01, ***<0.001. $27.27*AMH >24.73*Testosterone >11.24*DHT >12.24*Androstenedione >10*DHEAS. SE, standard error

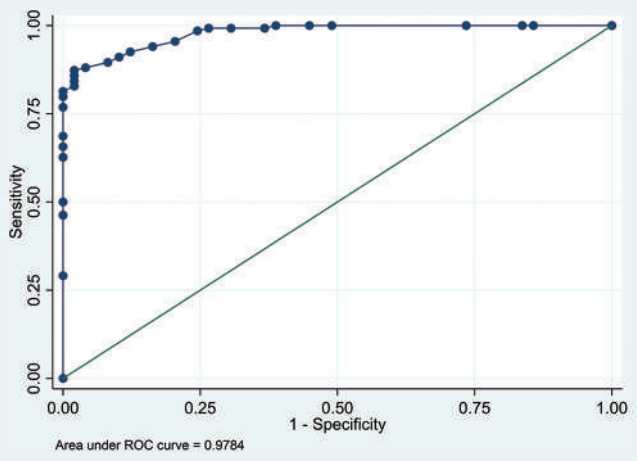


Figure. ROC curve for PCOS prediction model. Stepwise multivariable binary logistic regression model used to predict power of each biomarker. Cut-off score for prediction of PCOS: ≥39.56 with sensitivity (95% CI) of 91% (90.7, 96.8) and specificity (95% CI) 89.9% (88.5, 95.3). ROC, receiver operating characteristics.

controls whereas about 8.5 ng/ml in PCOS, *i.e*., nearly 3.5 times more indicating a substantial diagnostic value (*P*<0.001). The maximum AMH median value was observed in phenotype D (10.2 ng/ml), followed by phenotype B (8.9 ng/ml), and least with phenotype C (5.6 ng/ml). We have also compared the association of AMH with BMI (<25 and ≥25 kg/m^2), FG score (<9 and ≥9), as well as PCOM but found no relationship. Failure to find any significant correlation between PCOM and AMH could be due to the subjective nature of PCOM by abdominal ultrasonography (both operator and patient, particularly with obesity; ~50 per cent of PCOS cases were overweight). Similarly, Spearman's correlation of AMH (ng/ml) of total and phenotype A PCOS cases with biochemical variables such as FAI, androstenedione, DHEAS, and LH failed to detect any association.

The AMH cut-off value was derived from ROC curve analysis as 4.1 ng/ml in total PCOS cases (5.17 ng/ml for phenotype A). These cut-off values picked up 84 percent of total and 87 per cent of phenotype A PCOS cases. This association was much better than any other biomarkers and the FG score of ≥9 was observed in about 74 per cent of PCOS cases. The association of PCOS with other biomarkers was 81 per cent with testosterone, 78 per cent with DHT, 62 per cent with androstenedione, 70 per cent with FAI, 62 per cent with DHEAS, *etc*., using respective ROC-derived cut-off values. This finding showed that all women with PCOS, even those who did not have PCOM (phenotype B) or hyperandrogenism (phenotype D), had significantly higher AMH levels, indicating that AMH is associated with PCOS more strongly than any other biomarker of PCOS, irrespective of PCOS phenotypes. Various cut-off values of AMH have been reported in the literature and vary from 4.7 ng/ml[20,21] to 5 ng/ml[18,22,29] in Caucasians or even 10 ng/ml[30,31] in Japanese and Korean women. Our cut-off values (4.1 ng/ml for total and 5.17 ng/ml for phenotype A PCOS cases) are similar to Caucasians,[18,20-22,29] and much lower than orientals[30,31]. Phenotypes B, C and D were excluded from analyses due to the small number of cases. Serum AMH, as a diagnostic marker of PCOS was found to have high sensitivity (84%) and specificity (88%). ROC curve analysis suggests that AMH is superior to other biomarkers studied here in diagnosing PCOS. The area under the curve (AUC) of ROC was found to be 0.93 (95% CI: 0.88, 0.96) for total PCOS cases and 0.96 (95% CI: 0.91, 0.98) for phenotype A PCOS cases. The AUC of ROC of total and phenotype A PCOS cases was 0.87 and 0.92 with testosterone, 0.87 and 0.91 with DHT, 0.84 and 0.86 with FAI, 0.77 and 0.74 with androstenedione, 0.72 and 0.7 with DHEAS and 0.72 and 0.74 with LH, respectively. An AUC of ROC of more than 0.9 can be considered a strong correlation and may be used as a diagnostic marker. This signifies that AMH is likely to be associated with >93 per cent of total PCOS cases and >96 per cent with phenotype A, considering 4.1 ng/ml (total PCOS cases) or 5.17 ng/ml (phenotype A PCOS cases) as cut-o

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DBrbonTvmORJIFjXnfRyTj13d72cT54tKEWI+pjl2pzKImAveo49fIXRIRX143CQvDGwfbeJ+rXbwq3DF2HUm3HJQNgc34vxfFT4uIaqHq6ArJd0rTMxOoiU= on 11/11/2023

literature reported sensitivity between 49 per cent and 74 per cent when the specificity was set at 92 per cent; however, others reported higher sensitivity with a little lower specificity[16,28,31,32] similar to the present study (specificity kept at 88 and 90%). The AMH estimation seems comparatively simple, sensitive, and the best available marker associated with PCOS.

In this study, the mean age of PCOS cases was significantly less than controls, in particular with phenotype D. Relatively younger age in PCOS was also reported by other studies[33,34]. Similarly, the mean BMI in PCOS cases (25.4 kg/m^2) was significantly higher than controls (22.6 kg/m^2; P<0.01) as in other reports[35]. High BMI was observed with phenotypes A (26.1 kg/m^2) and B (25.3 kg/m^2), whereas phenotypes C (22.9 kg/m^2) and D (22.3 kg/m^2) were normal. High BMI was observed in 49 per cent of PCOS cases and 22 per cent in controls. In this study, unlike other studies[36,37], LH level in the total PCOS group (median: 4.6 mIU/ml) was similar to the control group (median: 4.2 mIU/ml). However, a significant difference was observed with phenotype A (median: 7.3 mIU/ml). Spearman's correlation of AMH concentration with clinical and biochemical variables of total and phenotype A PCOS cases did not find any association with BMI, FG score, PCOM, FAI, androstenedione, DHEAS, and LH; however, a weak correlation was associated with androgens (testosterone in total and DHT in phenotype A PCOS cases). Other studies[38,39] also have shown some association of AMH with androgens in PCOS. The prediction model for PCOS using multivariable binary logistic regression detects AMH as the best marker associated with PCOS, followed by testosterone and DHT. AMH could play an essential role in the diagnosis of PCOS, in particular cases with normal androgen levels, commonly observed in southeast Asian countries. Moreover, accurate estimation of testosterone is difficult. The incorporation of AMH will also help to differentiate PCOS like condition associated with non-classical CAH and premature ovarian insufficiency/failure.

In this study, serum testosterone was found to be the second-best biomarker of PCOS. However, the cut-off value of testosterone (0.3 ng/ml) was found to be much lower than that reported in literature (0.6 ng/ml)[40,41]. This could be true as high testosterone is rarely observed in Asian women with PCOS[6,7], thus it is time to think on race-specific cut-off value.

The major strength is a phenotype-wise characterized homogeneous group of primary PCOS cases. All secondary PCOS cases (CAH, gonadal tumour, premature ovarian failure, the disorder of sex development, sex reversal, *etc.*) were excluded by appropriate investigations. The weakness of this study is the fewer cases of phenotypes B, C, and D besides the relatively younger age group (23.5 yr in the study group and 26.2 yr in controls).

Overall, our results suggest that AMH is the best available biomarker with a maximum AUC of ROC (>0.9) and prediction score (weight/point) and has the potential as the diagnostic biomarker of PCOS. The cut-off level of AMH for diagnosing PCOS was 4.1 ng/ml in total PCOS cases (5.17 ng/ml for phenotype A PCOS cases) from north India and may be implemented in routine hospital laboratories to diagnose PCOS. In addition, AMH is an independent biomarker except for a weak correlation with androgens (testosterone and DHT) in women with PCOS. However, more studies with a large cohort are needed for the validation of this result, in particular with phenotypes B, C, and D.

***Acknowledgment*:** The authors acknowledge the departments of Obstetrics and Gynaecology, All India Institute of Medical Sciences and various hospitals of Delhi, India, for referring patients.

***Financial support & sponsorship*:** This study received funding by the Department of Science & Technology (DST), New Delhi, India through research project (EEQ/2017/000214).

***Conflicts of Interest*:** None.

References

1. Ganie MA, Vasudevan V, Wani IA, Baba MS, Arif T, Rashid A. Epidemiology, pathogenesis, genetics & management of polycystic ovary syndrome in India. *Indian J Med Res* 2019; *150* : 333-44.
2. Deswal R, Narwal V, Dang A, Pundir CS. The prevalence of polycystic ovary syndrome: A brief systematic review. *J Hum Reprod Sci* 2020; *13* : 261-71.
3. Halder A, Kumar H. Polycystic ovary syndrome (PCOS): The pros and cons of various diagnostic criteria. *EC Gynaecol* 2020; *9* : 39-41.
4. Dewailly D. Diagnostic criteria for PCOS: Is there a need for a rethink? *Best Pract Res Clin Obstet Gynaecol* 2016; *37* : 5-11.
5. Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group. Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome (PCOS). *Hum Reprod* 2004; *19* : 41-7.
6. Ramanand SJ, Ghongane BB, Ramanand JB, Patwardhan MH, Ghanghas RR, Jain SS. Clinical characteristics of polycystic ovary syndrome in Indian women. *Indian J Endocrinol Metab* 2013; *17* : 138-45.

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by IeJYX11TbBwRWyJAfUkPVGzKFoOYN8toKVpUAEoOxsWbtwIig1DB rbonTvmORJIFjXnfRyTj13d72cT54fKEWI+pjl2pzKImAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4u IaqHq6ArJd0rTMxOoiU= on 11/11/2023

7. Zhang HY, Guo CX, Zhu FF, Qu PP, Lin WJ, Xiong J. Clinical characteristics, metabolic features, and phenotype of Chinese women with polycystic ovary syndrome: A large-scale case-control study. *Arch Gynecol Obstet* 2013; *287* : 525-31.
8. Joshi B, Mukherjee S, Patil A, Purandare A, Chauhan S, Vaidya R. A cross-sectional study of polycystic ovarian syndrome among adolescent and young girls in Mumbai, India. *Indian J Endocrinol Metab* 2014; *18* : 317-24.
9. Rosner W, Auchus RJ, Azziz R, Sluss PM, Raff H. Position statement: Utility, limitations, and pitfalls in measuring testosterone: An Endocrine Society position statement. *J Clin Endocrinol Metab* 2007; *92* : 405-13.
10. Weenen C, Laven JS, Von Bergh AR, Cranfield M, Groome NP, Visser JA, *et al.* Anti-Müllerian hormone expression pattern in the human ovary: Potential implications for initial and cyclic follicle recruitment. *Mol Hum Reprod* 2004; *10* : 77-83.
11. Streuli I, Fraisse T, Pillet C, Ibecheole V, Bischof P, de Ziegler D. Serum antimüllerian hormone levels remain stable throughout the menstrual cycle and after oral or vaginal administration of synthetic sex steroids. *Fertil Steril* 2008; *90* : 395-400.
12. Tata B, Mimouni NEH, Barbotin AL, Malone SA, Loyens A, Pigny P, *et al.* Elevated prenatal anti-Müllerian hormone reprograms the fetus and induces polycystic ovary syndrome in adulthood. *Nat Med* 2018; *24* : 834-46.
13. Dumont A, Robin G, Catteau-Jonard S, Dewailly D. Role of anti-Müllerian hormone in pathophysiology, diagnosis and treatment of polycystic ovary syndrome: A review. *Reprod Biol Endocrinol* 2015; *13* : 137.
14. Cassar S, Teede HJ, Moran LJ, Joham AE, Harrison CL, Strauss BJ, *et al.* Polycystic ovary syndrome and anti-Müllerian hormone: Role of insulin resistance, androgens, obesity and gonadotrophins. *Clin Endocrinol (Oxf)* 2014; *81* : 899-906.
15. Bhide P, Kulkarni A, Dilgil M, Dhir P, Shah A, Gudi A, *et al.* Phenotypic variation in anti-Mullerian hormone (AMH) production per follicle in women with polycystic ovary syndrome (PCOS) and isolated polycystic ovarian morphology (PCOM): An observational cross-sectional study. *Gynecol Endocrinol* 2017; *33* : 801-6.
16. Wiweko B, Maidarti M, Priangga MD, Shafira N, Fernando D, Sumapraja K, *et al.* Anti-mullerian hormone as a diagnostic and prognostic tool for PCOS patients. *J Assist Reprod Genet* 2014; *31* : 1311-6.
17. Teede H, Misso M, Tassone EC, Dewailly D, Ng EH, Azziz R, *et al.* Anti-Müllerian hormone in PCOS: A review informing international guidelines. *Trends Endocrinol Metab* 2019; *30* : 467-78.
18. Dewailly D, Gronier H, Poncelet E, Robin G, Leroy M, Pigny P, *et al.* Diagnosis of polycystic ovary syndrome (PCOS): Revisiting the threshold values of follicle count on ultrasound and of the serum AMH level for the definition of polycystic ovaries. *Hum Reprod* 2011; *26* : 3123-9.
19. Pigny P, Jonard S, Robert Y, Dewailly D. Serum anti-Mullerian hormone as a surrogate for antral follicle count for definition of the polycystic ovary syndrome. *J Clin Endocrinol Metab* 2006; *91* : 941-5.
20. Iliodromiti S, Kelsey TW, Anderson RA, Nelson SM. Can anti-Mullerian hormone predict the diagnosis of polycystic ovary syndrome? A systematic review and meta-analysis of extracted data. *J Clin Endocrinol Metab* 2013; *98* : 3332-40.
21. Casadei L, Madrigale A, Puca F, Manicuti C, Emidi E, Piccione E, *et al.* The role of serum anti-Müllerian hormone (AMH) in the hormonal diagnosis of polycystic ovary syndrome. *Gynecol Endocrinol* 2013; *29* : 545-50.
22. Iglesias C, Banker M, Mahajan N, Herrero L, Meseguer M, Garcia-Velasco JA. Ethnicity as a determinant of ovarian reserve: Differences in ovarian aging between Spanish and Indian women. *Fertil Steril* 2014; *102* : 244-9.
23. Ferriman D, Gallwey JD. Clinical assessment of body hair growth in women. *J Clin Endocrinol Metab* 1961; *21* : 1440-7.
24. Kumar H, Halder A, Sharma M, Kalsi AK, Jain M. Dihydrotestosterone: a potential biomarker of hyperandrogenaemia in PCOS. *J Clin and Diag Res* 2022; *16*(2): QC09-14.
25. Stein IF, Leventhal ML. Amenorrhea associated with bilateral polycystic ovaries. *Am J Obstet Gynecol* 1935; *29* : 181-91.
26. Azziz R, Woods KS, Reyna R, Key TJ, Knochenhauer ES, Yildiz BO. The prevalence and features of the polycystic ovary syndrome in an unselected population. *J Clin Endocrinol Metab* 2004; *89* : 2745-9.
27. Nardo LG, Yates AP, Roberts SA, Pemberton P, Laing I. The relationships between AMH, androgens, insulin resistance and basal ovarian follicular status in non-obese subfertile women with and without polycystic ovary syndrome. *Hum Reprod* 2009; *24* : 2917-23.
28. Diamanti-Kandarakis E, Panidis D. Unravelling the phenotypic map of polycystic ovary syndrome (PCOS): A prospective study of 634 women with PCOS. *Clin Endocrinol (Oxf)* 2007; *67* : 735-42.
29. Pigny P, Gorisse E, Ghulam A, Robin G, Catteau-Jonard S, Duhamel A, *et al.* Comparative assessment of five serum antimüllerian hormone assays for the diagnosis of polycystic ovary syndrome. *Fertil Steril* 2016; *105* : 1063-9.e3.
30. Song DK, Oh JY, Lee H, Sung YA. Differentiation between polycystic ovary syndrome and polycystic ovarian morphology by means of an anti-Müllerian hormone cutoff value. *Korean J Intern Med* 2017; *32* : 690-8.
31. Matsuzaki T, Munkhzaya M, Iwasa T, Tungalagsuvd A, Yano K, Mayila Y, *et al.* Relationship between serum anti-Mullerian hormone and clinical parameters in polycystic ovary syndrome. *Endocr J* 2017; *64* : 531-41.
32. Lin YH, Chiu WC, Wu CH, Tzeng CR, Hsu CS, Hsu MI. Antimüllerian hormone and polycystic ovary syndrome. *Fertil Steril* 2011; *96* : 230-5.
33. Johnstone EB, Rousseau JA, Lamb JD, Huddleston HG, Cedars MI. Age bias in polycystic ovary syndrome (PCOS) diagnostic criteria limits diagnosis among those at greatest cardiovascular risk. *Fertil Steril* 2009; *92* : S38.
34. Johnstone EB, Rosen MP, Neril R, Trevithick D, Sternfeld B, Murphy R, *et al.* The polycystic ovary post-rotterdam: A common, age-dependent finding in ovulatory women without metabolic significance. *J Clin Endocrinol Metab* 2010; *95* : 4965-72.
35. Lim SS, Davies MJ, Norman RJ, Moran LJ. Overweight, obesity and central obesity in women with polycystic ovary syndrome: A systematic review and meta-analysis. *Hum Reprod Update* 2012; *18* : 618-3

Principal
Dyal Singh College
KARNAL

36. Coutinho EA, Kauffman AS. The role of the brain in the pathogenesis and physiology of polycystic ovary syndrome (PCOS). *Med Sci (Basel)* 2019; *7* : 84.

37. Coyle C, Campbell RE. Pathological pulses in PCOS. *Mol Cell Endocrinol* 2019; *498* : 110561.

38. Dewailly D, Pigny P, Soudan B, Catteau-Jonard S, Decanter C, Poncelet E, *et al.* Reconciling the definitions of polycystic ovary syndrome: The ovarian follicle number and serum anti-Müllerian hormone concentrations aggregate with the markers of hyperandrogenism. *J Clin Endocrinol Metab* 2010; *95* : 4399-405.

39. Skałba P, Cygal A, Madej P, Dąbkowska-Huć A, Sikora J, Martirosian G, *et al.* Is the plasma anti-Müllerian hormone (AMH) level associated with body weight and metabolic, and hormonal disturbances in women with and without polycystic ovary syndrome? *Eur J Obstet Gynecol Reprod Biol* 2011; *158* : 254-9.

40. Pinola P, Piltonen TT, Puurunen J, Vanky E, Sundström-Poromaa I, Stener-Victorin E, *et al.* Androgen profile through life in women with polycystic ovary syndrome: A nordic multicenter collaboration study. *J Clin Endocrinol Metab* 2015; *100* : 3400-7.

41. Bui HN, Sluss PM, Hayes FJ, Blincko S, Knol DL, Blankenstein MA, *et al.* Testosterone, free testosterone, and free androgen index in women: Reference intervals, biological variation, and diagnostic value in polycystic ovary syndrome. *Clin Chim Acta* 2015; *450* : 227-32.

For correspondence: Dr Ashutosh Halder, Department of Reproductive Biology, All India Institute of Medical Sciences, New Delhi 110 029, India
e-mail: ashutoshhalder@gmail.com

Principal
Dyal Singh College
KARNAL

Downloaded from http://journals.lww.com/ijmr by ieJYX11TbBwRWy/AfUkPVGzKFoOYN8toKVpUAEoOxsWbtwiig1DBrbonTvmORJIFjXnfRyTj13d72cT54fKEWl+pjl2pzKlmAveo49fiXRIRX143CZQvDGwfbeJ+/Xbwq3DF2HUm3HJQNgc34vxfFT4ulaqHq6ArJd0rTMxOoiU= on 11/11/2023

About the Journal : Indian Journal of Medical Research

Advertisement

About the Journal

The Indian Journal of Medical Research (IJMR) [Print ISSN: 0971-5916] is the flagship journal of the Indian Council of Medical Research (ICMR).

*In line with the priorities of ICMR in supporting and promoting biomedical research, the IJMR aims to disseminate quality biomedical research to all its readers in India as well as globally.

*In line with its mission to provide a platform to publish biomedical and public health investigations of national, regional and global interest, the Journal invites articles from a wide range of potential contributors conducting research based on quantitative, qualitative or mixed-method approach. Ease of access to expanding knowledge-base is ensured by the IJMR through its policy of free dissemination of contents to its readers.

***Note*:** Starting July 2022, all research content in the IJMR are being published under three main categories namely, POLICY, PROGRAMME and PRACTICE with a view to help readers to navigate through the Journal's content and to inform public health discussions as appropriate.

The IJMR is one of the oldest medical Journals not only in India, but probably in Asia, as it started in the year 1913. The Journal was started as a quarterly (4 issues/year) in 1913 and made bimonthly (6 issues/year) in 1958. It became monthly (12 issues/year) in the year 1964. The Journal is being indexed and abstracted by all major global current awareness and alerting services (Annexure).

The IJMR is published monthly, in two volumes and 12 issues per year. The IJMR publishes peer reviewed quality biomedical research in the form of original research articles, review articles, short papers, short notes. Research letters are also published in the corresponding section after peer review. Special issues and Supplements and are published in addition to the regular issues.

Criteria for consideration of papers - The papers should meet the following criteria – the material should be original, the methodology used should be standard and appropriate, results should be unambiguous supported with data/photographs, conclusions should be reasonable and based on the findings, the topic should be of biomedical interest and findings should have clinical significance. Papers involving human and animals should be ethically cleared by the local ethical committees.

Manuscript Preparation - Manuscript should be prepared in accordance with the Guidelines set by the International Committee of Medical Journal Editors (ICMJE) as uniform requirements for manuscripts submitted to biomedical journals and should be submitted online at http://www.journalonweb.com/ijmr . Abstract should be structured (of about 250 words) under the subheadings Background & objectives, Methods, Results, and Interpretation & conclusions.

Abstracting and Indexing Information

The journal is registered with the following abstracting partners:
Baidu Scholar, CNKI (China National Knowledge Infrastructure), EBSCO Publishing's Electronic Databases, Ex Libris – Primo Central, Google Scholar, Hinari, Infotrieve, National Science Library, ProQuest, TDNet, Wanfang Data

The journal is indexed with, or included in, the following:
DOAJ, Index Medicus for South-East Asia Region, Indian Science Abstracts, IndMed, MEDLINE/Index Medicus, PubMed Central, Scimago Journal Ranking, SCOPUS, Science Citation Index Expanded, Web of Science

Impact Factor® as reported in the 2022 Journal Citation Reports® (Clarivate Analytics, 2023): **4.2**

Principal
Dyal Singh College
KARNAL

Journal Ethics

The Indian Journal of Medical Research (IJMR) follows ethical principles laid down by scholarly bodies such as COPE (Committee on Publication Ethics), ICMJE (International Committee of Medical Journal Editors) and also Ethical Guidelines for Biomedical Research on Human Participants, 2017 https://icmr.nic.in/sites/default/files/guidelines/ICMR_Ethical_Guidelines_2017.pdf. All manuscripts based on research involving human participants or using human blood, tissues and other samples as also medical records need to be submitted along with a clearance certificate from the Institutional Ethics Committee. The members of the Committee should also be listed. For Clinical Images and case series duly signed Patient Consent Form needs to be submitted along with the manuscript. Studies involving animals need to be submitted with a clearance certificate from the Institutional Animal Ethics Committee.

Wolters Kluwer and Journal/Association are committed to meeting and upholding standards of ethical behavior at all stages of the publication process. We follow closely the industry associations, such as the Committee on Publication Ethics (COPE), International Committee of Medical Journal Editors (ICMJE) and World Association of Medical Editors (WAME), that set standards and provide

guidelines for best practices in order to meet these requirements. For a summary of our specific policies regarding duplicate publication, conflicts of interest, patient consent, etc., please visit www.Medknow.com/EthicalGuidelines.asp

Open Access Publication and Creative Commons Licensing

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Digital Archiving

Wolters Kluwer Medknow provides for long-term digital preservation through two primary partnerships, Portico and CLOCKSS.

Portico is a leading digital preservation service worldwide. The content is preserved as an archival version and is not publically accessible via Portico, but is provided when required under specific conditions, such as discontinuation of the collection or catastrophic failure of the website.

CLOCKSS will enable any library to maintain their own archive of content from Wolters Kluwer Medknow and other publishers, with minimal technical effort and using cheaply available hardware.

Ahead of Print policy

Articles published online under the Ahead of Print model are considered published and can be cited and quoted using the DOI as the reference source. Wolters Kluwer Medknow has a policy that changes will not be made after publication of an article without following accepted procedures for making corrections to the scientific record.

Advertisements

While advertisements are crucial to this journal to be able to keep all content free for everyone, ethical considerations are in place to ensure the integrity of the journal and its content:

- "Pop-up" and "banner" ads appear on a random, rotating basis. The advertiser has no control or input over the pages where their ads appear.
- The Editorial Board has full and final approval over the content of all advertisements.
- Advertisers will never be shown any manuscripts or other content prior to publication.

Scope of the journal

The Journal publishes original communications of biomedical research that advances or illuminates medical science or that educates the journal readers. Articles with clinical interest and implications will be given preference.

Medknow Publications

Medknow, part of Wolters Kluwer Health, is one of the largest open access publishers worldwide with more than 450+ medical journals in its portfolio. Students, researchers, clinicians and other healthcare professionals worldwide access Medknow journals to help them fuel new discoveries and improve patient care.

Founded in 1997, Medknow is a well-respected medical publisher that fully supports many of the popular open access models through its peer-review management system. Medknow's open access policy has resulted in more than a half a million article downloads monthly for all of its journals.

Wolters Kluwer Health (Philadelphia, PA) is a leading global provider of information, business intelligence and point-of-care solutions for the healthcare industry. Serving more than 150 countries and territories worldwide, Wolters Kluwer Health's customers include professionals, institutions and students in medicine, nursing, allied health and pharmacy. Major brands include Lippincott Williams & Wilkins, Ovid®, UpToDate®, Medi-Span®, Facts & Comparisons®, Pharmacy OneSource®, Lexicomp® and ProVation® Medical. Wolters Kluwer Health is part of Wolters Kluwer, a market-leading global information services company with annual revenues (2019) of €3.4 billion ($4.7 billion), approximately 19,000 employees worldwide and operations in over 40 countries across Europe, North America, Asia Pacific, and Latin America.

Medknow Specialties
Online and Print Scholarly Publishing, Peer-Review System, Specialized in Medical Research, Largest Open Access Publisher

SCOPE

The Indian Journal of Medical Research (IJMR) is a biomedical journal with international circulation. It publishes origi communications of biomedical research that *advance or illuminate medical science or that educate* the journal readers. monthly, in two volumes per year.

Principal
Dyal Singh College
KARNAL

Manuscripts dealing with clinical aspects will be considered for publication, provided they contain results of original investigations. Articles need to be of general interest - *e.g.*, they cross the boundaries of specialities or are of sufficient novelty and importance that

the journal's readers, whatever be their speciality, should be made aware of the findings. **Research papers reporting original research, review articles (both narrative and evidence based), research correspondence**, **letter to editor will be considered. View points and Perspectives are also considered**. Papers of routine nature which are merely records of interesting cases, as also those dealing with modifications of routine methodology are not encouraged. Further, serialization of articles by the same author(s) into various parts (1,2,3, *etc*.) is strongly discouraged. In such cases the authors are advised to submit independent papers with self-sufficient titles and text.

The IJMR strongly discourages duplication/reduplication of data already published in other journals (even when certain cosmetic changes/additions are made). If and when duplication is detected after publishing in IJMR, the journal will be forced to 'retract' such articles. Articles based on work carried out in private nursing homes and other non-recognized hospitals/research institutes will be discouraged.

Advertisement

^Back to Top



Never Miss an Issue

Get new journal Tables of Contents sent right to your email inbox Type your email Get New Issue Alerts

Browse Journal Content

- Most Popular
- For Authors
- About the Journal
- Past Issues
- Current Issue
- Register on the website
- Subscribe
- Get eTOC Alerts

Customer Service

- Contact us at:
  - Support:
    Submit a Service Request
  - TEL:
    800-638-3030 (within the USA)
    301-223-2300 (outside of the USA)
- Manage Cookie Preferences
- Privacy Policy (Updated June 29, 2023)
- Legal Disclaimer
- Terms of Use

Principal
Dyal Singh College
KARNAL

- Open Access Policy

- Copyright © 2023
- Indian Journal of Medical Research | Published by Wolters Kluwer – Medknow

Principal
Dyal Singh College
KARNAL

Exploration of Endocrine and Metabolic Diseases

Open Exploration

Open Access Original Article

Epigenetics in etiopathology of hyperprolactinemia

Amanpreet Kaur Kalsi[1*], Ashutosh Halder[2*], Manish Jain[2], Jai Bhagwan Sharma[3]

[1]Department of Zoology, Dyal Singh College, Karnal, Haryana 132001, India
[2]Department of Reproductive Biology, All India Institute of Medical Sciences, New Delhi 110029, India
[3]Department of Obstetrics and Gynecology, All India Institute of Medical Sciences, New Delhi 110029, India

***Correspondence:** Amanpreet Kaur Kalsi, Department of Zoology, Dyal Singh College, Karnal, Haryana 132001, India. kalsi.amanpreetkaur@gmail.com; Ashutosh Halder, Department of Reproductive Biology, All India Institute of Medical Sciences, New Delhi 110029, India. ashutoshhalder@gmail.com
Academic Editor: Charlotte Steenblock, University Clinic Carl Gustav Carus, Germany
Received: June 5, 2023 **Accepted:** August 22, 2023 **Published:** May 20, 2024

Cite this article: Kalsi AK, Halder A, Jain M, Sharma JB. Epigenetics in etiopathology of hyperprolactinemia. Explor Endocr Metab Dis. 2024;1:39–55. https://doi.org/10.37349/eemd.2024.00006

Abstract

Aim: Epigenetic alterations have been reported in patients with pituitary tumors and those on antipsychotic drugs, which are also responsible for hyperprolactinemia. This suggests a possible role of epigenetics in the etiopathology of hyperprolactinemia.

Methods: The study recruited 83 hyperprolactinemia cases with prolactin > 100 ng/mL and 65 controls. Global DNA methylation status was studied by MethylFlash Methylated DNA Quantification Kit and genome-wide methylation analysis (GWMA) by Infinium Methylation EPIC BeadChip 850K array.

Results: Hyperprolactinemia cases showed significant global DNA hypermethylation compared to controls. Around 66.67% of hypomethylated and 12.9% of hypermethylated cases were on antipsychotics. Gene enrichment analysis of 5-cytosine-phosphate-guanine-3 (CpG) site-associated genes demonstrated significantly enriched major histocompatibility complex (MHC)-related protein classes and cellular components.

Conclusion: The study suggested the role of epigenetics in the etiopathology of hyperprolactinemia.

Keywords

Epigenetics, hyperprolactinemia, prolactin, etiopathology, pituitary adenoma, antipsychotics, global DNA methylation, genome-wide methylation analysis

Introduction

An important mechanism by which environmental agents can affect gene expression is by changing epigenetics—DNA methylation, histone modification, and microRNA (miRNA) [1]. DNA methylation refers to adding a methyl group to the cytosine base of DNA. The sequence-specific pattern of DNA methylation is required for proper genome functioning. DNA methylation is often associated with transcription repression, although the effect may vary based on genomic context and locus [2, 3]. Studies have reported significant associations between DNA methylation patterns and hormonal variations [4, 5]. Nugent et al. [5]

© **The Author(s) 2024.** This is an Open Access article licensed under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

Principal
Dyal Singh College
KARNAL

reported that hormone levels affect DNA methylation status, regulating gene transcription throughout the entire lifetime.

Prolactin hormone is synthesized and secreted mainly by the anterior pituitary lactotroph cells and is regulated by a dopaminergic pathway [6]. Dopamine, released from the tuberoinfundibular neurons of the hypothalamus [7], binds to Gi/o coupled D2-type receptors on lactotroph cells of the anterior pituitary and inhibits prolactin synthesis and secretion [6, 8]. Besides dopaminergic regulation, prolactin is under direct regulation of corticosteroid hormones, which bind to glucocorticoid receptors on lactotroph cells and inhibit prolactin secretion [9]. Both receptor types employ different pathways to ultimately target the proximal promoter region of the prolactin gene, inhibiting prolactin gene transcription [10–15]. There is evidence for epigenetic role in dopamine D2 receptor (D2R)-dependent inhibition of the prolactin gene where histone deacetylation and corepressor complex recruitment occur at the prolactin gene promoter region [8]. A reduction in D2R has also been shown to increase prolactin production via epigenetic mechanisms [16].

The pathological condition where prolactin level rises above the normal range is called hyperprolactinemia, which has serious side effects like galactorrhoea, irregular menstrual cycle, secondary amenorrhea, infertility, bone loss, etc. [17]. The prevalence of hyperprolactinemia varies from 40–70% in patients with antipsychotics based on individual antipsychotic medication [18]. Besides antipsychotics, hyperprolactinemia is also caused by pituitary micro/macro adenomas [19], some anti-acidity drugs, other secondary causes, and some idiopathic cases [20]. Most pituitary tumors arise due to gene-specific changes in the epigenome [17, 21–26]. Studies are reporting epigenetic alterations in patients with pituitary tumors and those on antipsychotic drugs, conditions that are also responsible for hyperprolactinemia [24, 25]. Antipsychotic drugs are known to mediate their action by methylation changes in dopaminergic and non-dopaminergic pathways, which function by altering the transcription pattern of target genes [17, 26]. A single genetic cause of hyperprolactinemia was found in three sisters of the same family, showing germline loss-of-function mutation in the prolactin receptor gene [27].

Lack of familial cases and genetic associations of hyperprolactinemia on one side and evidence of epigenetic involvement in prolactin regulation in patients with pituitary tumors, on antipsychotic drugs, and those treated with dopamine agonist, cabergoline, used in treatment of hyperprolactinemia on the other side [28], makes it reasonable to hypothesize that epigenetic factors might be involved in etiopathology of hyperprolactinemia condition.

Material and methods

This study was conducted in the Department of Reproductive Biology, All India Institute of Medical Sciences (AIIMS), New Delhi. Patients having prolactin levels > 100 ng/mL on two occasions of > 1-month intervals were included in the study. Informed consent was obtained from all individual participants included in the study. Prolactin assays were performed using highly specific Chemiluminescence Microparticle Immunoassay (CMIA, 7K76 G6-5314/R06 B7K760) using ARCHITECT PLUS i2000SR automated immunoassay system (Abbott Laboratories, USA). Eighty-three female patients with prolactin levels > 100 ng/mL were prospectively enrolled in the study after obtaining written consent. Detailed clinical data was recorded as per predetermined proforma. The minimum initial evaluation consisted of a complete medical history, physical examination, and hormone measurements besides computed tomography (CT)/magnetic resonance imaging (MRI) to evaluate the pituitary fossa for prolactinoma and/or other pituitary adenoma. Screening for macroprolactinemia was done in all hyperprolactinemia patients using the polyethylene glycol (PEG) precipitation method [29]. Macroprolactinemia was considered when prolactin recovery was < 25% of the initial prolactin value.

Based on the cause of hyperprolactinemia, the cases were classified into drug-induced (n = 37), idiopathic (n = 28), and pituitary micro/macro adenoma (n = 18). Additionally, 65 healthy fertile females aged 20 to 35 with regular menstrual cycles were included as controls. Approximately 5 mL EDTA blood was taken for manual DNA extraction by Miller's method, as described further [30]. The blood was taken in

Principal
Dyal Singh College
KARNAL

a 50 mL Falcon tube. Then, 1X red blood cell (RBC) lysis buffer (RLB) was added to the 50 mL mark, and the contents were inverted and mixed. The Falcon tube was kept as such for 20 min at room temperature. The tube was centrifuged at 4,000 rpm for 10 min at room temperature. The supernatant was discarded. After this, 15 mL 1X RLB was added to the tube, and the pellet was dissolved by tapping. It was then centrifuged at 3,500 rpm for 10 min. The supernatant was discarded, and the tube was kept inverted on a blotting sheet to decant the supernatant completely. Around 12 mL nuclear lysis buffer (NLB) was added to the tube, and the pellet was dissolved by tapping. Following this, 800 µL 10% sodium dodecyl sulphate (SDS) was added, and contents were mixed thoroughly by tapping. In the next step, 50 µL proteinase K was added, and after the contents were thoroughly mixed, the tube was incubated in a water bath at 56°C for 2 h. When the incubation ended, 4 mL of 6 mol/L sodium chloride (NaCl) was added, and the contents were mixed by tapping. The tube was then centrifuged at 3,100 rpm for 30 min. The supernatant containing DNA was transferred to a new 50 mL Falcon tube. DNA was precipitated by adding 2X volume of 100% ethanol and inverting the tube several times until strands of precipitated DNA were visible. The precipitated DNA was transferred to 70% ethanol in a 1.5 mL Eppendorf tube with the help of a wide-bored pipette tip. The Eppendorf tube was centrifuged at 13,000 rpm for 10 min at room temperature. The supernatant was removed, and the pellet was allowed to dry completely. To the dried DNA pellet, 1 mL elution buffer was added and was left overnight for the pellet to dissolve in the buffer. The next day, the Eppendorf tube was incubated in a water bath at 56°C for 2 h to ensure complete DNA mixing in the elution buffer. DNA was finally quantified using Nanodrop (NanoDrop 1000, NanoDrop Technologies via Thermo Fisher Scientific USA Serial No. B571 Model ND-1000 UV/Vis).

Global DNA methylation

The global DNA methylation status of these 83 cases and 65 controls were studied by MethylFlash Methylated DNA Quantification Kit (colorimetric) from Epigentek (base catalog# P-1034). The assay was performed according to the manufacturer's protocol using 100 ng input DNA per sample, bound to the plate wells specifically treated to have a high affinity for DNA. Methylated DNA fraction was detected by capture and detection antibodies and quantified colorimetrically by reading absorbance at 450 nm in a microplate spectrophotometer. The amount of absolute methylated DNA was calculated by making a standard curve of optical density (OD) values and the amount of positive control (ME4) at each concentration point. ME4 is a methylated polynucleotide containing 50% of 5-methylcytosine (5-mC). The slope (OD/ng) of the standard curve was determined using linear regression, and the most linear part of the standard curve was used for optimal slope calculation. The amount and percentage of Methylated DNA (5-mC) in total DNA was then calculated using the formulas:

$$\text{5-mC (ng)} = \frac{\text{Sample OD} - \text{ME3 OD}}{\text{Slope} \times 2}$$

$$\text{5-mC (\%)} = \frac{\text{5-mC Amount (ng)}}{\text{S}} \times 100\%$$

Where "ME3" represents negative control, is an unmethylated polynucleotide containing 50% of cytosine, "S" represents the amount of input sample DNA in ng, "2" represents a factor to normalize 5-mC in the positive control to 100%, as the positive control contains only 50% of 5-mC.

The mean of 5-mC (%) of controls was calculated, and cases with 5-mC (%) > 2 fold or < 0.5 fold the control mean was said to have significant differences in global DNA methylation and thus were considered hypermethylated and hypomethylated. Statistical significance between groups was determined by comparing *P* values.

Genome-wide methylation analysis

Based upon the global DNA methylation study findings, six significantly hypomethylated and six hypermethylated cases and four controls were selected for genome-wide methylation anal[illegible]. The details of the selected 12 cases are described in Table 1.

Principal
Dyal Singh College
KARNAL

Table 1. Details of hyperprolactinemia cases selected for GWMA

Serial No.	Sample No.	Cause of hyperprolactinemia	True hyperprolactinemia or macroprolactinemia
1	DBN 6	Pituitary adenoma	True hyperprolactinemia
2	DBN 7	Pituitary adenoma	True hyperprolactinemia
3	DBN 8	Idiopathic	True hyperprolactinemia
4	DBN 16	Idiopathic	Macroprolactinemia
5	DBN 30	Antipsychotics	True hyperprolactinemia
6	DBN 39	Idiopathic	Macroprolactinemia
7	DBN 51	Pituitary adenoma	Macroprolactinemia
8	DBN 54	Idiopathic	Macroprolactinemia
9	DBN 68	Idiopathic	True hyperprolactinemia
10	DBN 75	Antipsychotics	True hyperprolactinemia
11	DBN 92	Antipsychotics	Macroprolactinemia
12	DBN 94	Antipsychotics	True hyperprolactinemia

DBN: data base number

Whole blood DNA samples of 12 hyperprolactinemia cases and four controls were sent to MedGenome Labs Ltd. for GWMA using Infinium Methylation EPIC BeadChip 850K array with Illumina iScan System. The 12 hyperprolactinemia cases and four controls assessed genome-wide methylation differences among various conditions (Table 2). Both site-level and region-level differential methylation analyses were performed.

Table 2. Grouping of hyperprolactinemia cases and controls for differential methylation analysis

Comparison NO.	Group control (*n*)	Group test (*n*)
1	CTRL (4)	HPRL-all (12)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 30, DBN 54, DBN 68, DBN 75, DBN 92, DBN 94, DBN 6, DBN 7, DBN 8, DBN 16, DBN 39, DBN 51
2	CTRL (4)	HPRL-hypomethylated (6)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 30, DBN 54, DBN 68, DBN 75, DBN 92, DBN 94
3	CTRL (4)	HPRL-hypermethylated (6)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 6, DBN 7, DBN 8, DBN 16, DBN 39, DBN 51
4	HPRL- hypomethylated (6)	HPRL-hypermethylated (6)
	DBN 30, DBN 54, DBN 68, DBN 75, DBN 92, DBN 94	DBN 6, DBN 7, DBN 8, DBN 16, DBN 39, DBN 51
5	CTRL (4)	HPRL-antipsychotics, all hypomethylated (4)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 30, DBN 75, DBN 92, DBN 94
6	CTRL (4)	HPRL-idiopathic, hypomethylated (2)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 54, DBN 68
7	CTRL (4)	HPRL-idiopathic, hypermethylated (3)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 8, DBN 16, DBN 39
8	CTRL (4)	HPRL-pituitary adenoma, all hypermethylated (3)
	CTRL 4, CTRL 12, CTRL 31, CTRL 54	DBN 6, DBN 7, DBN 51
9	HPRL-idiopathic, hypomethylated (2)	HPRL-idiopathic, hypermethylated (3)
	DBN 54, DBN 68	DBN 8, DBN 16, DBN 39

HPRL: hyperprolactinemia patients; CTRL: control (for Table 2 only)

Case wise comparison of differential methylation

Following by comparison between groups, the methylation level of individual cases was compared to the control mean methylation level to find differentially methylated 5-cytosine-phosphate-guanine-3 (CpG) sites in individual cases. All sites with a methylation change of 50% compared to the control mean methylation level were selected for gene ontology (GO) analysis.

Principal
Dyal Singh College
KARNAL

GO analysis was performed with the publicly available tool Protein Analysis Through Evolutionary Relationships (PANTHER, http://www.pantherdb.org/). A pathway or biological process was significantly enriched if the false discovery rate (FDR) *P* value was < 0.05.

Results

Global DNA methylation

Overall, hyperprolactinemia patients showed significant hypermethylation compared to controls (Table 3 and Figure 1). Of 83 cases, 40 hyperprolactinemia cases (48.19%) showed significant changes in global DNA methylation (Figure 2). Of these 40 cases, 9 showed hypomethylation, of which 6 cases (66.67%) were on antipsychotic drugs, one was on anti-acidity drugs, and 2 were idiopathic hyperprolactinemia cases. The remaining 31 cases out of 40 (77.5%) showed global DNA hypermethylation, out of which 4 cases (12.9%) were on antipsychotic drugs, 3 cases (9.6%) were on anti-acidity drugs, 12 cases (38.71%) had idiopathic hyperprolactinemia and 12 cases (38.71%) had hyperprolactinemia due to pituitary micro/macro adenoma. The percentage of cases with global DNA hypomethylation or hypermethylation in each category of hyperprolactinemia patients is presented in Figure 3. There were 25% hypermethylated and 38% hypomethylated cases among antipsychotics induced hyperprolactinemia patients, while 37% had no significant methylation change. In cases with hyperprolactinemia due to drugs other than antipsychotics, 14% were hypermethylated, 5% were hypomethylated, and 81% had no significant methylation change. In idiopathic hyperprolactinemia cases, 43% were hypermethylated, 7% were hypomethylated, and the remaining 50% showed no significant change in global DNA methylation. In cases with hyperprolactinemia due to pituitary adenoma, 67% of cases had significant hypermethylation, and the remaining 33% had no significant change in global DNA methylation.

Table 3. Comparison of global 5-mC (%) between different categories of hyperprolactinemia cases and controls

Group (*n*)	5-mC (%), mean ± SD (range)	*P* value
Controls (65)	2.82 ± 1.40 (< 0.2–6.74)	NA
Hyperprolactinemia patients (83)	4.98 ± 2.68 (< 0.2–15.98)	< 0.0001**
Drug-induced (37)	3.59 ± 1.91 (< 0.2–7.38)	0.0216*
Idiopathic (28)	5.94 ± 2.83 (0.63–15.98)	< 0.0001**
Pituitary adenoma (18)	6.34 ± 2.44 (1.8–11.41)	< 0.0001**
Macroprolactinemia (20)	5.47 ± 3.5 (< 0.2–15.98)	< 0.0001**
True hyperprolactinemia (63)	4.87 ± 2.33 (0.74–8.4)	< 0.0001**

* *P* < 0.05; ** *P* < 0.0001; NA: not applicable

GWMA

Site-level GO analysis did not yield statistically significant results for all pair-wise comparisons. Differential methylation for the different regions (Tiling, genes, promoters, and CpG islands) was performed. No significant gene enrichment analysis was found for all comparisons for differentially methylated sites in the CpG island or promoter region.

Case-wise comparison of differential methylation

The CpG methylation level of each of the 12 hyperprolactinemia patients was individually compared with the mean methylation level of controls. The number of differentially methylated CpG sites in each case (more than 50% change in methylation level compared to control mean) are presented in Table 4.

Table 4. The number of hypomethylated (< 50%) and hypermethylated (> 50%) CpG sites and the number of gene coding CpG sites showing a 50% change in methylation in each of the 12 hyperprolactinemia patients

Case	CpG sites differentially methylated	CpG sites hypomethylated (< 50%)	CpG sites hypermethylated (> 50%)
DBN 6	166	122	44
DBN 7	156	116	40

Principal
Dyal Singh College
KARNAL

Table 4. The number of hypomethylated (< 50%) and hypermethylated (> 50%) CpG sites and the number of gene coding CpG sites showing a 50% change in methylation in each of the 12 hyperprolactinemia patients (*continued*)

Case	CpG sites differentially methylated	CpG sites hypomethylated (< 50%)	CpG sites hypermethylated (> 50%)
DBN 8	167	113	54
DBN 16	194	155	39
DBN 30	171	139	32
DBN 39	161	119	42
DBN 51	164	118	44
DBN 54	181	153	28
DBN 68	164	118	46
DBN 75	182	149	33
DBN 92	169	109	60
DBN 94	152	105	47

DBN: data base number; CpG: 5-cytosine-phosphate-guanine-3

Gene set enrichment analysis of aberrantly methylated genes

In order to have further insight into the cellular components, molecular processes, biological processes, protein classes, and pathways associated with the aberrant methylated genes in individual cases, gene set enrichment analysis was performed for these genes using the PANTHER classification system. The gene set enrichment analyses for the aberrantly methylated genes in individual hyperprolactinemia patients compared to control mean methylation are shown in Figures 4 and 5.

Discussion

Global DNA methylation

The study showed that 48.19% (40/83) of hyperprolactinemia cases had significantly changed global DNA methylation. Of these, 66.67% (6/9) hypomethylated and 12.9% (4/31) hypermethylated hyperprolactinemia cases were on antipsychotic drugs. Earlier studies have observed an association of global DNA methylation in schizophrenia patients on antipsychotics [31]. Differential changes in methylation in our cases may be due to different combinations of antipsychotic drugs these patients are taking, which might be mediating their actions via different pathways, either by direct hypomethylation of prolactin promoter gene or indirectly, by hypermethylation of promoter regions of prolactin inhibitory factors such as dopamine. Decrease in D2R in the pituitary occurs by increased methylation of *D2R* gene promoter, which is accompanied by an increase in levels of DNA methylating gene mRNAs DNA methyltransferase 1 (*DNMT1*), *DNMT3b*, methyl CpG binding protein 2 (*MeCP2*), and histone modifying gene mRNAs histone deacetylase 2 (*HDAC2*), *HDAC4*, and *G9a*. The reduced D2R prevents dopamine from regulating prolactin, resulting in elevated prolactin levels and hyperprolactinemia [16].

Whether these changes in DNA methylation are part of the etiology/cause of psychiatric disorders or the effect of antipsychotic drugs used to treat psychiatric disorders is a major question to address. However, this cannot be commented upon as drug withdrawal was not possible. Studies, however, have associated psychiatric disorders with alteration in gene expression [32], potentiating the role of regulatory mechanisms such as DNA methylation in psychiatric disorders [33]. Various approaches have shown the role of DNA methylation in developing psychiatric disorders, including animal models [34], monozygotic twins [35], and post-mortem human brains [36]. A study conducted on medication-free schizophrenia subjects shows that changes in DNA methylation are part of the pathophysiology of the disease [37], acting via dopaminergic or non-dopaminergic pathways [38, 39]. On the other hand, studies on both human and animal models have given evidence that antipsychotic drugs may also mediate their action via DNA methylation [31, 38–42]. Significant hypomethylation was observed in schizophrenia patients on antipsychotics compared to those not on medication [38]. Studies on monozygotic twins with major depressive disorders on medication and their comparison with unaffected co-twins show similar effects of antipsychotics on DNA methylation patterns rather than a cause or effect of psychiatric conditions [43].

Principal
Dyal Singh College
KARNAL

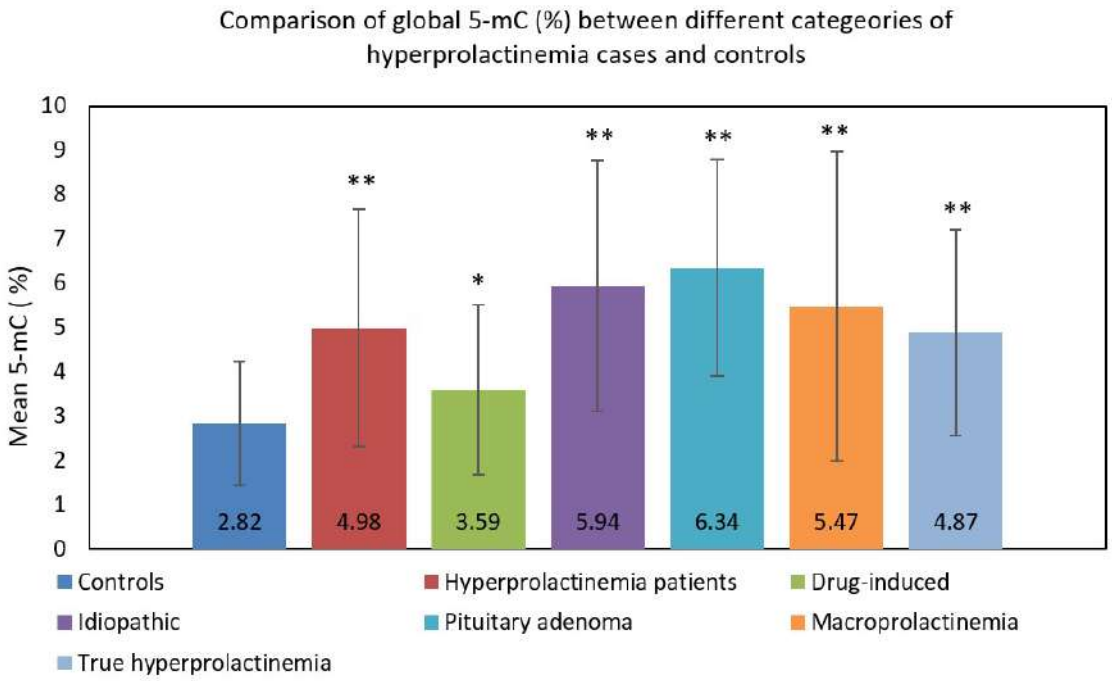


Figure 1. Bar graph showing the comparison of global 5-mC (%) between different categories of hyperprolactinemia cases and controls. * $P < 0.05$; ** $P < 0.0001$. 5-mC: 5-methylcytosine

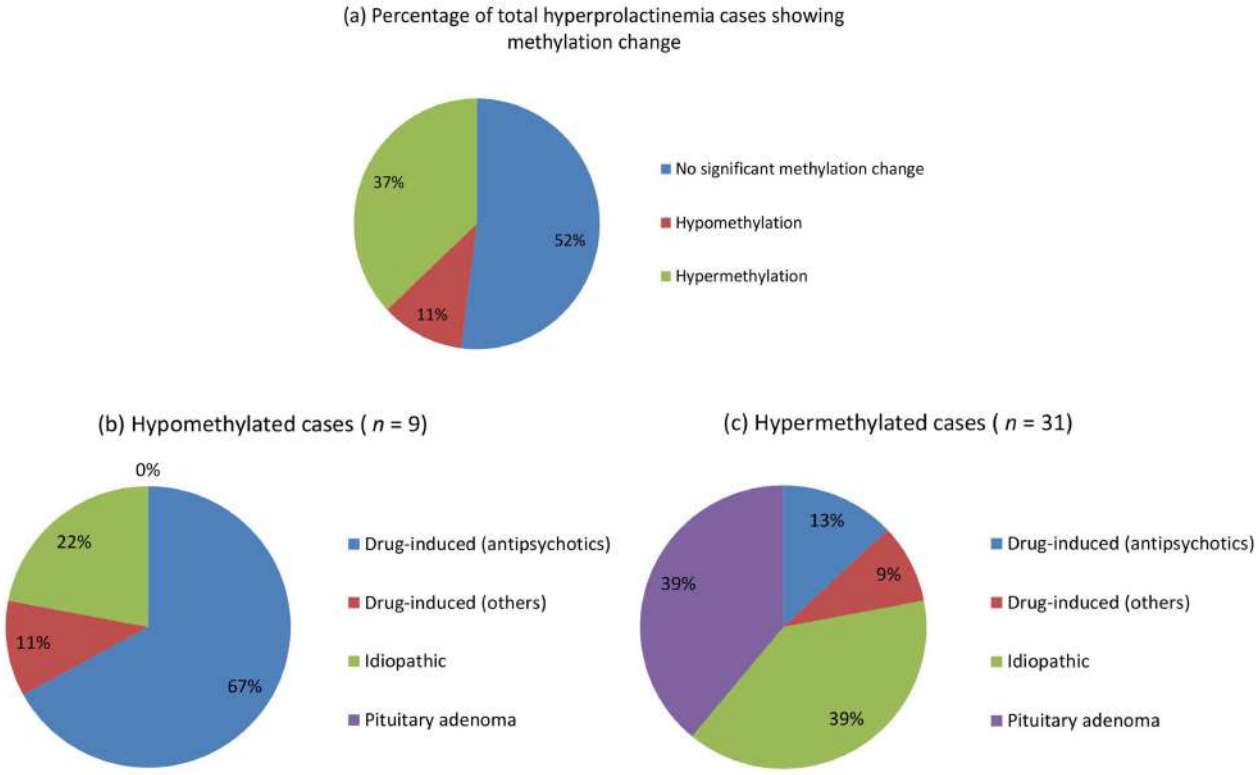


Figure 2. Pie chart showing (a) percentages of hyperprolactinemia cases with hyper/hypomethylation, (b) and (c) their categorization into different hyperprolactinemia categories

Antipsychotic drugs of dibenzepine derivatives (e.g., clozapine, quetiapine, olanzapine) induce chromatin remodeling changes and activate DNA demethylation of gamma amino butyric acidergic (GABAergic) gene promoters [40], which is well known to regulate prolactin secretion [44]. Methionine is related to increased s-adenosyl methionine (SAM) levels in the brain [42, 45–47], which is known to restore prolactin receptors in the brain [48]. Methionine is also related to elevated DNMT1 activity, hypermethylation of GAD67 promoters (an enzyme catalyzing the decarboxylation of glutamate to GABA), and alteration in

Principal
Dyal Singh College
KARNAL

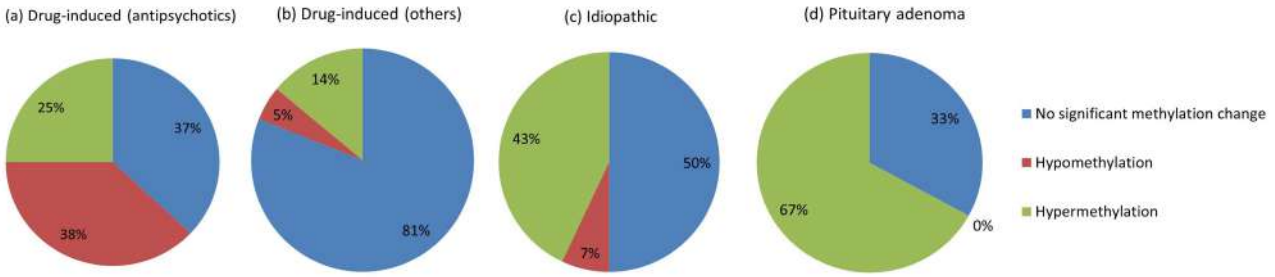


Figure 3. Pie chart showing the percentage of cases with global DNA hypo/hypermethylation in each category of hyperprolactinemia

physiological and behavioral responses [42, 45–47]. This suggests that changes in DNA methylation play a role in the development of psychiatric conditions and are also involved in the action of antipsychotic drugs [49, 50]. However, the effect of antipsychotics on DNA methylation may be direct or indirect via inhibition of HDAC [51], as is shown by the effect of valproate, an HDAC inhibitor, on methylation changes [52, 53]. Inhibition of HDAC might be interfering with the normal epigenetic prolactin regulatory mechanism of activation of D2R, causing histone deacetylation and recruitment of mSin3A/HDAC corepressor complex to the prolactin gene promoter [8]. Whether anti-acidity drugs also have a similar epigenetic role while causing their effect and side effects must be probed further.

Another concern in methylation studies is whether the changes in methylation are tissue-specific. The present study shows global DNA methylation changes in peripheral blood. Others have shown similar differential methylation patterns in distinct brain regions—hippocampus and cerebellum as an effect of antipsychotics which vary significantly in other regions like the liver [34]. Even blood and brain samples from schizophrenia patients had similar differences in DNA methylation compared to controls [36].

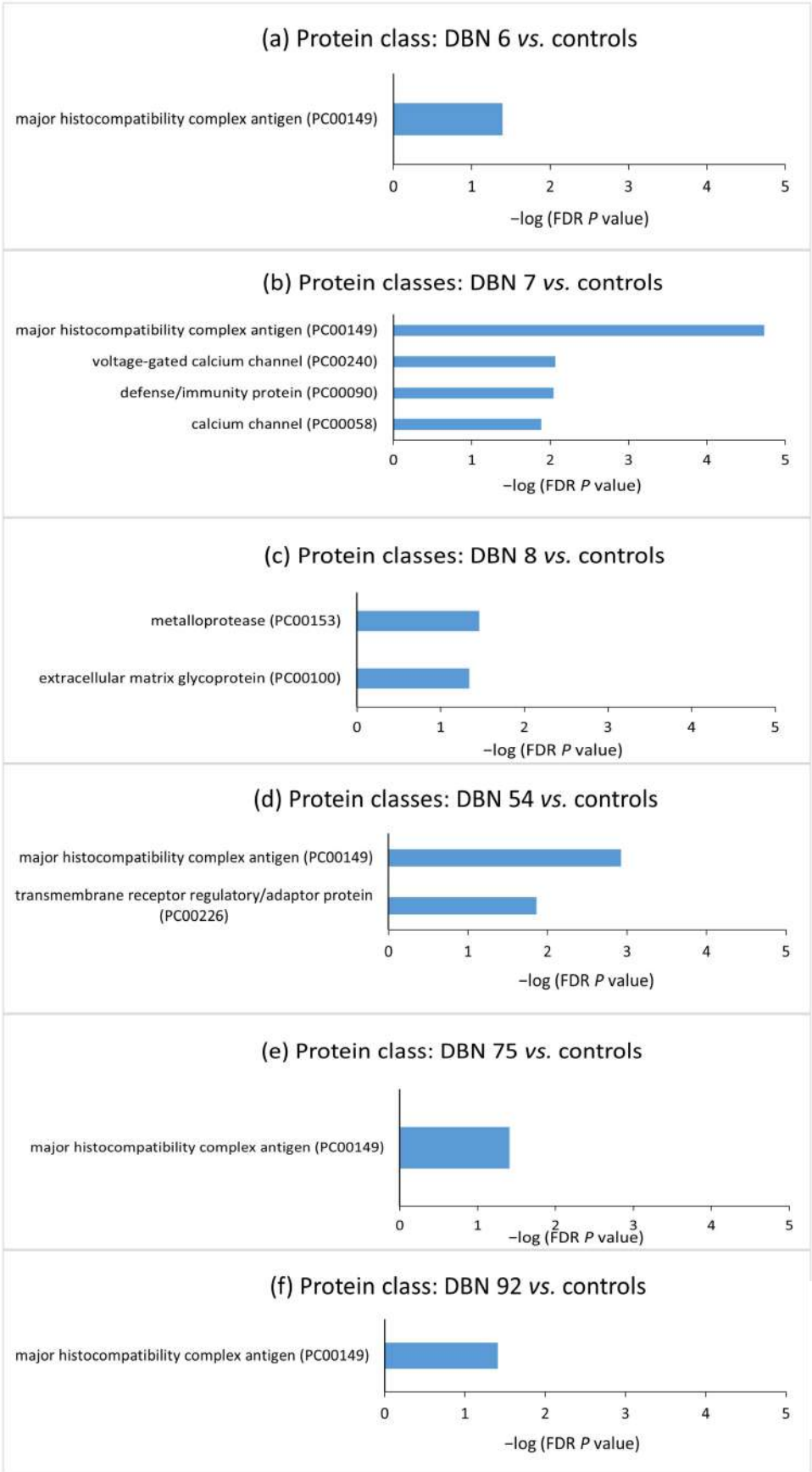
Among the hyperprolactinemia cases caused by pituitary adenoma, 66.67% (12/18) showed a significant change in methylation, and all these 12 cases were hypermethylated. Pituitary adenoma causes hyperprolactinemia by restricting dopamine from reaching D2R on the anterior pituitary lactotroph cells to regulate prolactin secretion. Hypermethylation in 66.67% of cases with hyperprolactinemia caused by pituitary adenoma stresses upon the role of epigenetics in pituitary micro/macro adenomas causing hyperprolactinemia which might occur by increasing methylation of D2R promoter resulting in reduced D2R expression on lactotroph cells, poor dopamine inhibition, and elevated prolactin levels as is seen in case of fetal alcohol exposure [16], However, further experiments are needed to verify this.

Since no significant genetic cause was found in idiopathic hyperprolactinemia cases (unpublished data), here also, epigenetics might be playing a role in the etiopathology of hyperprolactinemic condition as 50% (14/28) idiopathic hyperprolactinemia cases showed significant change in methylation compared to control mean, out of which 12 cases showed hypermethylation and 2 showed hypomethylation. The absence of heritability and lack of familial cases with hyperprolactinemia also emphasize the role of epigenetics in the manifestation of the condition.

GWMA

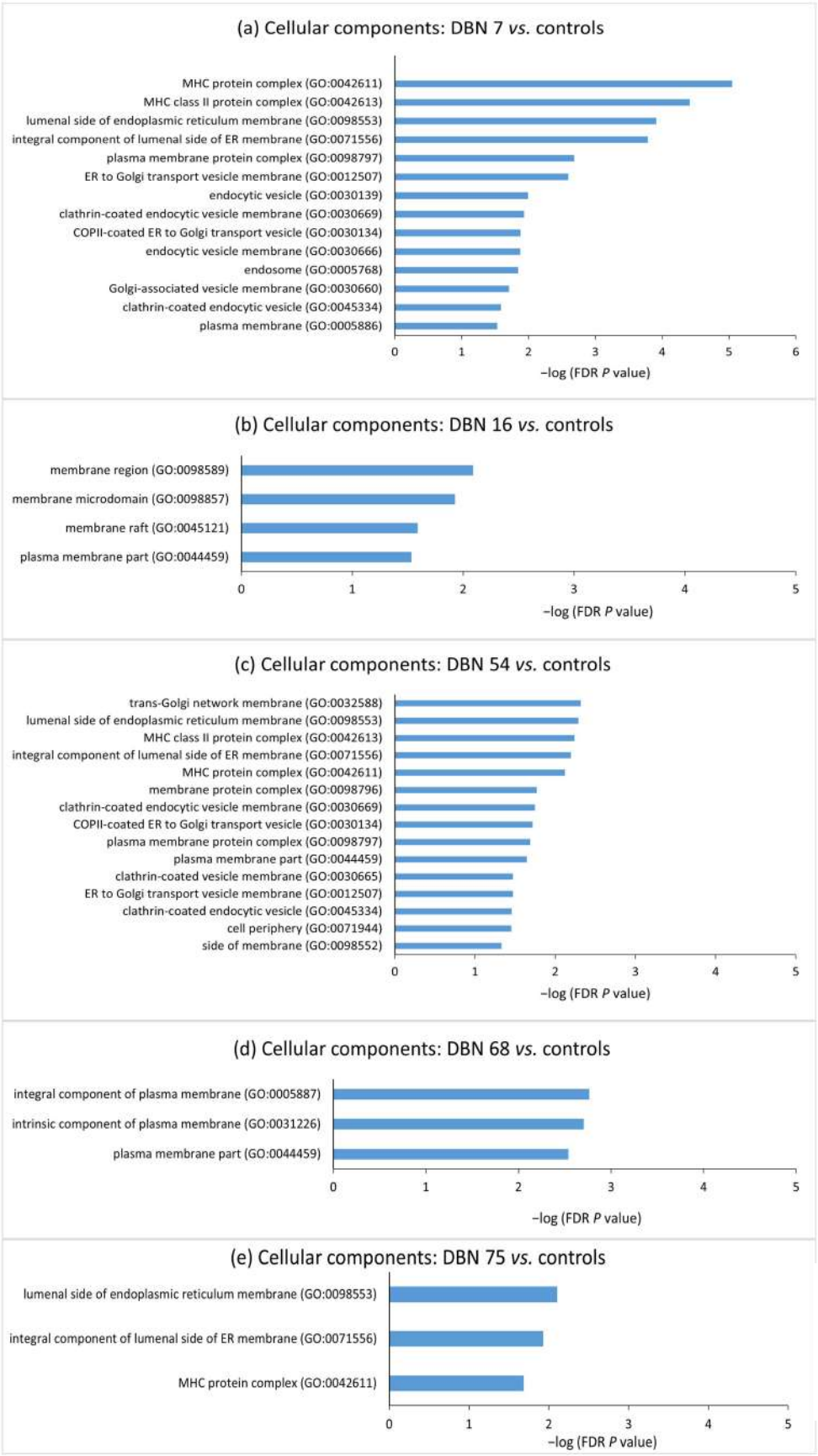
Since epigenetic methylation pattern varies from individual to individual and targeted therapy would focus on the methylation difference in the individual case, DNA methylation difference in individual hyperprolactinemia case from mean methylation of controls was analyzed by selecting CpG sites showing more than 50% deviation in methylation from the control mean. GO analysis was conducted to probe further into each case's biological functions of aberrantly methylated genes. Gene enrichment analysis of the hypermethylated and hypomethylated CpG site-associated genes demonstrated that "major histocompatibility complex (MHC) complex" protein classes, "MHC protein complex", "luminal side of endoplasmic reticulum (ER) membrane", "clathrin-coated endocytic vesicle" and "plasm protein complex" cellular components were significantly enriched in the majority of cases.

Principal
Dyal Singh College
KARNAL



Principal
Dyal Singh College
KARNAL

Figure 4. Gene set enrichment analyses for the aberrantly methylated genes belonging to protein classes between individual hyperprolactinemia cases and the controls. The terms were sorted according to the −log (FDR *P* value). DBN: data base number; FDR: false discovery rate



Principal
Dyal Singh College
KARNAL

Figure 5. Gene set enrichment analyses for the aberrantly methylated genes belonging to cellular components between individual hyperprolactinemia cases and the controls. The terms were sorted according to the −log (FDR *P* value). DBN: data base number; FDR: false discovery rate; MHC: major histocompatibility complex; ER: endoplasmic reticulum; COP II: coat protein complex II

Prolactin is known to upregulate MHC expression on dendritic cell surfaces [54]. Zinc-α2-glycoprotein (ZAG), an MHC class I-like molecule, accommodates prolactin-induced protein (PIP). PIP has structural similarity with the light chain [β_2-microglobulin (β_2M)] of MHC class I molecule [55]. β_2M is homologous to the third constant H chain (CH3) domain of immunoglobulin [56–58]. MHC I proteins are also involved in immune tolerance during pregnancy [59, 60]. MHC I refers to human leukocyte antigen (HLA). The expression of HLA-C (human classical MHC I) on the surface of trophoblast villi increases as they invade the endometrium and become more exposed to the maternal immune system [61]. The communication between HLA-C on trophoblast villi and killer cell immunoglobulin-like receptor 2D (KIR2D) receptors on uterine natural killer (uNK) cells maintains the blood supply to the trophoblast [62, 63]. The non-classical MHC I, HLA-E, HLA-F, and HLA-G are expressed on villous and extravillous trophoblast. These are responsible for both immune tolerance and support of pregnancy [62, 64, 65]. The immunological changes during pregnancy are regulated by changes in concentrations of various hormones, including prolactin [66]. The decidualized endometrial cells of the uterus (placental decidua) and uterine myometrium secrete large amounts of prolactin during pregnancy [67]. Thus, the increased prolactin during physiological pregnancy could regulate MHC I expression by epigenetic alterations and help maintain immune tolerance. Pathologically, raised prolactin may disrupt the immune balance and promote autoreactivity, resulting in autoimmune conditions. Immunity and defense-related protein classes were significantly enriched in the case of DBN 7, further strengthening the correlation between hyperprolactinemia and the immune system.

The significantly enriched cellular components included the ER and the Golgi complex. ER and Golgi are involved in the prolactin secretory pathway [68–70]. Components of plasma membrane and clathrin-coated vesicles were also significantly enriched in cellular components. Regarding the association of plasma membrane and clathrin-coated vesicles with prolactin, a study has related changes in protein trafficking with establishing plasma membrane polarity in mammary epithelial cells [71]. They also found that annexin VI, which probably acts as a sorting signal in prolactin transport, is increased in membrane fractions having excess endocytic clathrin-coated vesicles [71]. This suggests that epigenetic alterations may contribute to changes in the packaging and secretion of prolactin molecules in hyperprolactinemia.

No study has looked for methylation changes, specifically in hyperprolactinemia cases. A study on congenital hypopituitarism (CH) found 51 CpG sites significantly different in CH patients compared to controls [72]. Another study reported six genes in prolactin-secreting pituitary adenoma to be differentially methylated compared to controls [73]. Genome-wide significant DNA methylation patterns were found in association with prolactin level in a study on polycystic ovary syndrome (PCOS) women [74]. The ten significantly enriched functional pathways identified in the study were involved in immune function and immune-mediated inflammatory conditions suggesting a strong association of the immune system, in specific MHC region, in epigenetic regulation of prolactin in PCOS patients. Prolactin has a well-defined role in the immune system in maintaining immune tolerance and balance between apoptosis and proliferation of immune cells under normal conditions [75]. Since there is no association between hyperprolactinemia and PCOS [76], the changes in DNA methylation found in the study of Li et al. [74] can be considered specific to the hyperprolactinemia condition. On the contrary, Li et al. [74] suggested the association between methylation and prolactin levels to be specific to PCOS patients as no CpG site was found to be significantly associated with prolactin levels in their study on 30 healthy controls.

GO analysis did not yield statistically significant results for site-level or region-level differential methylation analysis for all comparisons. This could be due to some limitations of the study. The study had a very small sample size. The CpG methylation status was studied in whole blood DNA, and its consistency with prolactin-secreting cells of the pituitary is mainly unknown.

In conclusion, antipsychotic-induced changes in DNA methylation may mediate the efficacy as well as side effects of these drugs via variable pathways. Hypermethylation in 67% of hyperprolactinemia cases with pituitary adenoma suggests a role of epigenetics in pituitary micro/macro adenomas. About 50% of idiopathic hyperprolactinemia cases with a significant change in methylation also point towards the involvement of epigenetics in the etiopathology of hyperprolactinemia. Genome-wide methylation level

Principal
Dyal Singh College
KARNAL

analysis in hyperprolactinemia cases directed towards the association of hyperprolactinemia with the immune system, as MHC-related protein classes and cellular components were significantly enriched.

Limitations

Certain limitations of the present study were that it studied 5-mC percentage, however, changes in 5-hydroxymethylation, histone acetylation, and miRNAs might also be involved in epigenetic causes of hyperprolactinemia. DNA methylation was studied only in the peripheral blood of a relatively small number of samples. Also, the limited number of cases selected for GWMA belonged to something other than a homogenous group of patients.

Future aspects

Insight into case-specific epigenetic aberrations occurring during antipsychotic drug treatment would help know the genes and pathways modified and predict side-effects of drugs in each case which can be reversed as is shown by the epigenetic involvement in response of dopamine agonist—cabergoline, used in the treatment of hyperprolactinemia. This may lead to new pharmacological targets and drugs that aim at effective and targeted personalized therapies helping in methylation-based classification and treatment of individual patients. The MHC class of proteins is involved in immune tolerance during pregnancy. The increased prolactin during physiological pregnancy could regulate MHC I expression by epigenetic alterations and help maintain immune tolerance. Studies on methylation changes in pregnant females are expected to provide insight into the mechanisms involved in MHC-related immune tolerance during pregnancy, a state of physiological hyperprolactinemia.

Abbreviations

5-mC: 5-methylcytosine

CpG: 5-cytosine-phosphate-guanine-3

D2R: dopamine D2 receptor

DBN: data base number

DNMT1: DNA methyltransferase 1

ER: endoplasmic reticulum

FDR: false discovery rate

GO: gene ontology

GWMA: genome-wide methylation analysis

HDAC2: histone deacetylase 2

HLA: human leukocyte antigen

MHC: major histocompatibility complex

OD: optical density

PCOS: polycystic ovary syndrome

Principal
Dyal Singh College
KARNAL

Declarations

Author contributions

AKK: Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing—original draft preparation, Writing—review & editing. AH: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing—review & editing. MJ: Methodology, Project administration, Resources, Supervision, Validation. JBS: Resources, Supervision, Validation. All authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

Ethical clearance for the study was obtained from the Institute Ethics Committee, AIIMS, New Delhi, India (IESC/T-63/21.01.2015, RT-39/01.04.2015). All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional ethical committee. The study complies with the Declaration of Helsinki.

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Informed consent to publication was obtained from relevant participants.

Availability of data and materials

All relevant data is contained within the manuscript.

Funding

This work was supported by the Department of Reproductive Biology, AIIMS. AKK was supported by the Council of Scientific & Industrial Research-University Grants Commission (CSIR-UGC) fellowship [23/06/2013(i)EU-V]. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Copyright

© The Author(s) 2024.

References

1. Grayson DR. Special issue introduction: role of epigenetic gene regulation in brain function. Genes (Basel). 2017;8:181.
2. Wen L, Li X, Yan L, Tan Y, Li R, Zhao Y, et al. Whole-genome analysis of 5-hydroxymethylcytosine and 5-methylcytosine at base resolution in the human brain. Genome Biol. 2014;15:R49.
3. Jones PA. Functions of DNA methylation: islands, start sites, gene bodies and beyond. Nat Rev Genet. 2012;13:484–92.
4. McCarthy MM, Nugent BM. Epigenetic contributions to hormonally-mediated sexual differentiation of the brain. J Neuroendocrinol. 2013;25:1133–40.
5. Nugent BM, Schwarz JM, McCarthy MM. Hormonally mediated epigenetic changes to steroid receptors in the developing brain: implications for sexual differentiation. Horm Behav. 2011;59:338–44.
6. Rao ML, Gross G, Strebel B, Halaris A, Huber G, Bräunig P, et al. Circadian rhythm of tryptophan, serotonin, melatonin, and pituitary hormones in schizophrenia. Biol Psychiatry. 1994;35:151–63.
7. Ben-Jonathan N, Hnasko R. Dopamine as a prolactin (PRL) inhibitor. Endocr Rev. 2001;22:724–63.
8. Liu JC, Baker RE, Chow W, Sun CK, Elsholtz HP. Epigenetic mechanisms in the dopamine D2 receptor-dependent inhibition of the prolactin gene. Mol Endocrinol. 2005;19:1904–17.
9. Kononen J, Honkaniemi J, Gustafsson JA, Pelto-Huikko M. Glucocorticoid receptor colocalization with pituitary hormones in the rat pituitary gland. Mol Cell Endocrinol. 1993;93:97–103.
10. Elsholtz HP, Lew AM, Albert PR, Sundmark VC. Inhibitory control of prolactin and Pit-1 gene promoters by dopamine. Dual signaling pathways required for D2 receptor-regulated expression of the prolactin gene. J Biol Chem. 1991;266:22919–25.

Principal
Dyal Singh College
KARNAL

11. McChesney R, Sealfon SC, Tsutsumi M, Dong KW, Roberts JL, Bancroft C. Either isoform of the dopamine D2 receptor can mediate dopaminergic repression of the rat prolactin promoter. Mol Cell Endocrinol. 1991;79:R1–7.
12. Camper SA, Yao YA, Rottman FM. Hormonal regulation of the bovine prolactin promoter in rat pituitary tumor cells. J Biol Chem. 1985;260:12246–51.
13. Liu YF, Jakobs KH, Rasenick MM, Albert PR. G protein specificity in receptor-effector coupling. Analysis of the roles of G0 and Gi2 in GH4C1 pituitary cells. J Biol Chem. 1994;269:13880–6.
14. Day RN, Walder JA, Maurer RA. A protein kinase inhibitor gene reduces both basal and multihormone-stimulated prolactin gene transcription. J Biol Chem. 1989;264:431–6.
15. Lew AM, Yao H, Elsholtz HP. $G_{i\alpha 2}$- and $G_{o\alpha}$- mediated signaling in the Pit-1-dependent inhibition of the prolactin gene promoter. Control of transcription by dopamine D2 receptors. J Biol Chem. 1994;269: 12007–13.
16. Gangisetty O, Wynne O, Jabbar S, Nasello C, Sarkar DK. Fetal alcohol exposure reduces dopamine receptor D2 and increases pituitary weight and prolactin production via epigenetic mechanisms. PLoS One. 2015;10:e0140699.
17. Ajmal A, Joffe H, Nachtigall LB. Psychotropic-induced hyperprolactinemia: a clinical review. Psychosomatics. 2014;55:29–36.
18. Alosaimi FD, Fallata EO, Abalhassan M, Alhabbad A, Alzain N, Alhaddad B, et al. Prevalence and risk factors of hyperprolactinemia among patients with various psychiatric diagnoses and medications. Int J Psychiatry Clin Pract. 2018;22:274–81.
19. Melgar V, Espinosa E, Sosa E, Rangel MJ, Cuenca D, Ramírez C, et al. Current diagnosis and treatment of hyperprolactinemia. Rev Med Inst Mex Seguro Soc. 2016;54:111–21. Spanish.
20. Pałubska S, Adamiak-Godlewska A, Winkler I, Romanek-Piva K, Rechberger T, Gogacz M. Hyperprolactinaemia–a problem in patients from the reproductive period to the menopause. Prz Menopauzalny. 2017;16:1–7.
21. Egger G, Liang G, Aparicio A, Jones PA. Epigenetics in human disease and prospects for epigenetic therapy. Nature. 2004;429:457–63.
22. Bahar A, Simpson DJ, Cutty SJ, Bicknell JE, Hoban PR, Holley S, et al. Isolation and characterization of a novel pituitary tumor apoptosis gene. Mol Endocrinol. 2004;18:1827–39.
23. Bahar A, Bicknell JE, Simpson DJ, Clayton RN, Farrell WE. Loss of expression of the growth inhibitory gene GADD45γ, in human pituitary adenomas, is associated with CpG island methylation. Oncogene. 2004;23:936–44.
24. Simpson DJ, Bicknell JE, McNicol AM, Clayton RN, Farrell WE. Hypermethylation of the p16/CDKN2A/ MTSI gene and loss of protein expression is associated with nonfunctional pituitary adenomas but not somatotrophinomas. Genes Chromosomes Cancer. 1999;24:328–36.
25. Dudley KJ, Revill K, Whitby P, Clayton RN, Farrell WE. Genome-wide analysis in a murine Dnmt1 knockdown model identifies epigenetically silenced genes in primary human pituitary tumors. Mol Cancer Res. 2008;6:1567–74.
26. Madhusoodanan S, Parida S, Jimenez C. Hyperprolactinemia associated with psychotropics—a review. Hum Psychopharmacol. 2010;25:281–97.
27. Newey PJ, Gorvin CM, Cleland SJ, Willberg CB, Bridge M, Azharuddin M, et al. Mutant prolactin receptor and familial hyperprolactinemia. N Engl J Med. 2013;369:2012–20.
28. Davis JR. Prolactin and reproductive medicine. Curr Opin Obstet Gynecol. 2004;16:331–7.
29. Kalsi AK, Halder A, Jain M, Chaturvedi PK, Sharma JB. Prevalence and reproductive manifestations of macroprolactinemia. Endocrine. 2019;63:332–40.
30. Miller SA, Dykes DD, Polesky HF. A simple salting out procedure for extracting DNA from human nucleated cells. Nucleic Acids Res. 1988;16:1215.

Principal
Dyal Singh College
KARNAL

31. Melas PA, Rogdaki M, Ösby U, Schalling M, Lavebratt C, Ekström TJ. Epigenetic aberrations in leukocytes of patients with schizophrenia: association of global DNA methylation with antipsychotic drug treatment and disease onset. FASEB J. 2012;26:2712–8.
32. Schizophrenia Working Group of the Psychiatric Genomics Consortium. Biological insights from 108 schizophrenia-associated genetic loci. Nature. 2014;511:421–7.
33. Singh SM, Murphy B, O'Reilly R. Epigenetic contributors to the discordance of monozygotic twins. Clin Genet. 2002;62:97–103.
34. Melka MG, Laufer BI, McDonald P, Castellani CA, Rajakumar N, O'Reilly R, et al. The effects of olanzapine on genome-wide DNA methylation in the hippocampus and cerebellum. Clin Epigenetics. 2014;6:1.
35. Dempster EL, Pidsley R, Schalkwyk LC, Owens S, Georgiades A, Kane F, et al. Disease-associated epigenetic changes in monozygotic twins discordant for schizophrenia and bipolar disorder. Hum Mol Genet. 2011;20:4786–96.
36. Wockner LF, Noble EP, Lawford BR, Young RM, Morris CP, Whitehall VL, et al. Genome-wide DNA methylation analysis of human brain tissue from schizophrenia patients. Transl Psychiatry. 2014;4: e339.
37. Kinoshita M, Numata S, Tajima A, Shimodera S, Ono S, Imamura A, et al. DNA methylation signatures of peripheral leukocytes in schizophrenia. Neuromolecular Med. 2013;15:95–101.
38. Bönsch D, Wunschel M, Lenz B, Janssen G, Weisbrod M, Sauer H. Methylation matters? Decreased methylation status of genomic DNA in the blood of schizophrenic twins. Psychiatry Res. 2012;198: 533–7.
39. Shimabukuro M, Jinno Y, Fuke C, Okazaki Y. Haloperidol treatment induces tissue- and sex-specific changes in DNA methylation: a control study using rats. Behav Brain Funct. 2006;2:37.
40. Dong E, Nelson M, Grayson DR, Costa E, Guidotti A. Clozapine and sulpiride but not haloperidol or olanzapine activate brain DNA demethylation. Proc Natl Acad Sci USA. 2008;105:13614–9.
41. Mill J, Tang T, Kaminsky Z, Khare T, Yazdanpanah S, Bouchard L, et al. Epigenomic profiling reveals DNA-methylation changes associated with major psychosis. Am J Hum Genet. 2008;82:696–711.
42. Tremolizzo L, Doueiri MS, Dong E, Grayson DR, Davis J, Pinna G, et al. Valproate corrects the schizophrenia-like epigenetic behavioral modifications induced by methionine in mice. Biol Psychiatry. 2005;57:500-9.
43. Byrne EM, Carrillo-Roa T, Henders AK, Bowdler L, McRae AF, Heath AC, et al. Monozygotic twins affected with major depressive disorder have greater variance in methylation than their unaffected co-twin. Transl Psychiatry. 2013;3:e269.
44. Coiro V, Davoli C, Volpi R, Sorini E, Voltini E, Rossi G, et al. The gabaergic control of prolactin release is not affected by insulin-dependent diabetes mellitus: evidence from studies with sodium valproate. Acta Diabetol Lat. 1986;23:51–5.
45. Noh JS, Sharma RP, Veldic M, Salvacion AA, Jia X, Chen Y, et al. DNA methyltransferase 1 regulates reelin mRNA expression in mouse primary cortical cultures. Proc Natl Acad Sci USA. 2005;102: 1749–54.
46. Dong E, Agis-Balboa RC, Simonini MV, Grayson DR, Costa E, Guidotti A. Reelin and glutamic acid decarboxylase67 promoter remodeling in an epigenetic methionine-induced mouse model of schizophrenia. Proc Natl Acad Sci USA. 2005;102:12578–83.
47. Dong E, Guidotti A, Grayson DR, Costa E. Histone hyperacetylation induces demethylation of reelin and 67-kDa glutamic acid decarboxylase promoters. Proc Natl Acad Sci USA. 2007;104:4676–81.
48. Muccioli G, Di Carlo R. S-adenosyl-L-methionine restores prolactin receptors in the aged rabbit brain. Eur J Pharmacol. 1989;166:223–30.

Principal
Dyal Singh College
KARNAL

49. Phiel CJ, Zhang F, Huang EY, Guenther MG, Lazar MA, Klein PS. Histone deacetylase is a direct target of valproic acid, a potent anticonvulsant, mood stabilizer, and teratogen. J Biol Chem. 2001;276: 36734–41.
50. Sharma RP, Rosen C, Kartan S, Guidotti A, Costa E, Grayson DR, et al. Valproic acid and chromatin remodeling in schizophrenia and bipolar disorder: preliminary results from a clinical population. Schizophr Res. 2006;88:227–31.
51. Sharma RP, Grayson DR, Gavin DP. Histone deactylase 1 expression is increased in the prefrontal cortex of schizophrenia subjects: analysis of the National Brain Databank microarray collection. Schizophr Res. 2008;98:111–7.
52. Kurita M, Holloway T, García-Bea A, Kozlenkov A, Friedman AK, Moreno JL, et al. HDAC2 regulates atypical antipsychotic responses through the modulation of mGlu2 promoter activity. Nat Neurosci. 2012;15:1245–54.
53. Weaver IC, Cervoni N, Champagne FA, D'Alessio AC, Sharma S, Seckl JR, et al. Epigenetic programming by maternal behavior. Nat Neurosci. 2004;7:847–54.
54. Borba VV, Zandman-Goddard G, Shoenfeld Y. Prolactin and autoimmunity. Front Immunol. 2018;9:73.
55. Hassan MI, Kumar V, Singh TP, Yadav S. Purification and characterization of zinc α2-glycoprotein-prolactin inducible protein complex from human seminal plasma. J Sep Sci. 2008;31:2318–24.
56. Bjorkman PJ, Parham P. Structure, function, and diversity of class I major histocompatibility complex molecules. Annu Rev Biochem. 1990;59:253–88.
57. Hassan I, Ahmad F. Structural diversity of class I MHC-like molecules and its implications in binding specificities. Adv Protein Chem Struct Biol. 2011;83:223–70.
58. Madden DR. The three-dimensional structure of peptide-MHC complexes. Annu Rev Immunol. 1995; 13:587–622.
59. Davies CJ, Eldridge JA, Fisher PJ, Schlafer DH. Evidence for expression of both classical and non-classical major histocompatibility complex class I genes in bovine trophoblast cells. Am J Reprod Immunol. 2006;55:188–200.
60. Rapacz-Leonard A, Dąbrowska M, Janowski T. Major histocompatibility complex I mediates immunological tolerance of the trophoblast during pregnancy and may mediate rejection during parturition. Mediators Inflamm. 2014;2014:579279.
61. King A, Boocock C, Sharkey AM, Gardner L, Beretta A, Siccardi AG, et al. Evidence for the expression of HLAA-C class I mRNA and protein by human first trimester trophoblast. J Immunol. 1996;156: 2068–76.
62. Bainbridge DR. Evolution of mammalian pregnancy in the presence of the maternal immune system. Rev Reprod. 2000;5:67–74.
63. Trowsdale J, Moffett A. NK receptor interactions with MHC class I molecules in pregnancy. Semin Immunol. 2008;20:317–20.
64. Hviid TV. HLA-G in human reproduction: aspects of genetics, function and pregnancy complications. Hum Reprod Update. 2006;12:209–32.
65. Ishitani A, Sageshima N, Lee N, Dorofeeva N, Hatake K, Marquardt H, et al. Protein expression and peptide binding suggest unique and interacting functional roles for HLA-E, F, and G in maternal-placental immune recognition. J Immunol. 2003;171:1376–84.
66. Robinson DP, Klein SL. Pregnancy and pregnancy-associated hormones alter immune responses and disease pathogenesis. Horm Behav. 2012;62:263–71.
67. Mori M, Bogdan A, Balassa T, Csabai T, Szekeres-Bartho J. The decidua—the maternal bed embracing the embryo—maintains the pregnancy. Semin Immunopathol. 2016;38:635–49.
68. Haynes RL, Zheng T, Nicchitta CV. Structure and folding of nascent polypeptide chains during protein translocation in the endoplasmic reticulum. J Biol Chem. 1997;272:17126–33.

Principal
Dyal Singh College
KARNAL

69. Tougard C, Louvard D, Picart R, Tixier-Vidal A. The rough endoplasmic reticulum and the Golgi apparatus visualized using specific antibodies in normal and tumoral prolactin cells in culture. J Cell Biol. 1983;96:1197–207.
70. Walter P, Blobel G. Translocation of proteins across the endoplasmic reticulum. II. Signal recognition protein (SRP) mediates the selective binding to microsomal membranes of *in-vitro*-assembled polysomes synthesizing secretory protein. J Cell Biol. 1981;91:551–6.
71. Lavialle F, Rainteau D, Massey-Harroche D, Metz F. Establishment of plasma membrane polarity in mammary epithelial cells correlates with changes in prolactin trafficking and in annexin VI recruitment to membranes. Biochim Biophys Acta. 2000;1464:83–94.
72. Fang X, Chen C, Cai J, Xiang E, Li J, Chen P. Genome-wide methylation study of whole blood cells DNA in men with congenital hypopituitarism disease. Int J Mol Med. 2019;43:155–66.
73. Duong CV, Emes RD, Wessely F, Yacqub-Usman K, Clayton RN, Farrell WE. Quantitative, genome-wide analysis of the DNA methylome in sporadic pituitary adenomas. Endocr Relat Cancer. 2012;19: 805–16.
74. Li S, Zhu D, Duan H, Ren A, Glintborg D, Andersen M, et al. Differential DNA methylation patterns of polycystic ovarian syndrome in whole blood of Chinese women. Oncotarget. 2017;8:20656–66.
75. Díaz L, Muñoz MD, González L, Lira-Albarrán S, Larrea F, Méndez I. Prolactin in the immune system. In: Nagy GM, Toth BE, editors. Prolactin. IntechOpen; 2013. pp. 53–82.
76. Szosland K, Pawlowicz P, Lewiński A. Prolactin secretion in polycystic ovary syndrome (PCOS). Neuro Endocrinol Lett. 2015;36:53–8.

Principal
Dyal Singh College
KARNAL

Scope
Volume 14 Number 01 March 2024

Potassium Driven Nutritional Enhancement in Sweet Corn under Water Deficit

Suhana Rao[1], Sombir Singh[2*] Sushil Kumar[3] and Narender Singh[*]
[1]Assistant Professor, Botany Department, Dyal Singh College, Karnal
[2]Assistant Professor, Botany Department, Pt. C.L.S. Govt. College, Karnal
[3] Associate professor, R.K.S.D. College, Kaithal
[4] Professor, Department of Botany, Kurukshetra University, Kurukshetra
Corresponding Author: **Sombir Singh**

Abstract

Drought stress is a serious challenge for sweet corn in semi-arid and arid regions across the world. Potassium fertilization has been shown to be effective in mitigating the adverse effects of drought stress. However, the impact of potassium on nutritional quality of sweet corn has not been tested yet. Therefore this study investigated the role of potassium in alleviating the negative impacts of water scarcity and improving the nutritional quality of sweet corn. A pot experiment was conducted on two genotypes of sweet corn (SUGAR-75 and NSC901B) with three potassium levels (0, 500 ppm, and 700 ppm) recorded as control, K_1, and K_2, respectively under six different drought conditions to investigate the efficacy of potassium in improving the seed quality of sweet corn under drought stress. Drought stress considerably affected the yield quality of sweet corn in both genotypes, and when drought stress was sustained, these negative consequences were exacerbated. Furthermore, potassium supplementation reduced negative effects of drought and increases seed quality in sweet corn. Results of this experiment revealed that potassium fertilization can enhance the nutritional quality of sweet corn under normal as well as drought stress conditions.

Keywords: Potassium, Seed quality, Sweet corn, Water deficit.

Introduction

Plants are subjected to a variety of stresses during their growth and development in both natural and agricultural environments. Drought is one of the most serious environmental factors impacting plant productivity (Seleiman et al. 2021). Water content accounts for

Principal
Dyal Singh College
KARNAL

roughly 80-95% of the fresh biomass of the plant and is vital in several physiological activities, including metabolism plant growth and reproduction. (Brodersen et al. 2019). Water deficit arises when the amount of transpired water surpasses the volume of water received by the roots, which can be triggered by limited precipitation, low ground water levels, or soil with a poor water holding capacity (Lisar and Hamideh, 2016). According to the IPCC (2014) assessment, the decline in food yield and quality, mostly as a result of water scarcity, poses a severe danger to agriculture (IPCC, 2014; Zandalinas et al. 2018).

Globally, the productivity and nutritional value of main crops are negatively impacted by drought stress (Sabagh et al. 2019). In a field experiencing drought, yield losses normally range between 30% and 90% depending on the crop species (Hussain et al. 2019). Drought stress can impair the final quantitative and qualitative yield at any development stage (Prasad et al. 2017). According to Chen et al. (2014), drought stress that occurred during the period of growth and maturation had a significant impact not only on yield, but also on quality of tomato. Thus, maintaining nutritional quality in crops under drought stress may present an excellent prospect to supply sufficient food and nourishment to humans.

Potassium (K) is one of the most sought-after cationic minerals for growth and is strongly associated to yield and quality. Potassium (K) is among the most demanded cationic minerals for vegetative growth and is strongly linked to yield and quality (Kanai et al. 2011; Daoud et al. 2020). Potassium is involved in many metabolic and physiological processes such protein synthesis, enzyme activation, and plant photosynthesis (White and Karley, 2010). Application of potassium, fertilizer judiciously could increase both quantity and quality of the crop (Colpan et al. 2013).

Sweet corn (*Zea mays* convar. Saccharata var. rugosa) belongs to the Poaceae family. It is a sugar-rich maize type designed as a miracle crop. Sweet corn comprises 5-6% sugar, 10-11% starch, 3% water soluble carbohydrates and 70% water, in addition to moderate levels of protein, vitamin and minerals (Oktem and Oktem, 2005). The sweet corn kernel contains more protein and fat than other corn cultivars (Budak and Aydemir, 2018). Sweet corn is high in antioxidants such as carotenoids, lutein, and zeaxanthin (Ozata, 2019). Nowadays, improving the nutritional value and health benefits of food crops to minimize dietary inadequacies is becoming increasingly important. The aim of this research was to examine the impact of exogenously supplied potassium on the yield quality of sweet corn cultivars under water deficit.

Material and methods

A pot experiment was conducted for two consecutive years (2018-19) during the spring season at the anti-insect house of the Botany Department, Kurukshetra University,

Principal
Dyal Singh College
KARNAL

Kurukshetra, Haryana, India. This investigation was carried out by using two cultivars of sweet corn (SUGAR-75 and NSC901B). Sweet corn seeds were planted in the second week of March each year, and water treatments were administered following germination. The crop was maintained in 25 cm-diameter polythene bags that held 10 kg of soil. Completely randomized designs were used for the experimental analysis. The three-factor OP STAT developed by Sheoran et al. (1998) was used for statistical analysis.

Water scarcity was generated by withholding watering for varied stretches of time. a) Fully irrigated (FI): Daily watering after germination. c) Fully drought (FD): No watering after germination. b) Moderate early drought (MED): Weekly irrigation after germination. c) Severe early drought (SED): Irrigate every 14 days after germination. f) Moderate late drought (MED): Full irrigation till 50 days, then weekly irrigation. f) Severe late drought (SED): Irrigate continuously until 50 days, then after every 14 days.

Following germination, various potassium solutions with varying concentrations (control=0 ppm, K_1=500 ppm, and K_2=700 ppm) were applied in form of muriate of potash in addition to the present level (52 ppm) in the soil. At the time of harvest samples for various parameters were obtained.

The Potassium ion content was measured as per Allen et al. (1976). Standard KCl solutions were made by combining KCl with DDW and increasing the final volume to 1 litre. Sample solutions were prepared and diluted to volume as needed. The flame photometer was standardized by running various concentrations of standards solutions and then a calibration curve was drawn. Readings from the flame emission photometer's digital display were taken. The Bradford (1976) method was employed to determine the total soluble protein content. Seeds were heated in a hot water bath for 2 to 5 minutes with 10 ml of 80% ethanol. It was homogenized in ethanol using a pestle and mortar after 5 minutes cooling at room temperature and then centrifuged at 5000g. The residue was then subjected to a second extraction using 5ml of 5% perchloric acid, followed by 10 minutes of centrifugation at 5000g. The supernatant was discarded, and the leftover material was further extracted using 5 ml of 1 N NaOH. After addition of 0.8 ml double-distilled water and 2.5 ml dye to 0.2 ml of the aforementioned extract absorbance was recorded at 595nm. A standard curve was prepared using bovine serum albumin for protein estimation. The starch content was calculated using the Hassid and Neufeld procedure (1964). The residue was mixed in 5ml of ice cold 26% perchloric acid and left overnight. The above was then centrifuged at 5000g for 15 minutes, and the residue was extracted using 26% perchloric acid. Then 0.2 g of anthrone reagent was added, with100 ml of concentrated H_2SO_4. To make the final volume 1 ml, took 0.2 ml of the extract that was previously formed and added distilled water to it. Anthrone reagent (4 ml) was then added, and the entire mixture was heated on a water bath for roughly 10 minutes. After

Principal
Dyal Singh College
KARNAL

cooling, the absorbance was measured at 620 nm. The standard curve was created applying graded doses of glucose. The amount of total soluble sugar was determined using the Hart and Fisher (1971) method. After extracting 100 mg of seeds in 10 ml of DDW, the mixture was centrifuged in a Remi centrifuge for 10 min. The supernatant was pooled out and the leftover residue was discarded. Double-distilled water was then used to increase the volume to 50 ml. A 3 ml sample of the extract was placed in a water bath at 100°C for 5 minutes. Following the placement of test tubes in a boiling water bath, 6 ml of the anthrone reagent was slowly added and absorbance was recorded in UV-Vis spectrophotometer at 600 nm.

Result

Potassium content of kernel

The total potassium content of kernels was found to be higher in genotype SUGAR-75 than the NSC901B genotype of sweet corn. Drought stress reduced the total potassium content of kernels. Maximum decrement of 26% was found under fully drought conditions in genotype SUGAR-75. The addition of potassium enhanced the total potassium content of sweet corn kernels in both genotypes. Exogenously administered 700ppm potassium (K_2) exhibited an increase of 16% in genotype SUGAR-75 under moderate early drought. The same potassium dose resulted in a maximum boost of 22% in genotype SUGAR-75 over test control of severe early drought.

Protein content of kernel

Drought stress reduced kernel protein content, with the greatest decrease of 46% in genotype NSC901B under fully drought treatment. In contrast to genotype NSC901B, genotype SUGAR-75 had kernels with greater overall protein content. Potassium application increased overall protein content in sweet corn kernels in both genotypes. Potassium concentration of 700 ppm (K_2) showed maximum increase of 15% in genotype SUGAR-75 in moderate droughts over test control of moderate early drought. The highest gain among severe droughts was found to be 22% in genotype SUGAR-75 over test control of severe early drought under the influence of 700 ppm (K_2) potassium concentration.

Starch content of kernel

In comparison to SUGAR-75, the total starch content of the kernels was somewhat higher in the NSC901B genotype. Both genotypes of sweet corn kernels had lower total starch contents after potassium application. The NSC901B genotype showed a maximum reduction of 19% in moderate early drought under the influence of 700 ppm potassium concentration. When compared to the test control of a severe early drought, genotype SUGAR-75 demonstrated a maximum decrease of 26% when700 ppm potassium

Principal
Dyal Singh College
KARNAL

concentration was supplied exogenously. Overall potassium decreased the starch content in both genotypes.

Total soluble sugar content of kernel

Genotype SUGAR-75 had a relatively greater total soluble sugar content concentration than NSC901B. Both genotypes of sweet corn kernels showed higher total sugar content after potassium application. The highest increase among moderate droughts was found to be 17% in genotype NSC901B compared to test controls of moderate late drought when 700 ppm (K_2) potassium concentration was applied. Among severe droughts, a maximum increase of 26% in genotype NSC901B over test control of severe early drought was reported when 700 ppm (K_2) of potassium was supplied.

Discussion

In this investigation drought stress decreased starch content, protein content and potassium content of kernels but the total soluble sugar content increased under water deficit condition in both cultivars. Cultivar SUGAR-75 showed significantly higher content of protein, total soluble sugar and potassium than genotype NSC901B under normal and stressed conditions. Our findings are in agreement with Du et al. (2019) where drought stress induced a decrease in starch content however soluble sugar and sucrose content were increased in soyabeans. Drought inhibits the synthesis of starch and proteins, which in turn prevents the accumulation of other seed contents (Asthir et al. 2012; Farooq et al. 2017). Mass flow and diffusion are the mechanisms by which plants acquire potassium from soil, and both of these processes are greatly influenced by the presence adequate water (Oliveira et al. 2010). Soil moisture scarcity can diminish soil potassium availability, so the plant uptake and transportation (Waraich et al. 2011).

Seed protein, sugar content and potassium content of seeds increased significantly under the influence of potassium in both the cultivars irrespective of conditions however, seed starch content decreased under the influence of potassium. Similar to our findings, Khayyat et al. (2007) also observed that application of potassium increased protein content, carbohydrate content and ascorbic acid in fruits and improved its chemical composition. Fawzy et al. (2007) on eggplant and Dkhil et al. (2011) on potato evaluated the positive influence of applied potassium on crop quality. Potassium supplementation also improved groundnut quality in terms of total protein contents of seeds (Imas and

Principal
Dyal Singh College
KARNAL

Magen, 2008). Positive impact of soil applied potassium resulted in superior quality of the wheat straw and grain filling (Alderfasi and Refay, 2010). The foliar potassium application improved fruit marketable quality by improving its firmness, sugar content, ascorbic acid and beta-carotene (Lester et al. 2007).

Conclusion

The result indicates that water deficit reduced the kernel quality by negatively affected the protein, starch, sugar and potassium content of sweet corn seeds. Soil-applied potassium improved yield quality in drought-stressed plants by modulating the protein, starch, sugar, and potassium content. We conclude that the sugar-75 genotype of sweet corn paired with adequate potassium supply may be a promising technique for enhancing seed quality in drought conditions. However, more research on other crops is required to ensure its long-term sustainability.

Acknowledgements

The authors would like to express their gratitude to IARI, New Delhi, India, for providing certified seeds of sweet corn (*Zea mays* convar. Saccharata, var. rugosa) genotypes (SUGAR 75 and NSC901B) and to the Department of Botany, Kurukshetra University, Kurukshetra, India, for providing the necessary infrastructure for the experimental work.

References

1. Alderfasi, A.A., Refay, Y.A. 2010. Integrated use of potassium fertilizer and water schedules on growth and yield of two wheat genotypes under arid environment in Saudi Arabia 1-effect on growth characters. Am.-Eurasian J. Agric. Environ. Sci. 9(3): 239-247.
2. Allen, S.E., Terman, G.L., Clements, L.B. 1976. Greenhouse techniques for soil plant fertilizer research. NFDC-TVA Bulletin. Y. 104.
3. Asthir, B., Koundal, A., Bains, N.S. 2012. Putrescine modulates antioxidant defense response in wheat under high temperature stress. Plant Biol. 56: 757-761.
4. Bradford, M.M. 1976. A Rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of dye binding. Anal. Biochem. 72: 248-254.
5. Brodersen, C.R., Roddy, A.B., Wason, J.W., McElrone, A.J. 2019. Functional status of xylem through time. Annu. Rev. Plant Biol. 70: 407-433.
6. Budak, F., Aydemir, S.K. 2018. Grain yield and nutritional values of sweet corn (*Zea mays* var. Saccharata) in produced with good agricultural implementation. Nutr. Food Sci. 7(2): 555-710.

Principal
Dyal Singh College
KARNAL

7. Chen, J., Kang, S., Du, T., Guo, P., Qiu, R., Chen, R., Gu, F. 2014. Modeling relations of tomato yield and fruit quality with water deficit at different growth stages under greenhouse condition. Agric. Water Manag. 146: 131-148.
8. Çolpan, E., Zengin, M., Özbahçe, A. 2013. The effects of potassium on the yield and fruit quality components of stick tomato. J. Hortic. Envon. Biotechnol. 54 (1): 20-28.
9. Daoud, B. Pawelzik, E. and Naumann, M. 2020. Different potassium fertilization levels influence water-use efficiency, yield, and fruit quality attributes of cocktail tomato-A comparative study of deficient-to-excessive supply. Sci. Hortic. 272: 109562.
10. Dkhil, B., Denden, M., Aboud, S. 2011. Foliar potassium fertilization and its effect on growth, yield and quality of potato grown under loam-sandy soil and semi-arid conditions. Int. J. Agric. Res. 6: 593-600.
11. Du, Y., Zhao, Q., Chen, L., Yao, X., Zhang, W., Zhang, B., Xie, F. 2020. Effect of drought stress on sugar metabolism in leaves and roots of soybean seedlings, Plant Physiol. Biochem. 146: 1-12.
12. El-Sabagh, A., Hossain, A., Barutçular, C. et al. 2019. Effects of drought stress on the quality of major oilseed crops: Implications and possible mitigation strategies - Areview. Appl. Ecol. Environ. Res. 17: 4019-4043.
13. Farooq, M., Gogoi, N., Barthakur, S., Baroowa, B., Bharadwaj, N., Alghamdi, S.S. et al. 2017. Drought stress in grain legumes during reproduction and grain filling. J. Agron. Crop Sci. 203: 81-102.
14. Fawzy, Z.F., EL-Nemr, M.A., Saleh, S.A. 2007. Influence of levels and methods of potassium fertilizer application on growth and yield of eggplant. J. Appl. Sci. Res. 3(1): 42-49.
15. Hart, D.L., Fisher, H.J. 1971. Modern food analysis. New York: Springler-Verlarg.
16. Hassid, W.Z., Neufeld, E.F. 1964. Quantitative determination of starch in plant tissue. In Whistler, R. L. ed, Methods in Carbohydrate Chemistry. Academic press, N. Y. 4: 33-36.
17. Hussain, H.A., Men, S., Hussain, S., Chen, Y., Ali, S., Zhang, S., Wang, L. 2019. Interactive effects of drought and heat stresses on morpho-physiological attributes, yield, nutrient uptake and oxidative status in maize hybrids. Sci. Rep. 9(1): 1-12.
18. Imas, P., Magen, H. 2008. Role of potassium nutrition in balanced fertilization for soybean yield and quality - global perspective. in: recent advances in potassium nutrition management for soybean based cropping systems, eds. Vyas, A.K., Imas, P. Indore, India: NRCS. p. 1-20.

Principal
Dyal Singh College
KARNAL

19. IPCC. 2014. Climate change synthesis report contribution of working groups i. ii and iii to the fifth assessment report of the intergovernmental panel on climate change. Geneva: IPCC. p. 151.
20. Kanai, S., Moghaieb, R.E., El-Shemy, H.A., Panigrahi, R., Mohapatra, P.K., Nguyen, N.T., Saneoka, H., Fujita, K. 2011. Potassium deficiency affects water status and photosynthetic rate of the vegetative sink in green house tomato prior to its effects on source activity. Plant Sci.180: 368-374.
21. Khayyat, M., Tafazoli, E., Eshghi, S., Rahemi, M., Rajaee, S. 2007. Salinity, supplementary calcium and potassium effects on fruit yield and quality of strawberry (*Fragaria ananassa* Duch.). Am.-Eurasian J. Agric. Environ. Sci. 2: 539-544.
22. Lester, G.E., Jifon, J.L., Stewart, W.M. (2007). Better Crops. 91(1): 24-25.
23. Lisar, S.Y., Hamideh, B.A. 2016. Drought stress in plants: causes, consequences, and tolerance. Springer International Publishing, Switzerland. 1: 1-16.
24. Oktem, G., Oktem, A. 2005. Effect of nitrogen and intra row spaces on sweet corn (*Zea mays* saccharata Sturt) ear characteristics. Asian J. Plant Sci. 4: 361-364.
25. Oliveira, E.M.M., Ruiz, H.A., Alvarez, V.H., Ferreira, P.A., Costa, F.O., Almeida, I.C.C. 2010. Nutrient supply by mass flow and diffusion to maize plants in response to soil aggregate size and water potential. Rev. Bras. Cienc. Solo. 34: 317-327.
26. Özata, E. 2019. Evaluation of fresh ear yield and quality performance in super sweet corn. Int. J. Life Sci. Biotec. 2: 80-94.
27. Prasad, P.V.V., Bheemanahalli, R., Jagdish, S.K. 2017. Field crops and the fear of heat stress-opportunities, challenges and future directions. Field Crops Res. 200: 114-121.
28. Seleiman, M.F., Al-Suhaibani, N., Ali, N., Akmal, M., Alotaibi, M., Refay, Y., Dindaroglu, T., Abdul-Wajid, H.H., Battaglia, M.L. 2021. Drought stress impacts on plants and different approaches to alleviate its adverse effects. Plants, Basel, Switzerland. 10(2): 259.
29. Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C., Pannu, R.S. 1998. Statistical software package for agricultural research workers. Department of Mathematics and Statistics, CCS HAU, Hisar, 139-143.
30. Waraich, E.A., Ahmad, R., Ashraf, M., Saifullah, Y., Ahmad, M. 2011. Improving agricultural water use efficiency by nutrient management in crop plants. Acta. Agric. Scand. B Soil Plant Sci. 61: 291-304.
31. White, P.J., Karley, A.J. 2010. Potassium cell biology of metals and nutrients. Berlin: Springer. 199-224.

Principal
Dyal Singh College
KARNAL

32. Zandalinas, S.I., Mittler, R., Balfagón, D., Arbona, V., Gómez-Cadenas, A. 2018. Plant adaptations to the combination of drought and high temperatures. Plant Physiol. 162: 2–12.

Table 01: The effect of water stress and applied potassium on kernel protein content (mg/g DW) and kernels starch content (mg/g DW) in sweet corn cultivars.

Treatment	Kernel Protein content			Kernel Starch content		
	SUGAR-75	NSC901B	Mean	SUGAR-75	NSC901B	Mean
FI	12.58 ± 0.058	10.93 ± 0.043	11.75	163.6 ± 0.782	169.7 ± 0.832	166.6
FI+K_1	13.20 ± 0.101	11.36 ± 0.097	12.28	155.4 ± 1.355	164.6 ± 1.429	160.1
FI+K_2	13.71 ± 0.143	11.69 ± 0.132	12.76	148.8 ± 1.916	157.8 ± 1.959	153.3
FD	7.296 ± 0.049	5.902 ± 0.037	6.599	106.3 ± 0.618	105.2 ± 0.583	105.7
FD+K_1	8.755 ± 0.083	6.669 ± 0.054	7.712	87.16 ± 0.106	89.42 ± 0.121	88.29
FD+K_2	9.192 ± 0.122	6.964 ± 0.104	8.078	83.97 ± 1.863	87.31 ± 1.908	85.64
MED	10.31 ± 0.202	8.416 ± 0.138	9.363	135.7 ± 2.710	144.2 ± 2.987	139.9
MED+K_1	11.54 ± 0.072	9.257 ± 0.067	10.39	119.4 ± 0.553	124.1 ± 0.645	121.7
MED+K_2	11.85 ± 0.129	9.510 ± 0.112	10.68	113.9 ± 0.828	116.8 ± 0.912	115.3
SED	8.302 ± 0.136	6.885 ± 0.121	7.593	112.8 ± 1.327	112.0 ± 1.316	112.4
SED+K_1	9.713 ± 0.074	7.711 ± 0.068	8.712	87.98 ± 1.761	91.84 ± 1.934	89.91
SED+K_2	10.12 ± 0.122	8.330 ± 0.094	9.225	83.47 ± 1.293	88.48 ± 1.302	85.97
MLD	10.81 ± 0.113	8.962 ± 0.110	9.886	142.3 ± 1.034	142.5 ± 1.031	142.4
MLD+K_1	11.67 ± 0.124	9.589 ± 0.105	10.62	129.4 ± 1.276	133.9 ± 1.324	131.6
MLD+K_2	11.99 ± 0.062	9.858 ± 0.054	10.92	120.9 ± 0.629	126.8 ± 0.782	123.8
SLD	8.554 ± 0.057	6.995± 0.037	7.774	117.7 ± 0.718	115.3 ± 0.689	116.5
SLD+K_1	9.837 ± 0.048	8.254 ± 0.028	9.045	98.86 ± 1.265	101.4 ± 1.327	100.1
SLD+K_2	10.35 ± 0.039	8.394 ± 0.031	9.372	89.45 ± 1.187	92.24 ± 1.287	90.84
Mean	10.54	8.633		116.5	120.1	
CD at 5%	Genotype(G)= 0.117			Genotype(G) = 1.573		
	Water treatment(WT)= 0.203			Water treatment(WT) = 2.725		
	G×WT= 0.288			G×WT = 3.854		
	Potassium(K)= 0.117			Potassium(K) = 1.573		
	G×K= N/A			G×K = N/A		
	WT×K= 0.288			WT×K = 3.854		
	G×WT×K= 0.407			G×WT×K = 5.450		
FI= Fully irrigation, FD =Fully Drought, MED = Moderate early drought, SED= Severe early drought, MLD= Moderate latedrought, SLD= Severe late drought K_1= 500ppm (potassium treatment), K_2 = 700ppm (potassium treatment)						

Principal
Dyal Singh College
KARNAL

Table 02: The effect of water stress and applied potassium on kernel sugar content (mg/g DW) and kernel potassium content (mg/g DW) in sweet corn cultivars.

Treatment	Kernel Sugar content			Kernel Potassium content		
	SUGAR-75	NSC901B	Mean	SUGAR-75	NSC901B	Mean
FI	58.21 ± 0.420	54.64 ± 0.413	56.42	3.098 ± 0.020	2.756 ± 0.019	2.927
FI+K_1	62.27 ± 0.727	57.33 ± 0.621	59.81	3.244 ± 0.035	2.832 ± 0.028	3.038
FI+K_2	64.60 ± 1.028	58.96 ± 1.002	61.78	3.337 ± 0.050	2.942 ± 0.037	3.139
FD	73.33 ± 0.428	66.61 ± 0.328	69.97	2.286 ± 0.027	2.145 ± 0.023	2.215
FD+K_1	82.12 ± 0.594	75.93 ± 0.431	79.02	2.720 ± 0.058	2.445 ± 0.043	2.582
FD+K_2	84.32 ± 1.021	77.98 ± 1.001	81.15	2.834 ± 0.070	2.552 ± 0.067	2.693
MED	65.18 ± 1.454	62.79 ± 1.254	63.98	2.688 ± 0.014	2.447 ± 0.011	2.567
MED+K_1	71.04 ± 0.297	67.18 ± 0.217	69.11	3.010 ± 0.039	2.667 ± 0.031	2.838
MED+K_2	73.65 ± 0.413	69.69 ± 0.402	71.67	3.118 ± 0.058	2.765 ± 0.038	2.941
SED	68.09 ± 0.729	64.97 ± 0.698	66.53	2.472 ± 0.019	2.282 ± 0.015	2.377
SED+K_1	78.98 ± 1.035	77.96 ± 1.021	78.47	2.916 ± 0.021	2.601 ± 0.019	2.758
SED+K_2	82.38 ± 0.456	81.86 ± 0.423	82.12	3.015 ± 0.028	2.692 ± 0.024	2.853
MLD	63.43 ± 0.378	58.42 ± 0.327	60.92	2.626 ± 0.010	2.391 ± 0.009	2.508
MLD+K_1	69.43 ± 0.687	66.59 ± 0.533	68.01	2.888 ± 0.076	2.679 ± 0.067	2.783
MLD+K_2	72.31 ± 0.543	68.35 ± 0.439	70.33	2.993 ± 0.092	2.750 ± 0.081	2.871
SLD	66.34 ± 0.432	63.33 ± 0.412	64.83	2.379 ± 0.043	2.255 ± 0.038	2.317
SLD+K_1	75.62 ± 0.513	74.72 ± 0.505	75.17	2.735 ± 0.037	2.503 ± 0.028	2.619
SLD+K_2	78.28 ± 0.476	77.89 ± 0.378	78.08	2.854 ± 0.058	2.638 ± 0.049	2.746
Mean	71.69	68.06		2.845	2.574	
CD at 5%	Genotype(G)= 0.117			Genotype(G) = 1.573		
	Water treatment(WT)= 0.203			Water treatment(WT) = 2.725		
	G×WT= 0.288			G×WT = 3.854		
	Potassium(K)= 0.117			Potassium(K) = 1.573		
	G×K= N/A			G×K = N/A		
	WT×K= 0.288			WT×K = 3.854		
	G×WT×K= 0.407			G×WT×K = 5.450		
	FI= Fully irrigation, FD =Fully Drought, MED = Moderate early drought, SED= Severe early drought, MLD= Moderate late drought, SLD= Severe late drought K_1= 500ppm (potassium treatment) , K_2 = 700ppm (potassium treatment)					

Principal
Dyal Singh College
KARNAL

11:44 70%

scopus.com/sour

Scopus Preview

Source details

Feedback > Compare sources >

Scope

Years currently covered by Scopus: 2009, from 2011 to 2024

Publisher: Otago Polytechnic

ISSN: 1177-5653 E-ISSN: 1177-5661

Subject area: (Arts and Humanities: Visual Arts and Performing Arts)

Source type: Journal

View all documents > | Set document alert | Save to source list

CiteScore 2023
0.0

SJR 2023
0.103

SNIP 2023
0.177

CiteScore | CiteScore rank & trend | Scopus content coverage

CiteScore 2023

$0.0 = \frac{\text{4 Citations 2020 - 2023}}{\text{102 Documents 2020 - 2023}}$

Calculated on 05 May, 2024

CiteScoreTracker 2024

$0.1 = \frac{\text{5 Citations to date}}{\text{81 Documents to date}}$

Last updated on 05 October, 2024 • Updated monthly

CiteScore rank 2023

Category	Rank	Percentile
Arts and Humanities └ Visual Arts and Performing Arts	#598/667	10th

View CiteScore methodology > | CiteScore FAQ > | Add CiteScore to your site

About Scopus

What is Scopus
Content coverage
Scopus blog
Scopus API
Privacy matters

Language

日本語版を表示する
查看简体中文版本
查看繁體中文版本
Просмотр версии на русском языке

Customer Service

Help
Tutorials
Contact us

Principal
Dyal Singh College
KARNAL

ELSEVIER

Terms and conditions | Privacy policy | Cookies settings

All content on this site: Copyright © 2024 Elsevier B.V., its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the Creative Commons licensing terms apply.
We use cookies to help provide and enhance our service and tailor content. By continuing, you agree to the use of cookies.

RELX



Bioscene

Bioscene
Volume- 21 Number- 02
ISSN: 1539-2422 (P) 2055-1583 (O)
www.explorebioscene.com

Principal
Dyal Singh College
KARNAL

The Climate Crisis: Navigating the Impact of Climate Change on Agriculture

Dr. Suhana Rao[1], Dr. Sushil Kumar[2], Dr. Sombir Singh[3] ,
Dr. Neeraj Kumar[4] & Dr. Vijay Kumar[5]

[1]Assistant Professor, Botany Department, Dyal Singh College, Karnal
[2]Associate Professor, Botany Department, RKSD College, Kaithal
[3]Assistant Professor, Botany Department, Pt. C.L.S. Govt. College, Karnal
[4]Assistant Professor, Biotechnology Department, Pt. C.L.S. Govt. College, Karnal
[5]Assistant Professor, Zoology Department, Pt. C.L.S. Govt. College, Karnal

Corresponding Author: **Dr. Sombir Singh**

Abstract:
Global food and nutritional security are under threat from climate change. Temperature increasecoincide with an increase in greenhouse gas production in the atmosphere due to the greenhouse effect. The climate change is the main factor fostering many stresses that negatively affect the efficiency of agriculture. Rising temperatures, irregular precipitation and growing greenhouse gas emissions are all threatening global agriculture, resulting in lower crop yields and increased food insecurity. This review investigates the implications of changing the climate on soil fertility, water availability, pest infestations, yields and food security. It explores novel strategies including climate-smart agriculture, traditional breeding and genomic tools to alleviate the effects of abiotic stresses on crops, including heat, salinity and drought. In order to ensure food production and handle the urgent problem of climate-induced agricultural vulnerabilities, the review highlights the necessity of adaptive methods.

Keywords: climate-smart farming, food security, global warming, genetic engineering, molecular breeding

1. Introduction:

Climate change is one of the world's most pressing concerns today. The past few decades have indicated that the primary driver of significant changes in the global climate has been elevated human activity, which has altered the planet's atmosphere (IPCC, 2007).Carbon dioxide, nitrous oxide and methane concentrations have increased dramatically since 1750 (IPCC, 2014). According to Sathaye (2006), carbon dioxide emissions are the most significant source of greenhouse gas output.

Principal
Dyal Singh College
KARNAL

It increased from 22 billion metric tons in 1990 to 36 billion metric tons in 2014 (Abeydeera et al., 2019). Since 1975, the average planetary temperature has risen at a pace of around 0.20 °C every decade, and by 2021, an additional 5 °C is predicted (Arora et al., 2005). Catastrophic environmental changes had a significant impact on human health, agricultural productivity and ecological systems (Arunanondchai, 2018). As the world's population is growing rapidly, so does food demand, owing to worries about the global environment's stability. Agriculture production is significantly impacted by the pollution, fertility of the soiland water availability (Noya et al., 2018). As climatic conditions change abruptly, the adverse repercussions on plant production intensify due to effects of abiotic stresses. Varying rainfall has an undesirable effect on crops, particularly in developing states (Malhi et al., 2021). The worldwide food supply is going to be seriously threatened by global warming (Betts et al., 2018). It is widely acknowledged that climate change negatively affects agricultural output and estimates suggest that it will cut the world's cereal production of wheat and maize by around 5% (Lobell et al., 2011). Crop plants are subjected to several abiotic stresses, particularly salt, drought, heat stress and cold stressdue to variations in climate (Malhi et al., 2020). The primary adverse consequences of climate change are reduced soil fertility, agricultural insect infestations and water shortages (Baul and McDonald, 2015). According to IPCC-2014, the nineteenth and twenty-first centuries are thought to have seen catastrophic global warming (Pachauri et al., 2014). Extreme precipitation occurrences may generate floods, or scarcity of rainfall for over an extended amount of time which leads to drought stress (Khan et al., 2016). The global climate is constantly changing and industrialization is a major contributor to rising temperatures. According to Altieri & Nicholls (2017) compared to developing states, developed nations are more likely to experience climate change.

Food insecurity and climate change are the two main problems of 21st century. Sustainable development will have an additional challenge in achieving the global goal of ending hunger by 2030 because malnutrition affects more than 815 million people worldwide (Richardson et al., 2018. Globally, the productivity of main crops has clearly decreased with the increased temperature (Ito et al., 2018). By 2050, there will be roughly 9 billion people on the planet, and this will result in an 85% increase in food needs (FAOSTAT, 2017). According to Dhankher & Foyer (2018), it is predicted that the frequency of droughts, heavy rainfalls, temperature swings, salt stress and insect pest attacks will halt the crop productivity and raise the risk of famine. Severe environmental conditions have a significant impact on agricultural productivity, thus scientists have developed novel strategies to deal with these issues (Rosenzweig et al., 2014). To overcome these limitations and assure food security, new climate-conscious crop cultivars must be devised (Wheeler & Von Braun, 2013). This review

Principal
Dyal Singh College
KARNAL

addresses the consequences of climate change on food crops, as well as mitigation and adaptation strategies for combating climate change.

2. Climate change & agriculture

Earth's temperature fluctuates due to both natural and human-caused processes, which ultimately raises the level of greenhouse gasses. (Stern & Kaufmann, 2014). According to Montagka et al. (2021), anthropogenic activities cause the release of greenhouse gases such CO_2, methane and nitrous oxide in addition to other compounds that cause the depletion of atmosphere's ozone layer. The agricultural is particularly vulnerable to climate change because of its weather sensitivity, which would have a severe detrimental effect on the economy (Mendelsohn, 2009). Fluctuating precipitation, rising temperature and CO_2 fertilization negatively affects theagricultural crops (Malhi et al., 2021). Temperature surges are predicted to diminish agricultural yields by shortening their duration (Mahato, 2014). It is anticipated that the overall yield of the main cereals will decrease with every 2 °C increase in temperature(Challinor et al., 2014). Tropical regions are more affected by global warming because crops of tropical region are currently closer to the upper limit of their temperature tolerance range (Malhi et al., 2021). In most parts of the world, climate change is expected to increase the frequency of droughts, and by 2050, yields in drought afflicted zones are expected to drop around 50%(Li et al., 2009).

Lower harvests are predicted to cause a 0.3% annual loss in global GDP from agriculture by 2100, which could significantly impact agriculture worldwide and drive-up food prices(Stevanovic et al., 2016). These predicted changes could negatively impact the agriculture industry (Kumar &Gautam, 2014). It is anticipated that a 1 °C surge in the global mean temperature will worsen yield losses of key cereal grains by 10 to 25% (Deutsch et al., 2018). Temperature and precipitation variations have a significant impact on plant-water relations and physiological alterations and are more likely to be affected by abrupt shifts in these variables than by variations in the average climate (Reyer et al., 2012). Although C_3 crops are predicted to yield more but in the presence of stressful situations, both C_3 and C_4 crops are predicted to yield less (DaMatta et al., 2010).With higher CO_2 levels, non-leguminous C_3 crops have lower concentrations of nutrients (N, Zn, Fe, and S), which are mostly contained in proteins (Uddling et al., 2018). Human health is adversely influenced by the reduction in iron and zinc content of C3 crops owing to rising CO_2 levels(Myers et al., 2014).

The microbial community in the soil and its enzymatic activity are also impacted by climatic variations. Climate change also has an impact on crop weed infestation. C_3 weeds exhibit greater biomass and leaf area in response to elevated CO_2 concentrations. While C_4 weeds become less competitive in C_3 plants and C_3 weeds

Principal
Dyal Singh College
KARNAL

pose a significant threat to C_4 plants (Korreset al.,2016). Weeds contend with crops for both nutrients and water, because they demand more nutrients than agricultural crops (Malhi et al., 2020). As a result of climate change, weeds are expanding their geographic rangeand the only way to effectively control them is to develop new management strategies that take climate change into account. Climate change is expected to make pest infestations of different crops worse since warmer, more humid weather encourages the growth of pests. However, it will differ depending on the locality and how well-adapted the pests are to the changing environment ((Malhi et al., 2021).

2.1. Climate change & crop yield

Variability in the climate and harsh environmental conditions raised the possibility of different plant on crop plants(Thornton et al., 2014).According to a FAO (2007) report, climate change affects every agricultural region on the planet(Van Velthuizen, 2007). The impact of abiotic stresses on the efficiency of crops are challenging to quantify precisely but crop productivity is thought to be significantly impacted by these stresses, depending on how much of the entire cultivable region is damaged. It is predicted that in the future water scarcity, climate change and other factors will reduce the productivity of the world's major crops in many nations (Tebaldi&Lobell, 2018).Temperature extremes brought on by climate change have a significant impact on wheat production in many areas of world (Asseng et al., 2015). Two primary stresses with a considerable implication on crop yields are drought and high temperature (Barnabás et al., 2008).

Sorghum, maize and barley crops were studied for the cumulative impacts of drought and heat stress on cropsoutput and results showed that the combination of these stresseswas more detrimental than individual stresses (Wang& Huang, 2004). Water stress in cereals has been proven to have a deleterious impact on the development of flowers(Xu&Zhou,2006). Climate change is predicted to cause agricultural productivity to drop to 25.7% by 2080 (Hellin et al., 2014). In an investigation to look into the consequences of climate change on key crop yields, Zhao et al., (2017) found that maize, soybeans, rice and wheat all had showed significant yield losses. Drought stress has been shown to shrink the production of black gram from 31% to 57% during the flowering stage, and from 26% to 57% during the reproductive phase (Baroowa &Gogoi, 2014).According to Maleki et al. (2013), dry spell caused the 42% decrease in yield of soybean(Maleki et al. 2013). It was shown that the yield of maize was negatively impacted by every 1 °C upsurge in temperature (Lobell et al., 2011). Water scarcity is another keyproblem in sorghum, as noted by the majority of the leading producers (Otto et al., 2017).

Principal
Dyal Singh College
KARNAL

2.2. Climate change & Food Security

Food safety may be jeopardized by climate variation because it can reduce the agricultural yields and increase competition for resources. According to Wang et al. (2018) by the end of the 2050s, nations like Egypt, Botswana,Myanmar and India and will face severe food insecurity. Furthermore, as a result of rising temperatures the majority of Asian and African regions will suffer from severe shortages of food by the close of 2080(Zewdie, 2014).Food availability is the amount of food that is produced domestically or imported and is of a satisfactory quality that is available for consumption. According to Zewdie (2014), this is one of the main variables used to evaluate food safety.Numerous studies have indicated that by the end of the 2050, climate change may result in reduced production in wheat (Gammans et al., 2017), maize (Li et al., 2014) and rice (Li, 2018).

It will be extremely difficult to sustain this fast-rising population due to a drop in agricultural productivity induced by mounting temperatures. This might end in a severely limited supply of food in the future, jeopardizing food security and safety. Recent findings indicate that global warming has a negative impact on agricultural outputwhich caused the food prices to rise by 20% (Trostle et al., 2010). According to a number of predictions, the expected surge in population growth and global warming will cause market prices of corn to increase by 42 to 131% by the end of the 2050s. According to Conforti (2011), the market price of rice is expected to increase by 11% to 78% as a result of the reduced yield brought on by climate change.Numerous research found that food quality, including nutritional content was negatively impacted by climate change. Grain characteristics such as starch concentration, granular size and gelatinization of wheat can be negatively influenced by a 2 to 4 °C rise in temperature(Williams et al.,1995). However, new pests, diseasesand weeds may also arise as a result of climate change, which potentially have an impact on human health, the food chain, agricultural productivity and quality (Rosenzweig et al., 2001).

Global warming can push our food systems to the verge of catastrophic levels by raising food prices (Nelson et al., 2010). Maintaining food system security is backbreaking, particularly in light of rising temperatures (Wheeler and Von Braun, 2013).

3. Approaches to Combat Climate Changes

Environmental variability has long-lastingeffects on agriculture and food safety around the world. The harsh weather conditions create a menace to the safety and security of foods, and this is not an entirely novel problem. Farmers can use climate-resilient solutions by combining traditional and agroecological management practices, such as biodiversity, soil management and rainwater harvesting (Altieri & Nicholls, 2017). These management strategies improve carbon sequestration. soil

Principal
Dyal Singh College
KARNAL

health, soil quality and reduce soil erosion, resulting in healthier soils and agricultural systems (Lal et al., 2011). Therefore, the most pressing issue in the world now is to adapt to these weather variations. The subsequent measures must be implemented for crops to adjust to fluctuating circumstances.

3.1. Cultural Approaches

Farmers employ variety of useful strategies, including asirrigation techniques,crop rotation, varying cropping patterns and short-cycle crops. Under climatic stress circumstances, all of these actions may improve crop adaptability (Deligios et al., 2019). Shifting the cultivation time, planting novel crops and utilizing drought resistant cultivars are some vital approaches to reduce the risk of climate unpredictability and boost crop plant adaptability to assure food security and safety(Ali & Erenstein, 2017).Utilizing crop-management strategies that can improve crop development under a range of environmental stresses is another way to increase plant adaptation. The timing of sowing, planting density and optimal irrigating techniques are critical approaches to deal with meteorological challenges (Battisti et al., 2018). Fertilizers are also essential for mitigating the effects of global warming and assisting plants in adapting more effectively. It delivers significant energy to plants which helps to maintain soil fertility and productivity. As a result, the role of fertilizer in sustaining the earth is undeniable (Henderson et al., 2018).

3.2. Traditional Methods

Plant breeding is an adaptable method for crop development and improvement under a range of environmental variables. In addition to helping plants survival from various challenges during a critical stage of plant growth, it ensures food security and safety amid extreme weather variations (Blum, 2018). Inbreeding selection, Polymorphism and recombination are used in genetic divergence analysis to produce the ideal plant. In order to establish innovative cultivars based on genetic variation and affinities, genetic divergence analysis is considered an essential tool(Raza et al., 2018).

3.3. Genetics and Genomics Strategies

Breeding programs in several crops are combined with genomic techniques to identify elite genes with multi-trait assembly and reach new heights in molecular breeding (Bevan &Waugh, 2007). With the introduction of sequencing and phenotyping, genomic-led breeding paved the path for identifying genes involved in various mitigation stress. (Kole et al., 2015). Collins et al., (2008) propose that the development of new cultivars with enhanced stress resistance is enabled by QTL dissection of yield-related factors in crops. Molecular plant Breeding is a key approach for enhancing crop yields and productivity in the presence of multiple

Principal
Dyal Singh College
KARNAL

environmental stresses. (Wani et al., 2018). Genomic selection (GS) is an intriguing approach for crop improvement that uses high-throughput phenotyping and marker density to screen elite genes, improve polygenic characteristics, and produce cost-effective breeding lines (Kumar et al., 2018).

3.4. Genetic Engineering

Genetic engineering is a powerful technique to modify the genetic makeup of the genome for the benefit of humans. Identification of stress-responsive transcription factors is a crucial breakthrough for developing stress-resistant agricultural varieties. These transcription factors can regulate gene phenotypes in genetically engineered crops exposed to various stresses (Reynolds et al., 2015). Genetic engineering has produced a large number of transgenic plants to combat biotic and abiotic stresses.These genetically altered plants are significantly more resistant to environmental fluctuations than conventional plants (Nejat & Mantri, 2017). Several transcription factors are recognized like the AP2/ERFBP group, which is important for several plant growth pathways and has roles in all stress responses (Licausi et al., 2010). Genetically modified tobacco with an overexpressed GmERF3 gene shows improved resistance to TMV, dehydration, and salinity stress (Zhang et al., 2009) [193]. WRKY is another significant family of TFs that is widely distributed in response to abiotic stresses (Muthamilarasan et al., 2015).

Genome editing (GE) is a decidedly effective approach for manipulating the plant genome using sequence-specific nucleases. On a global scale GE-assisted crop modification has the potential to combat food insecurity and create a climate-conscious farming system (Liu et al., 2013). The use of GE technologies and the development of novel techniques for quick and precise genome editing to enhance crop output and protect crops from various stresses have had a significant impact on plant breeding techniques (Taranto et al., 2018). Therefore, in order to improve crop varieties with a high potential for producing yielding crops, it is necessary to develop innovative alterations in the gene pool of plant germplasm under different stresses (Kamburova et al., 2017).Genome editing technique uses specific to the site endonucleases such as zinc-finger nucleases, CRISPR-Cas9 and transcription activator-like effector nucleases(Zhu et al., 2017). The CRISPR/Cas9 system is emerging as the most effective GE technique among the genome editing toolsdue to its affordability, speed, accuracy, and ability to edit many sites within the genome at once (Abdelrahman et al., 2018). Plant genome editing using CRISPR/Cas9 has been widely studied to adapt to biotic and abiotic challenges (Khurshid et al., 2017). Shen et al. (2017) used Osann3 gene knockout to study japonica rice ability to withstand cold stress and found that this enhanced the cold stress tolerance. The development of herbicide tolerance in mutant rice lines was

Principal
Dyal Singh College
KARNAL

achieved through the use of CRISPR/Cas9 to knock down the PmCDA1 gene (Shimatani et al., 2017).

Conclusion and Future perspective:

Climate change is an undeniable issue that poses serious difficulties to global agriculture, jeopardizing crop production, soil health, water supplies and food security. This review emphasizes the negative effects of climate change on agricultural productivity, such as reduced crop yields, soil degradation, water scarcity and increased pest and disease pressures, as well as the need for adaptive strategies, such as climate-smart agriculture, genetic engineering, molecular breeding, and traditional farming practices, to mitigate these consequences. Future efforts must focus on developing resilient crop varieties through genetic engineering, molecular breeding, implementing climate-smart agricultural practices for sustainable cropping systems and assuring strong regulatory and institutional support.

Addressing the complex difficulties faced by climate change requires collaborative research, knowledge exchange, and the creation of monitoring and early warning systems. Additionally, efforts to reduce greenhouse gas emissions from agriculture must be enhanced. Integrating these measures allows the agricultural industry to better adapt to climate change, assuring food security and sustainability for future generations. Continued investment in research, innovation and collaboration will be critical to developing a resilient agricultural system that can survive the effects of climate change.

References:

1. Abdelrahman, M.; Al-Sadi, A.M.; Pour-Aboughadareh, A.; Burritt, D.J.; Tran, L.-S.P. (2018). Genome editing using CRISPR/Cas9–targeted mutagenesis: An opportunity for yield improvements of crop plants grown under environmental stresses. Plant Physiology and Biochemistry, Volume 131: Pages 31–36.
2. Abeydeera, L.H.U.W.; Mesthrige, J.W.; Samarasinghalage, T.I. (2019). Global research on carbon emissions: A scientometric review. Sustainability, Volume 11: Page 3972.
3. Ali, A.; Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. Climate Risk Management, Volume 16: Pages 183–194.
4. Altieri, M.A.; Nicholls, C.I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. Climate Change,
5. Arora, M.; Goel, N.K.; Singh, P. (2005). Evaluation of temperature trends over India. Hydrological Sciences Journal, Volume 50: Pages 81–93.

Principal
Dyal Singh College
KARNAL

6. Arunanondchai, P.; Fei, C.; Fisher, A.; McCarl, B.A.; Wang, W.; Yang, Y. (2018). How does climate change affect agriculture.In The Routledge Handbook of Agricultural Economics; Routledge: Abingdon-on-Thames, UK.
7. Asseng, S.; Ewert, F.; Martre, P.; Rötter, R.P.; Lobell, D.; Cammarano, D.; Kimball, B.; Ottman, M.; Wall, G.; White, J.W. (2015). Rising temperatures reduce global wheat production. Nature Climate Change, Volume 5: Page 143.
8. Baroowa, B.; Gogoi, N. (2014). Biochemical changes in black gram and green gram genotypes after imposition of drought stress. Journal of Food Legumes, Volume 27: Pages 350–353.
9. Battisti, R.; Sentelhas, P.C.; Parker, P.S.; Nendel, C.; Gil, M.D.S.; Farias, J.R.; Basso, C.J. (2018). Assessment of crop-management strategies to improve soybean resilience to climate change in Southern Brazil. Crop and Pasture Science, Volume 69: Pages 154–162.
10. Baul, T.K.; McDonald, M. (2015). Integration of Indigenous knowledge in addressing climate change. Indian Journal of Traditional Knowledge, Volume 1: Pages 20–27.
11. Betts, R.A.; Alfieri, L.; Bradshaw, C.; Caeser, J.; Feyen, L.; Friedlingstein, P.; Gohar, L.; Koutroulis, A.; Lewis, K.; Morfopoulos, C.; et al. (2018). Changes in climate extremes, fresh water availability and vulnerability to food insecurity projected at 1.5 °C and 2 °C global warming with a higher-resolution global climate model. Philosophical Transactions of the Royal Society A, Volume 376: Article 20160452.
12. Bevan, M.; Waugh, R. (2007). In Applying Plant Genomics to Crop Improvement; BioMed Central: London, UK.
13. Blum, A. (2018). Plant Breeding for Stress Environments; CRC Press: Boca Raton, FL, USA.
14. Challinor, A.J.; Watson, J.; Lobell, D.B.; Howden, S.M.; Smith, D.R.; Chhetri, N. (2014). A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, Volume 4: Pages 287–291.
15. Collins, N.C.; Tardieu, F.; Tuberosa, R. (2008). Quantitative trait loci and crop performance under abiotic stress: Where do we stand? Plant Physiology, Volume 147: Pages 469–486.
16. Conforti, P. (2011). Looking Ahead in World Food and Agriculture: Perspectives to 2050; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy.
17. DaMatta, F.M.; Grandis, A.; Arenque, B.C.; Buckeridge, M.S. (2010). Impacts of climate changes on crop physiology and food quality. Food Research International, Volume 43: Pages 1814–1823.
18. Deligios, P.A.; Chergia, A.P.; Sanna, G.; Solinas, S.; Todde, G.; Narvarte, L.; Ledda, L. (2019). Climate change adaptation and water saving by innovative

Principal
Dyal Singh College
KARNAL

irrigation management applied on open field globe artichoke. Science of the Total Environment, Volume 649: Pages 461–472.

19. Deutsch, C.A.; Tewksbury, J.J.; Tigchelaar, M.; Battisti, D.S.; Merrill, S.C.; Huey, R.B.; Naylor, R. (2018). Increase in crop losses to insect pests in a warming climate. Science, Volume 361: Pages 916–919.
20. Dhankher, O.P.; Foyer, C.H. (2018). Climate resilient crops for improving global food security and safety. Plant Cell and Environment, Volume 41: Pages 877–884.
21. FAOSTAT. (2017).
22. Gammans, M.; Mérel, P.; Ortiz-Bobea, A. (2017). Negative impacts of climate change on cereal yields: Statistical evidence from France. Environmental Research Letters, Volume 12: Article 054007.
23. Hellin, J.; Bellon, M.R.; Hearne, S.J. (2014). Maize landraces and adaptation to climate change in Mexico. Journal of Crop Improvement, Volume 28: Pages 484–501.
24. Henderson, B.; Cacho, O.; Thornton, P.; van Wijk, M.; Herrero, M. (2018). The economic potential of residue management and fertilizer use to address climate change impacts on mixed smallholder farmers in Burkina Faso. Agricultural Systems, Volume 167: Pages 195–205.
25. IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. In Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK.
26. IPCC. (2014). Climate Change 2014: Synthesis Report; Pachauri, R.K., Meyer, L.A., Eds.; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland; 151p.
27. Ito, R.; Vasconcelos, H.L.; Feeley, K.J. (2018). Global climate change increases risk of crop yield losses and food insecurity in the tropical Andes. Global Change Biology, Volume 24: Pages e592–e602.
28. Kamburova, V.S.; Nikitina, E.V.; Shermatov, S.E.; Buriev, Z.T.; Kumpatla, S.P.; Emani, C.; Abdurakhmonov, I.Y. (2017). Genome editing in plants: An overview of tools and applications. International Journal of Agronomy, Volume 2017: Pages 1–15.
29. Khan, A.; Ijaz, M.; Muhammad, J.; Goheer, A.; Akbar, G.; Adnan, M. (2016). Climate Change Implications for Wheat Crop in Dera Ismail Khan District of Khyber Pakhtunkhwa. Pakistan Journal of Meteorology, Volume 13: Pages 17–27.

Principal
Dyal Singh College
KARNAL

30. Khurshid, H.; Jan, S.A.; Shinwari, Z.K.; Jamal, M.; Shah, S.H. (2017). Current Issues in Molecular Biology, An Era of CRISPR/Cas9 Mediated Plant Genome Editing. Volume 26: Pages 47–54.
31. Kole, C.; Muthamilarasan, M.; Henry, R.; Edwards, D.; Sharma, R.; Abberton, M.; Batley, J.; Bentley, A.; Blakeney, M.; Bryant, J. (2015). Application of genomics-assisted breeding for generation of climate resilient crops: Progress and prospects. Frontiers in Plant Science, Volume 6: Article 563.
32. Korres, N.E.; Norsworthy, J.K.; Tehranchian, P.; Gitsopoulos, T.K.; Loka, D.A.; Oosterhuis, D.M.; Gealy, D.R.; Moss, S.R.; Burgos, N.R.; Miller, M.R.; et al. (2016). Cultivars to face climate change on crops and weeds: A review. Agronomy for Sustainable Development, Volume 36: Pages 12–22.
33. Kumar, R.; Gautam, H.R. (2014). Climate change and its impact on agricultural productivity in India. Journal of Climatology and Weather Forecasting, Volume 2: Pages 1–3.
34. Kumar, S.; Muthusamy, S.K.; Mishra, C.N.; Gupta, V.; Venkatesh, K. (2018). Advanced Molecular Plant Breeding: Meeting the Challenge of Food Security;CRC Press: Boca Raton, FL, USA; p. 275.
35. Lal, R.; Delgado, J.A.; Groffman, P.M.; Millar, N.; Dell, C.; Rotz, A. (2011). Management to mitigate and adapt to climate change. Journal of Soil and Water Conservation, Volume 66: Pages 276–285.
36. Li, M. (2018). Climate Change to Adversely Impact Grain Production in China by 2030; IFPRI: Washington, DC, USA.
37. Li, X.; Takahashi, T.; Suzuki, N.; Kaiser, H.M. (2014). Impact of climate change on maize production in Northeast and Southwest China and risk mitigation strategies. APCBEE Procedia, Volume 8: Pages 11–20.
38. Li, Y.; Ye, W.; Wang, M.; Yan, X. (2009). Climate change and drought: A risk assessment of crop-yield impacts. Climatic Research, Volume 39: Pages 31–46.
39. Licausi, F.; Giorgi, F.M.; Zenoni, S.; Osti, F.; Pezzotti, M.; Perata, P. (2010). Genomic and transcriptomic analysis of the AP2/ERF superfamily in Vitis vinifera.BMC Genomics, Volume 11: Article 719.
40. Liu, W.; Yuan, J.S.; Stewart, C.N., Jr. (2013). Advanced genetic tools for plant biotechnology. Nature Reviews Genetics, Volume 14: Pages 781.
41. Lobell, D.B.; Bänziger, M.; Magorokosho, C.; Vivek, B. (2011). Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change, Volume 1: Pages 42.
42. Lobell, D.B.; Schlenker, W.; Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, Volume 333: Pages 616–620.
43. Mahato, A. (2014). Climate change and its impact on agriculture. International Journal of Scientific Research and Publications, Volume 4: Pages 1–6.

Principal
Dyal Singh College
KARNAL

44. Maleki, A.; Naderi, A.; Naseri, R.; Fathi, A.; Bahamin, S.; Maleki, R. (2013). Physiological performance of soybean cultivars under drought stress. Bulletin of Environmental Pharmacology and Life Sciences, Volume 2: Pages 38–44.
45. Malhi, G.S.; Kaur, M.; Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. Sustainability, Volume 13, Issue 3: Article 1318.
46. Malhi, G.S.; Kaur, M.; Kaushik, P.; Alyemeni, M.N.; Alsahli, A.; Ahmad, P. (2020). Arbuscular mycorrhiza in combating abiotic stresses in vegetables: An eco-friendly approach.Saudi Journal of Biological Sciences, Volume 28(2):Pages 1465-1476.
47. Malhi, G.S.; Rana, M.C.; Rana, S.S.; Kaushik, P. (2020). Effect of individual or combined application of herbicide imazethapyr on nutrient uptake by blackgram (Vigna mungo L.). Journal of Experimental Biology and Agricultural Sciences, Volume 8: Pages 441–446.
48. Mendelsohn, R. (2009). The impact of climate change on agriculture in developing countries. Journal of Natural Resources Policy Research, Volume 1: Pages 5–19.
49. Montzka, S.A.; Dlugokencky, E.J.; Butler, J.H. (2011). Non-CO2 greenhouse gases and climate change. Nature, Volume 476: Pages 43–50.
50. Muthamilarasan, M.; Bonthala, V.S.; Khandelwal, R.; Jaishankar, J.; Shweta, S.; Nawaz, K.; Prasad, M. (2015). Global analysis of WRKY transcription factor superfamily in Setaria identifies potential candidates involved in abiotic stress signaling. Frontiers in Plant Science, Volume 6: Article 910.
51. Myers, S.S.; Zanobetti, A.; Kloog, I.; Huybers, P.; Leakey, A.D.B.; Bloom, A.J.; Carlisle, E.; Dietterich, L.H.; Fitzgerald, G.; Hasegawa, T.; et al. (2014). Increasing CO2 threatens human nutrition. Nature, Volume 510: Pages 139–142.
52. Nejat, N.; Mantri, N. (2017). Plant immune system: Crosstalk between responses to biotic and abiotic stresses the missing link in understanding plant defence. Current Issues in Molecular Biology, Volume 23: Pages 1–16.
53. Nelson, G.C.; Rosegrant, M.W.; Palazzo, A.; Gray, I.; Ingersoll, C.; Robertson, R.; Tokgoz, S.; Zhu, T.; Sulser, T.B.; Ringler, C. (2010). Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options; IFPRI: Washington, DC, USA; Volume 172.
54. Noya, I.; González-García, S.; Bacenetti, J.; Fiala, M.; Moreira, M.T. (2018). Environmental impacts of the cultivation-phase associated with agricultural crops for feed production. Journal of Cleaner Production,Volume 172: Pages 3721–3733.
55. Otto, I.M.; Reckien, D.; Reyer, C.P.; Marcus, R.; Le Masson, V.; Jones, L.; Norton, A.; Serdeczny, O. (2017). Social vulnerability to climate change: A review of

Principal
Dyal Singh College
KARNAL

concepts and evidence. Regional Environmental Change, Volume 17: Pages 1651–1662.

56. Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R.; Church, J.A.; Clarke, L.; Dahe, Q.; Dasgupta, P. (2014). Climate Change 2014: Synthesis Report; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland.
57. Raza, A.; Shaukat, H.; Ali, Q.; Habib, M. (2018). Assessment of RAPD markers to analyse the genetic diversity among sunflower (Helianthus annuus L.) genotypes. Turkish Journal of Agriculture, Food Science and Technology, Volume 6: Pages 107–111.
58. Reyer, C.P.O.; Leuzinger, S.; Rammig, A.; Wolf, A.; Bartholomeus, R.P.; Bonfante, A.; Lorenzi, F.D.; Dury, M.; Gloning, P.; Jaoude, R.A.; et al. (2012). A plant's perspective of extremes: Terrestrial plant responses to changing climatic variability. Global Change Biology, Volume 19: Pages 75–89.
59. Reynolds, M.; Tattaris, M.; Cossani, C.M.; Ellis, M.; Yamaguchi-Shinozaki, K.; Saint Pierre, C. (2015). Advances in Wheat Genetics: From Genome to Field;Springer: Berlin/Heidelberg, Germany; Pages 355–368.
60. Richardson, K.J.; Lewis, K.H.; Krishnamurthy, P.K.; Kent, C.; Wiltshire, A.J.; Hanlon, H.M. (2018). Food security outcomes under a changing climate: Impacts of mitigation and adaptation on vulnerability to food insecurity. Climate Change, Volume 147: Pages 327–341.
61. Rosenzweig, C.; Elliott, J.; Deryng, D.; Ruane, A.C.; Müller, C.; Arneth, A.; Boote, K.J.; Folberth, C.; Glotter, M.; Khabarov, N. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceedings of the National Academy of Sciences USA, Volume 111: Pages 3268–3273.
62. Rosenzweig, C.; Iglesias, A.; Yang, X.; Epstein, P.R.; Chivian, E. (2001). change and extreme weather events; implications for food production, plant diseases, and pests. Global Change and Human Health, Climate Volume 2: Pages 90–104.
63. Sathaye, J.; Shukla, P.R.; Ravindranath, N.H. (2006). Climate change, sustainable development and India: Global and national concerns. Current Science, Volume 90: Pages 314–325.
64. Shen, C.; Que, Z.; Xia, Y.; Tang, N.; Li, D.; He, R.; Cao, M. (2017). Knock out of the annexin gene OsAnn3 via CRISPR/Cas9-mediated genome editing decreased cold tolerance in rice. Journal of Plant Biology, Volume 60: Pages 539–547.
65. Shimatani, Z.; Kashojiya, S.; Takayama, M.; Terada, R.; Arazoe, T.; Ishii, H.; Teramura, H.; Yamamoto, T.; Komatsu, H.; Miura, K. (2017). Targeted base editing in rice and tomato using a CRISPR-Cas9 cytidine deaminase fusion. Nature Biotechnology, Volume 35: Pages 441.

Principal
Dyal Singh College
KARNAL

66. Stern, D.I.; Kaufmann, R.K. (2014). Anthropogenic and natural causes of climate change.Climate Change, Volume 122: Pages 257–269.
67. Stevanovic, M.; Popp, A.; Campen, H.L.; Dietrich, J.P.; Muller, C.; Bonsch, M.; Schmitz, C.; Bodirsky, B.L.; Humpenoder, F.; Weindl, I. (2016). The impact of high-end climate change on agricultural welfare. Science Advances, Volume 2: Article e1501452.
68. Taranto, F.; Nicolia, A.; Pavan, S.; De Vita, P.; D'Agostino, N. (2018). Biotechnological and digital revolution for climate-smart plant breeding. Agronomy, Volume 8: Article 277.
69. Tebaldi, C.; Lobell, D. (2018). Estimated impacts of emission reductions on wheat and maize crops. Climate Change, Volume 146: Pages 533–545.
70. Thornton, P.K.; Ericksen, P.J.; Herrero, M.; Challinor, A.J. (2014). Climate variability and vulnerability to climate change: A review. Global Change Biology, Volume 20: Pages 3313–3328.
71. Trostle, R. (2010). Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices;DIANE Publishing: Collingdale, PA, USA.
72. Uddling, J.; Broberg, M.C.; Feng, Z.; Pleijel, H. (2018). Crop quality under rising atmospheric CO2. Current Opinion in Plant Biology, Volume 45: Pages 262–267.
73. Van Velthuizen, H. (2007). Mapping Biophysical Factors That Influence Agricultural Production and Rural Vulnerability; Food & Agriculture Organization: Rome, Italy.
74. Wang, J.; Vanga, S.K.; Saxena, R.; Orsat, V.; Raghavan, V. (2018). Effect of Climate Change on the Yield of Cereal Crops: A Review. Climate, Volume 6: Article 41.
75. Wang, Z.; Huang, B. (2004). Physiological recovery of Kentucky bluegrass from simultaneous drought and heat stress. Crop Science, Volume 44: Pages 1729–1736.
76. Wani, S.H.; Choudhary, M.; Kumar, P.; Akram, N.A.; Surekha, C.; Ahmad, P.; Gosal, S.S. (2018). Biotechnologies of Crop Improvement; Springer: Berlin/Heidelberg, Germany; Volume 3: Pages 1–23.
77. Wheeler, T.; Von Braun, J. (2013). Climate change impacts on global food security. Science, Volume 341: Pages 508–513.
78. Wheeler, T.; Von Braun, J. (2013). Climate change impacts on global food security. Science, Volume 341: Pages 508–513.
79. Williams, M.; Shewry, P.; Lawlor, D.; Harwood, J. (1995). The effects of elevated temperature and atmospheric carbon dioxide concentration on the quality of grain lipids in wheat (Triticum aestivum L.) grown at two levels of nitrogen application. Plant Cell and Environment, Volume 18: Pages 999–1009.

Principal
Dyal Singh College
KARNAL

80. Xu, Z.Z.; Zhou, G.S. (2006). Combined effects of water stress and high temperature on photosynthesis, nitrogen metabolism and lipid peroxidation of a perennial grass Leymus chinensis. Planta, Volume 224: Pages 1080–1090.
81. Zewdie, A. (2014). Impacts of climate change on food security: A literature review in Sub-Saharan Africa. Journal of Earth Science and Climate Change, Volume 5: Article 225.
82. Zhang, G.; Chen, M.; Li, L.; Xu, Z.; Chen, X.; Guo, J.; Ma, Y. (2009). Overexpression of the soybean GmERF3 gene, an AP2/ERF type transcription factor for increased tolerances to salt, drought, and diseases in transgenic tobacco. Journal of Experimental Botany, Volume 60: Pages 3781–3796.
83. Zhao, C.; Liu, B.; Piao, S.; Wang, X.; Lobell, D.B.; Huang, Y.; Huang, M.; Yao, Y.; Bassu, S.; Ciais, P. (2017). Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences USA, Volume 114: Pages 9326–9331.
84. Zhu, C.; Bortesi, L.; Baysal, C.; Twyman, R.M.; Fischer, R.; Capell, T.; Schillberg, S.; Christou, P. (2017). Characteristics of genome editing mutations in cereal crops. Trends in Plant Science, Volume 22: Pages 38–52.

Principal
Dyal Singh College
KARNAL

11:46 69%
scopus.com/sour
29

Scopus 20

Source details

Bioscene

Years currently covered by Scopus: from 2004 to 2023

Publisher: Association of College and Univesity Biology Educators

ISSN: 1539-2422

Subject area: Social Sciences: Education | Agricultural and Biological Sciences: General Agricultural and Biological Sciences

Source type: Journal

View all documents > | Set document alert | Save to source list

CiteScore | CiteScore rank & trend | Scopus content coverage

CiteScore 2023

$$0.5 = \frac{17 \text{ Citations } 2020 - 2023}{32 \text{ Documents } 2020 - 2023}$$

Calculated on 05 May, 2024

CiteScoreTracker 2024

$$0.5 = \frac{13 \text{ Citations to date}}{25 \text{ Documents to date}}$$

Last updated on 05 October, 2024 • Updated monthly

CiteScore rank 2023

Category	Rank	Percentile
Social Sciences — Education	#1308/1543	15th
Agricultural and Biological Sciences — General Agricultural and Biological Sciences	#200/221	9th

View CiteScore methodology > | CiteScore FAQ > | Add CiteScore to your site

About Scopus

What is Scopus
Content coverage
Scopus blog
Scopus API
Privacy matters

Principal
Dyal Singh College
KARNAL

Language

IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Customer Satisfaction Towards Mobile Banking

Author

Dr. Komal Gupta

Assistant Professor

Dyal Singh College, Karnal

Co-Author

Dr. Chanchal Gupta

Assistant Professor

Dyal Singh College, Karnal

Abstract

Mobile banking is a service provided by a bank or other financial institution that allows its customers to conduct financial transactions using a mobile device such as a smartphone or tablet. Unlike the related internet banking it uses software, usually called an app, provided by the financial institution for the purpose. Mobile banking is usually available on a 24-hour basis. Mobile banking is dependent on the availability of an internet or data connection to the mobile device. Transactions through mobile banking depend on the features of the mobile banking app provided and typically includes obtaining account balances and lists of latest transactions, electronic bill payments, remote check deposits, P2P payments, and funds transfers between a customer's or another's accounts. Some apps also enable copies of statements to be downloaded and sometimes printed at the customer's premises. Using a mobile banking app increases ease of use, speed, flexibility and also improves security because it integrates with the user built-in mobile device security mechanisms. From the bank's point of view, mobile banking reduces the cost of handling transactions by reducing the need for customers to visit a bank branch for non-cash withdrawal and deposit transactions. Mobile banking does not handle transactions involving cash, and a customer needs to visit an ATM or bank branch for cash withdrawals or deposits. My study is related to identify the satisfaction level of the bank customers about mobile banking services. Other Objectives of my study to examine the factors affecting the use of mobile banking services with bank customers, to identify the facilities provided by Mobile Banking Services, to study the benefits and limitations of Mobile banking Services, to know the future prospects of mobile banking in India, to suggest different ways to improve the functioning of Mobile Banking facilities and offer new business opportunities. The main tool used for primary data collection is the questionnaire. We use different journals, articles and newspaper for collecting secondary data.

Principal
Dyal Singh College
KARNAL

Keywords: Mobile banking, Internet banking, Customer satisfaction

Introduction

Mobile Banking is a technique to carry out banking transactions on the mobile phone through a data service-provider. Banks need to provide services to their customers whenever they require it and wherever they are required. So Mobile banking is one of the major significant tool through which the customers can their business transactions and their office functions to indirect passage. Mobile banking saves our time and this saved time can be effectively and efficiently utilized for business development and cost reduction. Cellular phones have achieved so much prominence in the present-day scenario that a person cannot survive without this communication channel. Once upon a time, a mobile phone was an expensive thing and only for rich, but now it is an important necessity. In every state the number of customers using cell phones has increased to unexpected ratio. At least 90% of these customers have bank accounts in several banks which use of mobile banking facilities. Therefore, banks are providing mobile banking services to their customers. Customers are also taking full advantage of these facilities.

Facilities available on Mobile Banking:

- Balance Enquiry: This facility provides all customers, the available balance in his or her account that are connected to the customer identification number. The maximum number of accounts one can avail is five and not more than that.
- Cost Transactions: This kind of transaction provides the customer with the information about the previous five debits or credits done to the account.
- Cheque Book Request: This is an alternate for going personally to the bank, the consumer can request for a cheque book to be mailed to his or her address as per the records of the bank. This saves his or her precious time.
- Bill Payment: For those organizations which register with the bank for this particular facility, the payment is made on request on mobile phone banking.
- Change of Primary Account: The customer has the choice to change their already existing account to another new account number for carrying out further transactions.
- Help: Customers can know the transaction codes for several kinds of transactions through this alternative. Mobile phone bank-users will be notified about external clearing cheque realizations, internal cheque returns, notification on term deposits matured, on loan installment due

Principal
Dyal Singh College
KARNAL

Ancillary service to mobile banking by banks:

- Top-up mobile talk time by refilling through the ATM system.
- Refill the prepaid mobile phone through the ATM or SMS.
- Have distinct memorandum of undertaking with other telecom organization and sell this product to earn commission.

Mobile banking services

- Mini-statements and checking of account history.
- Alerts on account activity or passing of set thresholds.
- Monitoring of term deposits.
- Access to loan statements.
- Access to card statements.
- Mutual funds / equity statements.
- Insurance policy management.
- Accessing the bank 24/7. ...
- Making it easier to save. ...
- Paying IOUs. ...
- Strengthening security. ...
- Offering clarity about where your financial data is going. ...
- Tracking expenses. ...
- Giving you tailored options.

Indian Mobile Payment Market leaders

1. PAYTM PAYMENTS BANK LIMITED
2. PhonePe
3. Alphabet Inc. (Google Pay.)
4. Amazon Payments, Inc. (Amazon Pay)
5. ICICI Bank Limited (ICICI Pockets)

Principal
Dyal Singh College
KARNAL

Devices Used for online banking

Mobile	59%
Laptop	32%
Tablet	9%

Sources: GlobalWebIndex Q4 2019 Base 1,08000 Internet users ages 16-64

This data showed that number of mobile device users is more than laptop and tablets.As discussed above due to various benefits of mobile banking services more and more people use this facility. The above data shows that in today's time 59% respondents use Mobile Banking.

Objectives:

1. To identify the satisfaction level of the bank customers about mobile banking services.
2. To examine the factors affecting the use of mobile banking services with bank customers.
3. To study the benefits and limitations of Mobile banking Services.
4. To know the future prospects of mobile banking in India.
5. To suggest different ways to improve the functioning of Mobile Banking facilities and offer new business opportunities.

Data Collection Method:

Here we use both secondary as well as primary data collection methods. Through various articles, journal and newspapers we get data about the mobile banking services, Major mobile payment Indian players. We get data about more and more people use mobile device to their online transactions . But we get data about the customer satisfaction towards mobile banking, their dissatisfactory factors ,their suggestions for improvement services through questionnaire. Here we get data from the sample of age group above 20 onwards of different occupations.

Principal
Dyal Singh College
KARNAL

Findings :

- From the total respondents there are 57.7% Female and 42.3 Male.
- All have bank Accounts and all banks are providing mobile banking services.
- Out of these 42.3% having account in public sector banks and 57.7% having account in private sector banks.
- Out of total respondents 88.5% use mobile banking services and 11.5% does not use.
- Factors that motivated to operate the account through Mobile banking services.

1. Through advertising- 16.7%
2. Friends and relatives- 4.2%
3. Self-motivated -70.8%
4. Others-8.3%

This data shows people's awareness about the mobile banking benefits that mostly people are self-motivated and are using mobile banking. The second source of awareness for Mobile Banking is Newspapers/ Magazines/ Other Printed Ads. Family / Friends/ Colleagues who are the users of Mobile Banking with 4.2%.

- Customers opinion regarding Mobile banking services

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Mobile Banking is Time saving	66.7%	29.2%	4.1%		
Mobile Banking is Cost saving	41.7%	54.2%	4.1%		
Mobile Banking is Flexible or Convenient	37.5%	54.2%	8.3%		
Mobile Banking is Easy to use	37.5%	54.2%	4.2%	4.1%	
Mobile Banking is Secure	37.5%	54.2%	8.3%		
The System, Network etc. for Mobile Banking is easily available	29.2%	50%	20.8%		

Principal
Dyal Singh College
KARNAL

Mobile Banking has better Problem Hand ling capability	25%	41.7%	25%	4.2%	4.1%
Mobile Banking have full filled my expec tation	29.2%	50%	16.7%	4.1%	

Source: questionnaire

This data shows that easy access at any time anywhere is the biggest reason for adopting Mobile Banking out of respondents 54.2% adopts M- Banking due to this reason only. 29.2% adopt it because it saves time. 41.7% using it because Mobile for banking makes banking hassle free and effortless. 54.2% says it involves lower cost as compared to the traditional or older modes of Banking. Here 4.1% people do not agree that mobile banking has better problem handling capacity.

- **Overall satisfaction level**

	Highly Satisfied	Satisfied	Neutral	Dissatisfied	Highly Dissatisfied
Number of overall satisfied	23.1	65.4	3.8	7.6	

This data shows the overall customer satisfaction level. Most of the people are fully satisfied from mobile banking services. Highest 65.4% out of all show satisfaction ratio only 7.6% ratio show dissatisfaction level.

- **Reasons behind your dissatisfaction**

1. Services are not Enough-33.3%
2. High Cost-0%
3. Error in Network-50%
4. Low Safety-25%
5. Difficult to understand-16.7%
6. Not Reliable in providing services-0%

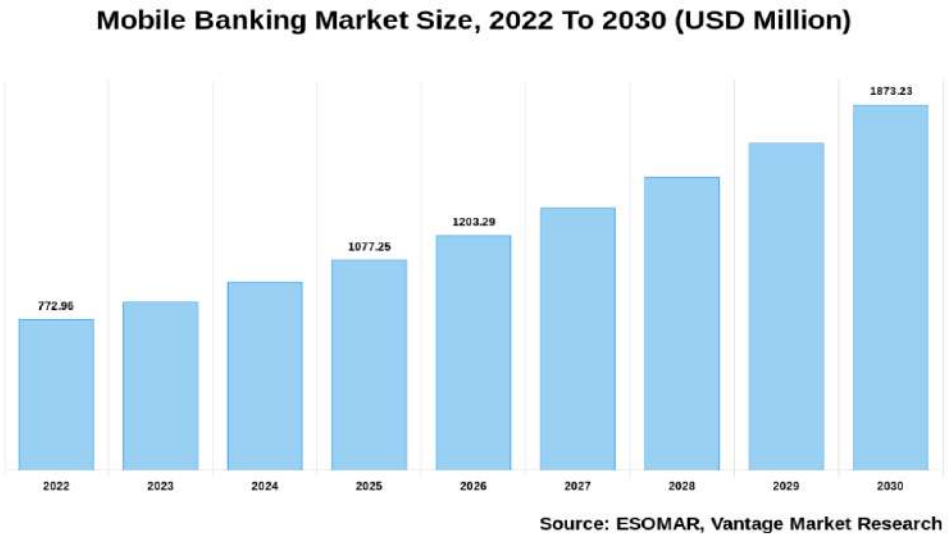
Today respondents are dissatisfied from mobile banking services because many times network issues arise in mobile banking and banking services are also not sufficient. Therefore, they are dissatisfied with the mobile banking services.

Principal
Dyal Singh College
KARNAL

Suggestions for further improvement of mobile banking services

- Network connectivity should be improved especially in rural areas and cyber security with more advancement.
- Banks should update their server time to time
- In my view they should expand the credit reporting systems as it will enhance the efficiency of payment system and improve the issue related to leakage of personal data .
- Overall Good initiative
- fast process
- Only network problem some time faced.
- Sometimes there is a server error.... please find some way out
- Make it more user friendly

Future Trend:



This graph shows that as per the data of 2022 to 2030 the size of mobile banking will keep increasing in the future and people will use it a lot due to te benefits of mobile banking services.

Principal
Dyal Singh College
KARNAL

Safety Tips

Even with the best Mobile Banking App, customers should take adequate measures to enhance the safety of their digital transactions. Here are some tips to make your experience safer-

- Avoid using a Mobile Banking App on public networks as they're not secure
- Keep the smartphone protected with a PIN, fingerprint, or facial recognition
- Never leave your phone unattended
- Avoid storing confidential data like Mobile Banking passwords, Debit Card PINs, etc., on your smartphone

References:

- Bureau, E. (2020, October 27). economictimes.indiatimes. Retrieved from The Economic Times: https://economictimes.indiatimes.com/industry/telecom/telecomnews/telcos-urge-trai-to-speed-up-setting-of-data-tariffloor/articleshow/78882965.cms Bureau, F. (2018, May 21). Financial Express. Retrieved from Financial Express Read to Lead: https://www.financialexpress.com/opinion/modi-governments-six-pointaction-plan
- News Service, I.-A. (2020, January 30). Gadgetsndtv. Retrieved from Gadget 360: https://gadgets.ndtv.com/mobiles/news/over-500-million-indians-now-usesmartphones-77-percent-of-who-are-online-techarc-2172219
- Deshwal, Dr. Parul International Journal of Advanced Research in IT and Engineering. ISSN: 2278-6244, Impact Factor: 5.418
- Achieng, B. M., & Ingari, B. K. (2015). Factors influencing the adoption of mobile banking in Kenya's commercial banks: A case of Kenya Commercial Bank (KCB) Kilindini branch. International Journal of Scientific and Research Publications, 5(10), 1-14. http://www.ijsrp.org/research-paper1015.php?rp=P464742
- https://www.researchgate.net/publication/363007742_The_Impact_of_Mobile_Banking_Service_on_Customer_Satisfaction_A_Case_Study_of_Commercial_Banks_in_China/link/6309
- 2021International Journal of Management Practice 12(1):1263-1271 DOI:10.34218/IJM.12.1.2021.111

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

INDIA IN THE LANDSCAPE OF CLIMATE FINANCE: PROSPECTS AND CHALLENGES

Dr. Chanchal Gupta
Assistant Professor, Dyal Singh College Karnal (Chanchal160511@gmail.com)

Dr Komal Gupta
Assistant Professor, Dyal Singh College Karnal (Komalk2k85@gmail.com)

Abstract:
As one of the world 's most populous and rapidly developing countries, India occupies a crucial position in the global landscape of climate finance. This paper provides an overview of the prospects and challenges facing India in accessing and mobilizing climate finance to support its efforts towards mitigating and adapting to climate change. Drawing on existing literature and empirical evidence, the paper examines India's current status in climate finance, including its contributions to international climate funds and domestic efforts to mobilize finance for climate-related projects. The analysis highlights the opportunities presented by India's ambitious renewable energy targets, growing green bond market, and innovative financing mechanisms. However, it also identifies several challenges, including limited access to international climate funds, financing gaps for adaptation projects, and the need for stronger policy frameworks to attract private investment in climate-resilient infrastructure. The paper concludes by discussing policy recommendations and potential pathways for India to enhance its position in the landscape of climate finance, emphasizing the importance of domestic reforms, international cooperation, and innovative financing approaches to accelerate climate action and sustainable development.

Key Words: Climate Change, Climate Finance, Green Climate Fund.

Introduction:

India stands at a critical juncture in the global fight against climate change, balancing the imperatives of economic growth with the urgent need for environmental sustainability. As one of the world's largest and fastest-growing economies, India's trajectory has significant implications for global efforts to mitigate greenhouse gas emissions and build climate resilience. Central to this endeavor is the mobilization of finance to support the transition to a low-carbon, climate-resilient economy.This paper explores the landscape of climate finance in India, examining the opportunities and challenges that shape the country's ability to access and deploy financial resources for climate action. With a population exceeding 1.3 billion and a rapidly expanding economy, India faces unique circumstances in addressing climate change. On one hand, the country is highly vulnerable to the impacts of climate change, including extreme weather events, water scarcity, and agricultural disruptions. On the other hand, India's development aspirations necessitate substantial investments in infrastructure, energy, and industrial development, presenting opportunities to pursue low-carbon pathways and integrate climate considerations into economic planning.The introduction provides an overview of the context and significance of climate finance in India, setting the stage for a detailed examination of the prospects and challenges that lie ahead.

The objectives of the paper, which include:

1. Assessing India's current position in the global climate finance landscape, including its contributions to international climate funds and domestic financing mechanisms.
2. Identifying key opportunities for India to leverage climate finance to achieve its national climate goals and sustainable development objectives.
3. Analyzing the barriers and constraints that impede India's access to climate finance and hinder the implementation of climate-related projects.

Principal
Dyal Singh College
KARNAL

4. Exploring policy options and recommendations to enhance India's capacity to mobilize and utilize climate finance effectively, in alignment with its national priorities and international commitments.

Research Methodology :

The present paper is based on the secondary data obtained from various repositories like Pub Med, EMBASE, SCOPUS, and the Google scholar. The search was performed by typing various variables like IPCC, global warming, economics of climate change, climate finance and green technology. Though a number of searched were made, we included only few suitable studies. All included research publications were systematically evaluated and conclusions were drawn accordingly. Information was also obtained from press releases and other web sites and articles addressing environmental issues.

By examining India's experiences, challenges, and opportunities in the realm of climate finance, this paper aims to contribute to the broader discourse on financing climate action and advancing global efforts towards a sustainable and resilient future.

Climate finance in India comes through the following agencies-

Union Budgetary support
State Budgetary support
The National Adaptation Fund
The National Clean Energy Fund.
The compensatory Afforestation Fund
Mitigation part of the National Disaster Response Fund.
The National Action Plan on Climate Change is a comprehensive response of India to the Menace of Climate change.
The National Mission for Enhanced Energy Efficiency under the NAPCC gives practical Financial mechanisms through its programmes like-
PAT- Perform, Achieve and Trade.
MTEE - Market Transformation for Energy Efficiency.
EEFP - Energy Efficiency Financing Platform.
FEEED- Framework for Energy Efficient Economic Development.
External Support by Global Environment Facility, Adaptation fund, Global Climate fund Etc

Data on India's Position in Climate Finance:

The National Adaptation Fund for Climate Change (NAFCC) was established in August, 2015 to meet the cost of adaptation to climate change for the State and Union Territories of India that are particularly vulnerable to the adverse effects of climate change.

In May, the Reserve Bank of India said the country should seek to deploy green financing equaling at least 2.5% of gross domestic product each year until 2030. It will need new investments in the range of $7.2 trillion to $12.1 trillion by 2050, the central bank noted in a report 22 Aug 2023.

Contributions to International Climate Funds:

Green Climate Fund (GCF): India's contributions to the GCF are significant, reflecting its commitment to global climate finance initiatives. As of [latest available data], India has pledged [amount] to the GCF, supporting projects aimed at climate mitigation, adaptation, and resilience building.

Climate Finance Tracking: Data from [relevant sources] track India's disbursements to international climate funds, providing insights into the allocation of funds across sectors and projects. Analysis of India's contributions to the GCF can be disaggregated to assess the proportion allocated to adaptation projects versus mitigation projects, highlighting priority areas for climate finance in the country.

Domestic Financing Mechanisms:

Government Schemes: India has implemented various government schemes a estic finance for climate-related projects. Data from [official sources] document and

Principal
Dyal Singh College
KARNAL

disbursements for initiatives such as the National Action Plan on Climate Change (NAPCC), the National Clean Energy Fund (NCEF), and the Green India Mission (GIM).

Private Investment:[Data sources] track private investment flows into renewable energy and clean technology sectors in India, providing insights into the scale and trends of private financing for climate-resilient infrastructure.

Analysis of investment patterns and trends can shed light on the effectiveness of policy incentives and regulatory frameworks in attracting private capital to climate-related projects.

Opportunities for Climate Finance in India:

Renewable Energy Transition:

Installed Capacity: Data from [reliable sources] provide information on India's current installed capacity for renewable energy, including solar, wind, hydro, and bio energy. Trends in capacity additions and investments can be analyzed to assess progress towards India's renewable energy targets and identify areas for further investment and development.

Policy Support:[Data sources] document policy measures such as feed-in tariffs, tax incentives, and renewable purchase obligations, which support renewable energy deployment in India.

Analysis of policy effectiveness and investment trends can inform future policy decisions and strategies for accelerating the transition to a low-carbon economy.

Green Bonds and Sustainable Investments:

Green Bond Issuance: Data from [relevant platforms] track the issuance of green bonds by Indian corporates, financial institutions, and government entities.

Analysis of green bond proceeds and allocation to climate-related projects can assess the impact of green finance instruments in mobilizing capital for sustainable development.

Investment Opportunities:[Market data] provide insights into investment opportunities in green infrastructure, sustainable agriculture, energy efficiency, and climate-resilient projects in India.

Analysis of investment trends and market dynamics can inform investment strategies and decision-making processes for stakeholders in the climate finance ecosystem.

Challenges and Constraints:

Access to International Climate Funds:

Application Procedures: Data on [application processes] and timelines for accessing international climate funds can highlight procedural challenges faced by Indian stakeholders.

Analysis of application success rates and approval timelines can identify bottlenecks and opportunities for streamlining the funding process.

Capacity Building:[Data sources] track capacity-building efforts aimed at enhancing India's readiness to access and utilize international climate finance.

Assessment of capacity-building initiatives can inform strategies for strengthening institutional capacities and project readiness in the country.

Financing Gaps for Adaptation:

Sectoral Analysis: Data on [financing gaps] for climate adaptation in key sectors such as agriculture, water management, and coastal resilience provide insights into priority areas for investment.

Analysis of financing needs versus available resources can inform resource allocation and policy interventions to address adaptation challenges

Innovative Financing Mechanisms:[Data sources] document innovative financing mechanisms such as climate resilience bonds, insurance schemes, and public-private partnerships in India.

Assessment of the effectiveness and scalability of these mechanisms can inform strategies for bridging financing gaps and enhancing resilience to climate impacts.

Policy Recommendations:

Principal
Dyal Singh College
KARNAL

Strengthening Policy Frameworks:

Policy Evaluation: Data on policy impacts and outcomes provide evidence for evaluating the effectiveness of existing policy frameworks in attracting climate finance and driving sustainable development.

Analysis of policy gaps and barriers can inform recommendations for policy reform and enhancement to create an enabling environment for climate finance in India.

Regulatory Incentives:[Data sources] track regulatory incentives such as tax breaks, subsidies, and preferential tariffs for climate-related investments in India.

Assessment of the impact of regulatory incentives on investment flows and project outcomes can inform policy decisions on incentivizing climate-resilient infrastructure and clean technology development.

Enhancing International Cooperation:

Partnership Data: Data on international partnerships, collaborations, and funding initiatives involving India provide insights into the scope and impact of international cooperation in climate finance.

Analysis of partnership dynamics and outcomes can inform strategies for strengthening international cooperation and leveraging external resources for climate action in India.

Knowledge Sharing:[Data sources] document knowledge-sharing initiatives, capacity-building programs, and best practice exchanges related to climate finance in India.

Assessment of knowledge-sharing efforts can identify lessons learned, success stories, and areas for improvement in international cooperation for climate finance.

Conclusion:

The synthesis of data on India's position in climate finance underscores the multifaceted nature of the country's climate finance landscape, characterized by diverse opportunities, challenges, and policy imperatives. By leveraging available data and insights, policymakers, researchers, and practitioners can develop informed strategies and interventions to accelerate progress towards a sustainable and resilient future in India.

References

1. https://www.context.news/net-zero/how-will-india-find-the-climate-finance-it-needs-to-go-green.
2. Das, S., Ghosh, A., Hazra, S., Ghosh, T., de Campos, R. S., & Samanta, S. (2020). Linking IPCC
3. AR4 & AR5 frameworks for assessing vulnerability and risk to climate change in the Indian
4. Bengal Delta. Progress in Disaster Science, 7, 100110.
5. Khan, M., Robinson, S. A., Weikmans, R., Ciplet, D., & Roberts, J. T. (2020). Twenty-five years
6. of adaptation finance through a climate justice lens. Climatic Change, 161(2), 251-269.
7. Kriegler, E., Bertram, C., Kuramochi, T., Jakob, M., Pehl, M., Stevanović, M., & Edenhofer, O.
8. (2018). Short term policies to keep the door open for Paris climate goals. Environmental
9. Research Letters, 13(7), 074022.
10. Majid, M. A. (2020). Renewable energy for sustainable development in India: current status, future
11. prospects, challenges, employment, and investment opportunities. Energy, Sustainability
12. and Society, 10(1), 1-36.
13. Nithin Thomas, P. (2021). Economic Survey 2021: India Needs $206 Billion Between 2015-2030 https://mercomindia.com/economic-survey-2021-india.
14. Raptis, C. E., Oberschelp, C., & Pfister, S. (2020). The greenhouse gas emissions, water
15. consumption, and heat emissions of global steam-electric power production: a generating
16. unit level analysis and database. Environmental Research Letters, 15(10), 104029.
17. Reddy, P.B. (2015). Intergovernmental Panel on Climate Change: The Big Global Scam. Research

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

INDIA IN THE LANDSCAPE OF CLIMATE FINANCE: PROSPECTS AND CHALLENGES

Dr. Chanchal Gupta
Assistant Professor, Dyal Singh College Karnal (Chanchal160511@gmail.com)

Dr Komal Gupta
Assistant Professor, Dyal Singh College Karnal (Komalk2k85@gmail.com)

Abstract:
As one of the world 's most populous and rapidly developing countries, India occupies a crucial position in the global landscape of climate finance. This paper provides an overview of the prospects and challenges facing India in accessing and mobilizing climate finance to support its efforts towards mitigating and adapting to climate change. Drawing on existing literature and empirical evidence, the paper examines India's current status in climate finance, including its contributions to international climate funds and domestic efforts to mobilize finance for climate-related projects. The analysis highlights the opportunities presented by India's ambitious renewable energy targets, growing green bond market, and innovative financing mechanisms. However, it also identifies several challenges, including limited access to international climate funds, financing gaps for adaptation projects, and the need for stronger policy frameworks to attract private investment in climate-resilient infrastructure. The paper concludes by discussing policy recommendations and potential pathways for India to enhance its position in the landscape of climate finance, emphasizing the importance of domestic reforms, international cooperation, and innovative financing approaches to accelerate climate action and sustainable development.

Key Words: Climate Change, Climate Finance, Green Climate Fund.

Introduction:

India stands at a critical juncture in the global fight against climate change, balancing the imperatives of economic growth with the urgent need for environmental sustainability. As one of the world's largest and fastest-growing economies, India's trajectory has significant implications for global efforts to mitigate greenhouse gas emissions and build climate resilience. Central to this endeavor is the mobilization of finance to support the transition to a low-carbon, climate-resilient economy.This paper explores the landscape of climate finance in India, examining the opportunities and challenges that shape the country's ability to access and deploy financial resources for climate action. With a population exceeding 1.3 billion and a rapidly expanding economy, India faces unique circumstances in addressing climate change. On one hand, the country is highly vulnerable to the impacts of climate change, including extreme weather events, water scarcity, and agricultural disruptions. On the other hand, India's development aspirations necessitate substantial investments in infrastructure, energy, and industrial development, presenting opportunities to pursue low-carbon pathways and integrate climate considerations into economic planning.The introduction provides an overview of the context and significance of climate finance in India, setting the stage for a detailed examination of the prospects and challenges that lie ahead.

The objectives of the paper, which include:

1. Assessing India's current position in the global climate finance landscape, including its contributions to international climate funds and domestic financing mechanisms.
2. Identifying key opportunities for India to leverage climate finance to achieve its national climate goals and sustainable development objectives.
3. Analyzing the barriers and constraints that impede India's access to climate finance and hinder the implementation of climate-related projects.

Principal
Dyal Singh College
KARNAL

4. Exploring policy options and recommendations to enhance India's capacity to mobilize and utilize climate finance effectively, in alignment with its national priorities and international commitments.

Research Methodology :

The present paper is based on the secondary data obtained from various repositories like Pub Med, EMBASE, SCOPUS, and the Google scholar. The search was performed by typing various variables like IPCC, global warming, economics of climate change, climate finance and green technology. Though a number of searched were made, we included only few suitable studies. All included research publications were systematically evaluated and conclusions were drawn accordingly. Information was also obtained from press releases and other web sites and articles addressing environmental issues.

By examining India's experiences, challenges, and opportunities in the realm of climate finance, this paper aims to contribute to the broader discourse on financing climate action and advancing global efforts towards a sustainable and resilient future.

Climate finance in India comes through the following agencies-

Union Budgetary support
State Budgetary support
The National Adaptation Fund
The National Clean Energy Fund.
The compensatory Afforestation Fund
Mitigation part of the National Disaster Response Fund.
The National Action Plan on Climate Change is a comprehensive response of India to the Menace of Climate change.
The National Mission for Enhanced Energy Efficiency under the NAPCC gives practical Financial mechanisms through its programmes like-
PAT- Perform, Achieve and Trade.
MTEE - Market Transformation for Energy Efficiency.
EEFP - Energy Efficiency Financing Platform.
FEEED- Framework for Energy Efficient Economic Development.
External Support by Global Environment Facility, Adaptation fund, Global Climate fund
Etc

Data on India's Position in Climate Finance:

The National Adaptation Fund for Climate Change (NAFCC) was established in August, 2015 to meet the cost of adaptation to climate change for the State and Union Territories of India that are particularly vulnerable to the adverse effects of climate change.

In May, the Reserve Bank of India said the country should seek to deploy green financing equaling at least 2.5% of gross domestic product each year until 2030. It will need new investments in the range of $7.2 trillion to $12.1 trillion by 2050, the central bank noted in a report 22 Aug 2023.

Contributions to International Climate Funds:

Green Climate Fund (GCF): India's contributions to the GCF are significant, reflecting its commitment to global climate finance initiatives. As of [latest available data], India has pledged [amount] to the GCF, supporting projects aimed at climate mitigation, adaptation, and resilience building.

Climate Finance Tracking: Data from [relevant sources] track India's disbursements to international climate funds, providing insights into the allocation of funds across sectors and projects. Analysis of India's contributions to the GCF can be disaggregated to assess the proportion allocated to adaptation projects versus mitigation projects, highlighting priority areas for climate finance in the country.

Domestic Financing Mechanisms:

Government Schemes: India has implemented various government schemes aimed at mobilizing domestic finance for climate-related projects. Data from [official sources] document the budget allocations and

Principal
Dyal Singh College
KARNAL

disbursements for initiatives such as the National Action Plan on Climate Change (NAPCC), the National Clean Energy Fund (NCEF), and the Green India Mission (GIM).

Private Investment:[Data sources] track private investment flows into renewable energy and clean technology sectors in India, providing insights into the scale and trends of private financing for climate-resilient infrastructure.

Analysis of investment patterns and trends can shed light on the effectiveness of policy incentives and regulatory frameworks in attracting private capital to climate-related projects.

Opportunities for Climate Finance in India:

Renewable Energy Transition:

Installed Capacity: Data from [reliable sources] provide information on India's current installed capacity for renewable energy, including solar, wind, hydro, and bio energy. Trends in capacity additions and investments can be analyzed to assess progress towards India's renewable energy targets and identify areas for further investment and development.

Policy Support:[Data sources] document policy measures such as feed-in tariffs, tax incentives, and renewable purchase obligations, which support renewable energy deployment in India.

Analysis of policy effectiveness and investment trends can inform future policy decisions and strategies for accelerating the transition to a low-carbon economy.

Green Bonds and Sustainable Investments:

Green Bond Issuance: Data from [relevant platforms] track the issuance of green bonds by Indian corporates, financial institutions, and government entities.

Analysis of green bond proceeds and allocation to climate-related projects can assess the impact of green finance instruments in mobilizing capital for sustainable development.

Investment Opportunities:[Market data] provide insights into investment opportunities in green infrastructure, sustainable agriculture, energy efficiency, and climate-resilient projects in India.

Analysis of investment trends and market dynamics can inform investment strategies and decision-making processes for stakeholders in the climate finance ecosystem.

Challenges and Constraints:

Access to International Climate Funds:

Application Procedures: Data on [application processes] and timelines for accessing international climate funds can highlight procedural challenges faced by Indian stakeholders.

Analysis of application success rates and approval timelines can identify bottlenecks and opportunities for streamlining the funding process.

Capacity Building:[Data sources] track capacity-building efforts aimed at enhancing India's readiness to access and utilize international climate finance.

Assessment of capacity-building initiatives can inform strategies for strengthening institutional capacities and project readiness in the country.

Financing Gaps for Adaptation:

Sectoral Analysis: Data on [financing gaps] for climate adaptation in key sectors such as agriculture, water management, and coastal resilience provide insights into priority areas for investment.

Analysis of financing needs versus available resources can inform resource allocation and policy interventions to address adaptation challenges

Innovative Financing Mechanisms:[Data sources] document innovative financing mechanisms such as climate resilience bonds, insurance schemes, and public-private partnerships in India.

Assessment of the effectiveness and scalability of these mechanisms can inform strategies for bridging financing gaps and enhancing resilience to climate impacts.

Policy Recommendations:

Principal
Dyal Singh College
KARNAL

Strengthening Policy Frameworks:

Policy Evaluation: Data on policy impacts and outcomes provide evidence for evaluating the effectiveness of existing policy frameworks in attracting climate finance and driving sustainable development.

Analysis of policy gaps and barriers can inform recommendations for policy reform and enhancement to create an enabling environment for climate finance in India.

Regulatory Incentives:[Data sources] track regulatory incentives such as tax breaks, subsidies, and preferential tariffs for climate-related investments in India.

Assessment of the impact of regulatory incentives on investment flows and project outcomes can inform policy decisions on incentivizing climate-resilient infrastructure and clean technology development.

Enhancing International Cooperation:

Partnership Data: Data on international partnerships, collaborations, and funding initiatives involving India provide insights into the scope and impact of international cooperation in climate finance.

Analysis of partnership dynamics and outcomes can inform strategies for strengthening international cooperation and leveraging external resources for climate action in India.

Knowledge Sharing:[Data sources] document knowledge-sharing initiatives, capacity-building programs, and best practice exchanges related to climate finance in India.

Assessment of knowledge-sharing efforts can identify lessons learned, success stories, and areas for improvement in international cooperation for climate finance.

Conclusion:

The synthesis of data on India's position in climate finance underscores the multifaceted nature of the country's climate finance landscape, characterized by diverse opportunities, challenges, and policy imperatives. By leveraging available data and insights, policymakers, researchers, and practitioners can develop informed strategies and interventions to accelerate progress towards a sustainable and resilient future in India.

References

1. https://www.context.news/net-zero/how-will-india-find-the-climate-finance-it-needs-to-go-green.
2. Das, S., Ghosh, A., Hazra, S., Ghosh, T., de Campos, R. S., & Samanta, S. (2020). Linking IPCC
3. AR4 & AR5 frameworks for assessing vulnerability and risk to climate change in the Indian
4. Bengal Delta. Progress in Disaster Science, 7, 100110.
5. Khan, M., Robinson, S. A., Weikmans, R., Ciplet, D., & Roberts, J. T. (2020). Twenty-five years
6. of adaptation finance through a climate justice lens. Climatic Change, 161(2), 251-269.
7. Kriegler, E., Bertram, C., Kuramochi, T., Jakob, M., Pehl, M., Stevanović, M., & Edenhofer, O.
8. (2018). Short term policies to keep the door open for Paris climate goals. Environmental
9. Research Letters, 13(7), 074022.
10. Majid, M. A. (2020). Renewable energy for sustainable development in India: current status, future
11. prospects, challenges, employment, and investment opportunities. Energy, Sustainability
12. and Society, 10(1), 1-36.
13. Nithin Thomas, P. (2021). Economic Survey 2021: India Needs $206 Billion Between 2015-2030 https://mercomindia.com/economic-survey-2021-india.
14. Raptis, C. E., Oberschelp, C., & Pfister, S. (2020). The greenhouse gas emissions, water
15. consumption, and heat emissions of global steam-electric power production: a generating
16. unit level analysis and database. Environmental Research Letters, 15(10), 104029.
17. Reddy, P.B. (2015). Intergovernmental Panel on Climate Change: The Big Global Scam. Research

Principal
Dyal Singh College
KARNAL

IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Customer Satisfaction Towards Mobile Banking

Author

Dr. Komal Gupta

Assistant Professor

Dyal Singh College, Karnal

Co-Author

Dr. Chanchal Gupta

Assistant Professor

Dyal Singh College, Karnal

Abstract

Mobile banking is a service provided by a bank or other financial institution that allows its customers to conduct financial transactions using a mobile device such as a smartphone or tablet. Unlike the related internet banking it uses software, usually called an app, provided by the financial institution for the purpose. Mobile banking is usually available on a 24-hour basis. Mobile banking is dependent on the availability of an internet or data connection to the mobile device. Transactions through mobile banking depend on the features of the mobile banking app provided and typically includes obtaining account balances and lists of latest transactions, electronic bill payments, remote check deposits, P2P payments, and funds transfers between a customer's or another's accounts. Some apps also enable copies of statements to be downloaded and sometimes printed at the customer's premises. Using a mobile banking app increases ease of use, speed, flexibility and also improves security because it integrates with the user built-in mobile device security mechanisms. From the bank's point of view, mobile banking reduces the cost of handling transactions by reducing the need for customers to visit a bank branch for non-cash withdrawal and deposit transactions. Mobile banking does not handle transactions involving cash, and a customer needs to visit an ATM or bank branch for cash withdrawals or deposits. My study is related to identify the satisfaction level of the bank customers about mobile banking services. Other Objectives of my study to examine the factors affecting the use of mobile banking services with bank customers, to identify the facilities provided by Mobile Banking Services, to study the benefits and limitations of Mobile banking Services, to know the future prospects of mobile banking in India, to suggest different ways to improve the functioning of Mobile Banking facilities and offer new busine s. The main tool used for primary data collection is the questionnaire. We use different journ ld newspaper for collecting secondary data.

Principal
Dyal Singh College
KARNAL

Keywords: Mobile banking, Internet banking, Customer satisfaction

Introduction

Mobile Banking is a technique to carry out banking transactions on the mobile phone through a data service-provider. Banks need to provide services to their customers whenever they require it and wherever they are required. So Mobile banking is one of the major significant tool through which the customers can their business transactions and their office functions to indirect passage. Mobile banking saves our time and this saved time can be effectively and efficiently utilized for business development and cost reduction. Cellular phones have achieved so much prominence in the present-day scenario that a person cannot survive without this communication channel. Once upon a time, a mobile phone was an expensive thing and only for rich, but now it is an important necessity. In every state the number of customers using cell phones has increased to unexpected ratio. At least 90% of these customers have bank accounts in several banks which use of mobile banking facilities. Therefore, banks are providing mobile banking services to their customers. Customers are also taking full advantage of these facilities.

Facilities available on Mobile Banking:

- Balance Enquiry: This facility provides all customers, the available balance in his or her account that are connected to the customer identification number. The maximum number of accounts one can avail is five and not more than that.
- Cost Transactions: This kind of transaction provides the customer with the information about the previous five debits or credits done to the account.
- Cheque Book Request: This is an alternate for going personally to the bank, the consumer can request for a cheque book to be mailed to his or her address as per the records of the bank. This saves his or her precious time.
- Bill Payment: For those organizations which register with the bank for this particular facility, the payment is made on request on mobile phone banking.
- Change of Primary Account: The customer has the choice to change their already existing account to another new account number for carrying out further transactions.
- Help: Customers can know the transaction codes for several kinds of transactions through this alternative. Mobile phone bank-users will be notified about external clearing cheque realizations, internal cheque returns, notification on term deposits matured, on loan installment due

Principal
Dyal Singh College
KARNAL

Ancillary service to mobile banking by banks:

- Top-up mobile talk time by refilling through the ATM system.
- Refill the prepaid mobile phone through the ATM or SMS.
- Have distinct memorandum of undertaking with other telecom organization and sell this product to earn commission.

Mobile banking services

- Mini-statements and checking of account history.
- Alerts on account activity or passing of set thresholds.
- Monitoring of term deposits.
- Access to loan statements.
- Access to card statements.
- Mutual funds / equity statements.
- Insurance policy management.
- Accessing the bank 24/7. ...
- Making it easier to save. ...
- Paying IOUs. ...
- Strengthening security. ...
- Offering clarity about where your financial data is going. ...
- Tracking expenses. ...
- Giving you tailored options.

Indian Mobile Payment Market leaders

1. PAYTM PAYMENTS BANK LIMITED
2. PhonePe
3. Alphabet Inc. (Google Pay.)
4. Amazon Payments, Inc. (Amazon Pay)
5. ICICI Bank Limited (ICICI Pockets)

Principal
Dyal Singh College
KARNAL

Devices Used for online banking

Mobile	59%
Laptop	32%
Tablet	9%

Sources: GlobalWebIndex Q4 2019 Base 1,08000 Internet users ages 16-64

This data showed that number of mobile device users is more than laptop and tablets.As discussed above due to various benefits of mobile banking services more and more people use this facility. The above data shows that in today's time 59% respondents use Mobile Banking.

Objectives:

1. To identify the satisfaction level of the bank customers about mobile banking services.
2. To examine the factors affecting the use of mobile banking services with bank customers.
3. To study the benefits and limitations of Mobile banking Services.
4. To know the future prospects of mobile banking in India.
5. To suggest different ways to improve the functioning of Mobile Banking facilities and offer new business opportunities.

Data Collection Method:

Here we use both secondary as well as primary data collection methods. Through various articles, journal and newspapers we get data about the mobile banking services, Major mobile payment Indian players. We get data about more and more people use mobile device to their online transactions . But we get data about the customer satisfaction towards mobile banking, their dissatisfactory factors ,their suggestions for improvement services through questionnaire. Here we get data from the sample of age group above 20 onwards of different occupations.

Principal
Dyal Singh College
KARNAL

Findings :

- From the total respondents there are 57.7% Female and 42.3 Male.
- All have bank Accounts and all banks are providing mobile banking services.
- Out of these 42.3% having account in public sector banks and 57.7% having account in private sector banks.
- Out of total respondents 88.5% use mobile banking services and 11.5% does not use.
- Factors that motivated to operate the account through Mobile banking services.

1. Through advertising- 16.7%
2. Friends and relatives- 4.2%
3. Self-motivated -70.8%
4. Others-8.3%

This data shows people's awareness about the mobile banking benefits that mostly people are self-motivated and are using mobile banking. The second source of awareness for Mobile Banking is Newspapers/ Magazines/ Other Printed Ads. Family / Friends/ Colleagues who are the users of Mobile Banking with 4.2%.

- Customers opinion regarding Mobile banking services

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Mobile Banking is Time saving	66.7%	29.2%	4.1%		
Mobile Banking is Cost saving	41.7%	54.2%	4.1%		
Mobile Banking is Flexible or Convenient	37.5%	54.2%	8.3%		
Mobile Banking is Easy to use	37.5%	54.2%	4.2%	4.1%	
Mobile Banking is Secure	37.5%	54.2%	8.3%		
The System, Network etc. for Mobile Banking is easily available	29.2%	50%	20.8%		

Principal
Dyal Singh College
KARNAL

Mobile Banking has better Problem Hand ling capability	25%	41.7%	25%	4.2%	4.1%
Mobile Banking have full filled my expec tation	29.2%	50%	16.7%	4.1%	

Source: questionnaire

This data shows that easy access at any time anywhere is the biggest reason for adopting Mobile Banking out of respondents 54.2% adopts M- Banking due to this reason only. 29.2% adopt it because it saves time. 41.7% using it because Mobile for banking makes banking hassle free and effortless. 54.2% says it involves lower cost as compared to the traditional or older modes of Banking. Here 4.1% people do not agree that mobile banking has better problem handling capacity.

- **Overall satisfaction level**

	Highly Satisfied	Satisfied	Neutral	Dissatisfied	Highly Dissatisfied
Number of overall satisfied	23.1	65.4	3.8	7.6	

This data shows the overall customer satisfaction level. Most of the people are fully satisfied from mobile banking services. Highest 65.4% out of all show satisfaction ratio only 7.6% ratio show dissatisfaction level.

- **Reasons behind your dissatisfaction**

1. Services are not Enough-33.3%
2. High Cost-0%
3. Error in Network-50%
4. Low Safety-25%
5. Difficult to understand-16.7%
6. Not Reliable in providing services-0%

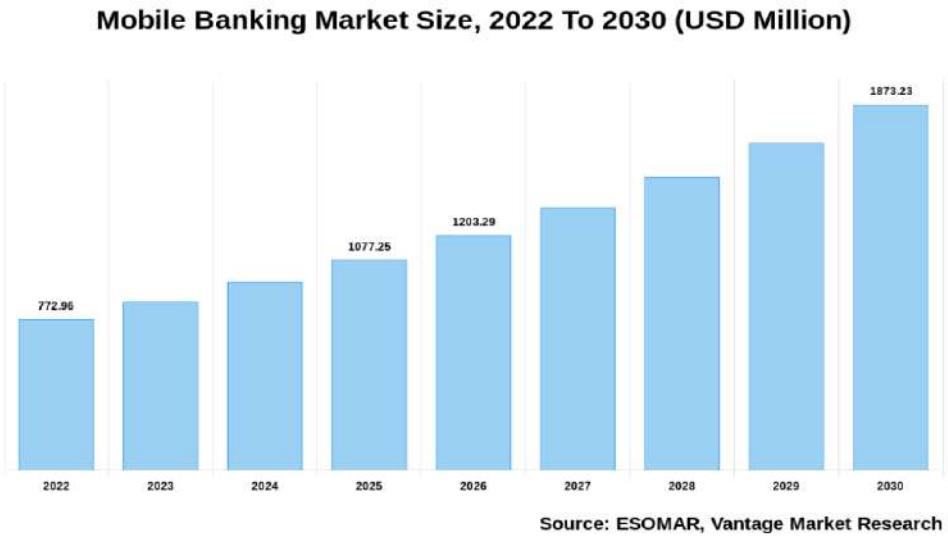
Today respondents are dissatisfied from mobile banking services because many times network issues arise in mobile banking and banking services are also not sufficient. Therefore, they are dissatisfied with the mobile banking services.

Principal
Dyal Singh College
KARNAL

Suggestions for further improvement of mobile banking services

- Network connectivity should be improved especially in rural areas and cyber security with more advancement.
- Banks should update their server time to time
- In my view they should expand the credit reporting systems as it will enhance the efficiency of payment system and improve the issue related to leakage of personal data .
- Overall Good initiative
- fast process
- Only network problem some time faced.
- Sometimes there is a server error.... please find some way out
- Make it more user friendly

Future Trend:



This graph shows that as per the data of 2022 to 2030 the size of mobile banking will keep increasing in the future and people will use it a lot due to te benefits of mobile banking services.

Principal
Dyal Singh College
KARNAL

Safety Tips

Even with the best Mobile Banking App, customers should take adequate measures to enhance the safety of their digital transactions. Here are some tips to make your experience safer-

- Avoid using a Mobile Banking App on public networks as they're not secure
- Keep the smartphone protected with a PIN, fingerprint, or facial recognition
- Never leave your phone unattended
- Avoid storing confidential data like Mobile Banking passwords, Debit Card PINs, etc., on your smartphone

References:

- Bureau, E. (2020, October 27). economictimes.indiatimes. Retrieved from The Economic Times: https://economictimes.indiatimes.com/industry/telecom/telecomnews/telcos-urge-trai-to-speed-up-setting-of-data-tariffloor/articleshow/78882965.cms Bureau, F. (2018, May 21). Financial Express. Retrieved from Financial Express Read to Lead: https://www.financialexpress.com/opinion/modi-governments-six-pointaction-plan
- News Service, I.-A. (2020, January 30). Gadgetsndtv. Retrieved from Gadget 360: https://gadgets.ndtv.com/mobiles/news/over-500-million-indians-now-usesmartphones-77-percent-of-who-are-online-techarc-2172219
- Deshwal, Dr. Parul International Journal of Advanced Research in IT and Engineering. ISSN: 2278-6244, Impact Factor: 5.418
- Achieng, B. M., & Ingari, B. K. (2015). Factors influencing the adoption of mobile banking in Kenya's commercial banks: A case of Kenya Commercial Bank (KCB) Kilindini branch. International Journal of Scientific and Research Publications, 5(10), 1-14. http://www.ijsrp.org/research-paper1015.php?rp=P464742
- https://www.researchgate.net/publication/363007742_The_Impact_of_Mobile_Banking_Service_on_Customer_Satisfaction_A_Case_Study_of_Commercial_Banks_in_China/link/6309
- 2021International Journal of Management Practice 12(1):1263-1271 DOI:10.34218/IJM.12.1.2021.111

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

प्रेम और सौंदर्य के कवि जयशंकर प्रसाद

डॉ. यशवन्ती देवी
असिस्टेंट प्रोफ़ेसर, दयाल सिंह कॉलेज, करनाल

आधुनिक हिंदी साहित्य जब अपने लड़कपन को छोड़कर युवा हो रहा था ऐसे समय में जयशंकर प्रसाद का जन्म सन् 1890 में काशी में हुआ। आर्थिक संपन्नता के वातावरण में पालन-पोषण होने के बावजूद भी जयशंकर प्रसाद के जीवन में विषाद और करुण भावनाओं का आना तब तय होता है, जब महज 12 साल की आयु में उनके सिर से उनके पिता का साया उठ जाता है। इसके बाद तो उनके जीवन में दुःखों यह सिलसिला चलता ही रहता है क्योंकि कुछ ही साल बाद इनकी माता की भी मृत्यु हो जाती है। काशी के समृद्ध सुंघनी साहू परिवार में जन्म लेने के बाद भी प्रसाद जी घोर आर्थिक संकट के तूफ़ानों में पड़ जाते हैं। ऐसा माना जाता है कि उनकी कविताएँ व्यथा की बेटी है। मात्र 9 साल की अवस्था से ही लेखन में लीन रहते हुए जयशंकर प्रसाद ने अपनी जीवन-पीड़ा का सहारा लेकर प्रेम और सौंदर्य से युक्त काव्य लिखे। हालांकि, प्रसाद के परिवार को उनका लिखना क़तई पसंद नहीं आता था इसलिए जयशंकर प्रसाद जी कलाधर हो जाते हैं और इसी नाम से उनका लेखन आगे भी जारी रहता है। उनके जीवन की दुःख और पीड़ा की कहानी अभी ख़त्म नहीं होती कि उनके बड़े भाई का भी असमय निधन हो जाता है। इसके बाद जयशंकर प्रसाद को बड़ा धक्का लगता है और वे संन्यास की ओर प्रेरित हो जाते हैं। लेकिन यह कहा जाता है कि अपनी विधवा भाभी के निवेदन पर वे सांसारिक जीवन में एक बार फिर वापिस लौट आते हैं। हालांकि, उनका यह लौटना संपूर्ण नहीं हो पाता। क्योंकि प्रसाद का साहित्य और उनका शेष जीवन तो यही दुहाई देता दिखाई देता है कि वे केवल शरीर से ही वापिस आए हैं। उनका मन तो कहीं न कहीं विरही ही हो गया थाः-

"अधरों में राग अमंद पिये,
अलकों में मलयज बंद किये।
तू अब तक सोई है आली,
आँखों में भरे विहाग री।"

"खग-कुल कुल-कुल सा बोल रहा,
किसलय का अंचल डोल रहा।
लो यह लतिका भी भर लाई,
मधु मुकुल नवल रस गागरी।"

"बीती विभावरी जाग री!
अम्बर पनघट में डुबो रही,
तारा घट ऊषा नागरी।"

Principal
Dyal Singh College
KARNAL

जयशंकर प्रसाद जी की आयु 48 वर्ष की रही। इतनी छोटी सी उम्र में वे कविता, कहानी, नाटक और उपन्यास आदि सभी क्षेत्रों में एक नये जीवन-दर्शन की स्थापना करने में पूर्णतः सफल हुये थे। वे 'छायावाद' के आधारस्तंभों में से एक हैं। कविता के क्षेत्र में सबसे पहले नयी-अनुभूति के वाहक यही रहे तथा सबसे पहले विरोध भी इन्हीं को सहन करना पड़ा। भाषा के संबंध में जितना संघर्ष प्रसाद जी को करना पड़ा, उतना संघर्ष दूसरे साहित्यकारों को नहीं करना पड़ा। बनारस के प्रसिद्ध सुंघनी साहु घराने में जन्म लेने के बाद भी उनका पूरा परिवार अपनी व्यावसायिक हैसियत गंवाकर कर्ज के पहाड़ के नीचे दब चुका था। जयशंकर प्रसाद को काव्य लिखने की प्रेरणा अपने परिवार के विद्वानों से मिली। 'आँसू' में पवित्र मानुषी आसक्ति को प्रेम में बदल देने की प्रवृत्ति रखने वाले के स्वर को बहुत ऊँचा कर देती है। 'आँसू' में

प्रेम-भावना के सम्बन्ध में श्री रामनाथ सुमन जी लिखते है- आँसू में कवि के मानव-जीवन का वह सत्य विद्यमान् है, जो जीवन की समस्याओं के बीच दबकर कुंठित नहीं होता बल्कि इनसे रस लेकर पुष्ट एवं जाग्रत होता है। कवि का प्रिय से जो मिलन हुआ था, वह मिलन क्षणिक था, परन्तु उसमें इतना आह्लाद और आकर्षण था कि कवि के लिए वह महामिलन ही था। अतः कवि के हृदय में उस महामिलन के अब कुछ चिह्न ही शेष रह गये हैं-

"ये सब स्फुर्लिंग हैं मेरी,
इस ज्वालामयी जलन के।
कुछ शेष चिह्न हैं केवल,
मेरे उस महामिलन के।"

प्रेम का प्रारम्भ सौंदर्य से ही हुआ है। प्रसाद जी का प्रिय नैसर्गिक सुषमाओं से मंडित है। इसमें 'प्रीति पुरातन लखै न कोई' की भी बात नजर आती है। वह कवि को मिलन के प्रथम पल में ही बहुत पहले का जाना पहचाना सा लगता है तथा प्रिय उसे स्वयं मिलने के लिए आता है, यह प्रेमी के लिए बहुत ही गौरव की बात है। वह उसे उठता देखते ही इठला उठता है और प्रेमी की यह विरह-वेदना बढ़ती जाती है तथा वह आँसू बनकर उसके नेत्रों से बरसने लगती है। यह विरह-वेदना जब चरमोत्कर्ष पर पहुँच जाती है तो जलती हुई विश्व मन्दिर का मणि-दीप बन जाती है:-

"मणिदीप विश्व मन्दिर की,
पहने किरणों की माला ।
तुम एक अकेले तब भी,
जलती हो मेरी ज्वाला ।"

उसकी इस विरह-वेदना का इतना अधिक उदात्तीकरण होता है कि वह उसे समस्त संसार में व्याप्त देखने लगता है। उसे अपने समान ही सारा संसार व्यथित और पीड़ित दिखाई देता है। वह उसे 'व्यथित विश्व पतझड़ की जलती हुई मृदु होली' और 'मानवता के सिर की रोली' कहता हुआ उससे निवेदन करता है कि वह जीवन-सागर में बड़वानल की ज्वाला-सी जलकर संसार का सारा कलुष जला दे:-

"इस व्यथित विश्व पतझड़ की,
तुम जलती हो मृदु होली ।
हे अरुणे ! सदा सुहागिनि,
मानवता सिर की रोली ।।"
"जीवन-सागर में पावन,
बड़वानल की ज्वाला-सी।"

अतः कवि का प्रेम व्यष्टि की सीमा को लाँगकर समष्टि का प्रेम बन जाता है और तब उसकी यह वेदना विश्व की वेदना बन जाती है। अन्त में अपनी प्रेम-वेदना का वह समस्त जड़-चेतन सृष्टि में प्रसार करता हुआ मानवता के लिए विपुल वरदानों की वर्षा करने की चाह करने लगता है:-

"सबका निचोड़ लेकर तुम,
सुख से भूखे जीवन में ।
बरसो प्रभात हिम कण-सा,
आँसू इस विश्व-सदन में ।।"

यह 'आँसू' का आदर्श प्रेम ही है जो लौकिक धरातल से उठ कर विरह-वेदना की ज्वाला में तपकर अलौकिकता के क्षितिज को स्पर्श करता हुआ विश्व-संवेदना में बदल जाता है। उनके प्रेम-निरूपण में आदि से अन्त तक निर्मलता और सात्विकता बनी रहती है और उसका विकास भी अनुभूति की गहरी घाटियों से होकर [illegible] है। इस तरह 'आँसू'

Principal
Dyal Singh College
KARNAL

प्रेम-वेदना का वह अथाह सागर है, जिसमें गोता लगाकर पाठक रस-मग्न हो जाता है, परन्तु फिर भी उसकी थाह नहीं पाता। 'आँसू' में प्रेम-वेदना के सागर में उठी हुई उत्ताल तरंगें पाठकों को सराबोर कर देती हैं। अतः प्रसाद जी छायावाद के प्रतिष्ठापक ही नहीं थे अपितु वे छायावादी ढर्रे पर लयबद्ध गीतों के लिखने वाले सर्वश्रेष्ठ कवि भी थे। उनकी रचनाओं में प्रेम परक मनोभावों का सूक्ष्म निरूपण हुआ है। उनके विचार में प्रेम के वियोग-संयोग दोनो ही पक्ष अपनी पूरी छवि के साथ विद्यमान रहते हैं। 'आँसू' उनका प्रसिद्ध वियोग काव्य है। उसके एक-एक छन्द में विरह की स्वाभाविक पीड़ा पूर्ण रूप से चित्रित हैः -

"जो धनीभूत पीड़ा थी,
मस्तक में स्मृति-सी छायी।
दुर्दिन में आँसू बनकर,
वह आज बरसने आयी।"

प्रसाद जी ने अपने काव्य में विविध छन्दों का प्रयोग करके अपने भावों की सुन्दर अभिव्यक्ति की है। भावों के अनुसार छन्द-परिवर्तन 'कामायनी' उनका जीता जागता उदाहरण है। 'आँसू' के छन्द भी इस विषय में सर्वधा अनुकूल हैं। 'कामायनी' प्रसाद जी की न केवल हिन्दी साहित्य की अपितु विश्व साहित्य की विभूति है। इसमें इन्होंने भारतीय संस्कृति के विश्व जन्य प्रसंगों को प्रस्तुत करके तथा इतिहास के गौरवमयी पन्नों को सामने लाकर हर भारतीय के हृदय को आत्म-गौरव का सुख प्रदान किया है। हिन्दी साहित्य में प्रसाद जी का आना माँ सरस्वती का ही प्रसाद हैं। उनके साहित्य में सौन्दर्यानुभूति की सजीवता देखते ही बनती हैः-

"नील परिधान बीच सुकुमार,
खुल रहा मृदुल अधखुला अंग।
खिला हो ज्यों बिजली का फूल,
मेघ-वन बीच गुलाबी रंग।"1

'कामायनी' जयशंकर प्रसाद का अमर महाकाव्य है तथा यह आधुनिक छायावादी युग की सर्वोतम प्रतिनिधि रचना है। इसे छायावाद का 'उपनिषद' भी कहा जाता है। प्रसाद जी की इस अंतिम काव्यकृति का प्रकाशन सन् 1936 में हुआ था। कामायनी मधुरस से सना वह महाकाव्य है जो मानव जीवन के सामंजस्य की सनातन कहानी हमारे सामने बयां करता है। कामायनी में मनु और प्रजा के मध्य भयंकर संघर्ष होने के बाद समस्त सारस्वत प्रदेश जब दुःखी दिखाई देता है तो इड़ा सोचने लगती है कि मानव कितना निर्दयी है। इसने मेरी समस्त पूजा की हत्या कर दी। अब उसे मनु के पतन से आत्मग्लानी होती है। जब उस सुनसान राजमंदिर में मनु अचेत अवस्था में पड़े हुए थे तो इड़ा के अलावा वहाँ कोई भी नहीं था। तभी उसे दूर से आती हुई एक ध्वनि गुंजायमान होती है। क्योंकि मनु के साथ श्रद्धा का प्रेम केवल मनु के लिए ही नहीं है बल्कि वह समूची मानवता का कल्याण करने वाला है। अतः उनमें समूची मानवता के प्रति प्रेम का भाव छिपा हुआ है। इनके प्रेम में गीता का निष्काम कर्म योग विद्यमान् है। बच्चा भी अपने पिता को पाकर बहुत खुश होता है। यह अत्यंत सुख देने वाला पति-पत्नी और पिता-पुत्र का मिलन था। तब मनु को अत्यंत आनंद मिला था। मनु श्रद्धा से कहता है "तुमने मुझे जीवन का रहस्य बताया है।" फिर मनु श्रद्धा से कहता है कि वह उसे कहीं दूर ले जाए। लेकिन श्रद्धा कहती अभी आप स्वस्थ नहीं हैं। मनु कहते हैं प्रलय से बचने के बाद आपने मुझे सहारा देने के साथ-साथ प्रेम और विश्वास भी दिया। तुमने मुझे पुंजीभूत किया और कष्टों को सहने की शक्ति भी दी। परन्तु फिर भी मैं स्वार्थी बना रहा और तुम्हारा मूल्य नहीं समझ सका। मैं बहुत ही पापी हूँ मेरी अंतरात्मा मुझे कचोट रही है। अब एक बार फिर मनु ग़ायब हो जाते हैं। लेकिन दोबारा फिर से श्रद्धा मनु को ढूँढते-श्रद्धा नदी के निर्जन तट पर एक गुफा में मनु को देख लेती है। अब श्रद्धा के साथ इड़ा भी थी। लेकिन मनु ने इड़ा का तिरस्कार करते हुए श्रद्धा के गुणों का बखान किया। उसी समय ऐसा लगा मानो कैलाश पर्वत पर अन्धकार को चीरती हुई एक विराट शक्ति उत्पन्न हुई। वे कोई और नहीं शिव थे

Principal
Dyal Singh College
KARNAL

जो तांडव नृत्य में लीन थे। जिसके कारण एक ओर तामसी पदार्थों का सर्वश्नाश हो रहा था और दूसरी ओर सात्विक पदार्थों की सृष्टि हो रही थी। शिव को इस मुद्रा में देख कर मनु ने श्रद्धा से अनुरोध कि वह उनको शिव के चरणों तक ले जाए और उन्होंने आगे कहा कि इन चरणों में पहुँचकर सभी पाप पवित्र हो जाएगें तथा इसके बाद आनन्द ही आनन्द होगा। मनु के अत्यधिक आग्रह करने पर श्रद्धा मनु को लेकर हिमालय पर चढ़ने लगती है और श्रद्धा मनु को एक समतल भूमि पर लेकर जाती है। वहाँ जाकर उसमें एक नवीन चेतन शक्ति का उदय होता है। वहाँ जानकर उन्होंने तीन बिन्दु अथार्त् तीन लोक को देखा जो कि इस तरह से थे- इच्छा, क्रिया और ज्ञान। श्रद्धा ने इन लोकों देखकर कहा कि इन तीनों लोकों के अलग रहने के कारण ही मानव जीवन में दुःख आते हैं। यथाः-

"ज्ञान दूर कुछ क्रिया भिन्न है,
इच्छा क्यों पूरी हो मन की।
एक दूसरे से न मिल सके,
यह विडंबना है जीवन की।"2

प्रसाद की प्रेम और सौंदर्य की उनकी यह दृष्टि ही उनको वैश्विक बनाती है। यही कारण है कि 'कामायनी' में कैलास पर्वत पर पारस्परिक प्रेम और तपस्या के स्वरुप को देखकर इड़ा स्वयं को धन्य समझने लगती है। मानव ने भी अपनी माँ को प्रेमपूर्वक आलिंगन में भर लिया। इड़ा ने जब मनु को अपने आने का कारण बताते हुए कहा कि वह अपने पापों का नाश करने के लिए यहाँ आए हैं तब मनु ने मुस्कुराकर कहा यहाँ कोई पराया नहीं है और हम सभी ब्रह्ममय हैं। यहाँ कोई भी प्राणी दुःखी नहीं है। वे आगे कहते हैं कि यहाँ पर दूसरों की सेवा करना अपनी ही सेवा करना समझा जाता है।यथाः-

"सब भेद-भाव भुलवा कर
दुःख-सुख को दृश्य बनाता
मानव कह रे! यह मैं हूँ,
यह विश्व नीड़ बन जाता।"3
"किंतु न परिमित करो प्रेम,
सौहार्द विश्वव्यापी कर दो।"4

प्रसाद जी ने अपने साहित्य में जहाँ नारी सौंदर्य और मानव सौंदर्य का चित्रण किया है वहीं उन्होंने प्रकृति सौंदर्य का भी अनोखा वर्णन किया है। इनके साहित्य की प्रकृति कई बार तो इतनी सुंदर हो जाती है कि उसके आगे न केवल नारी सौंदर्य बल्कि मानव सौंदर्य भी फीका पड़ जाता है। 'कामायनी' में प्रसाद लिखते हैं कि कैलाश पर्वत की समस्त प्रकृति प्रफुल्लित हो उठती और चारों तरफ सुगन्धित वायु बहने लगती है, लताएँ नाचने लगती हैं, कोयल कूकने लगती हैं और भ्रमर गूँजार करने लगते हैं। इस दिव्य अलौकिक सौंदर्य को देखकर सभी आनंद विभोर हो जातें हैं तथा वहाँ पर वियमान् सभी प्राणी चाहे जड़ हो या चेतन सभी आपस में भेदभाव भुलाकर परम सत्ता के अखंड आनंद में डूब गए और हिमालय की पाषाणी प्रकृति मंगलमय हो जाती है। यह देखकर हम यह कहने को मजबूर हो जाते हैं कि प्रकृति के प्रत्येक कण में जयशंकर प्रसाद को सौंदर्य के ही दर्शन हुए हैंः-

"समरस थे जड़ या चेतन,
सुंदर साकार बना था।
चेतनता एक विलासती,
आनंद अखंड घना था।"

"मिल गए प्रियतम हमारे मिल गए,
यह अलख जीवन सफल अब हो गया।

Principal
Dyal Singh College
KARNAL

कौन कहता है जगत है दुखमय,
यह सरस संसार सुख का सिंधु है।"5

कामायनी का प्रारंभ देवसृष्टि के विनाश के साथ होता है। इस विनाश में देव-सृष्टि नष्ट हो जाती है और मानव सृष्टि का आरंभ होता है। मानव मनु वह है जो अमर देवताओं का वंशज है, जो प्रलय में मर गए हैं। प्रसाद कामायनी के माध्यम से कहना चाहते हैं कि जब देव-सृष्टि का विनाश होता है तब मानव-सृष्टि आकार लेती है। इस महाकाव्य में प्रसाद ने मानव मनु के माध्यम से तकरीबन संपूर्ण मानवीय संवेदनाओं का विस्तार से व्याख्यान लिखा है। कामायनी का हर सर्ग किसी स्थान, घटना या पात्र के नाम के शीर्षक के साथ प्रारंभ होने की बजाय मानव मन की वृत्तियों के आधार पर होता है। लगभग सभी विद्वान जयशंकर प्रसाद में प्रेम और सौंदर्य की छटा देखते हैं। जीवन में इतने प्रिय लोगों का असमय दुनिया को छोड़कर चले जाना प्रसाद जी को विरह-व्यथा के प्रश्नों की ओर लेकर जाता है। इन्हीं सवालों के उत्तर में 'आंसू' और 'झरना' की सृष्टि होती है। जयशंकर प्रसाद की इन कविताओं से हमें प्रेम और सौंदर्य की गहराई के बारे में जानने को मिलता है। उन्होंने अपनी कविताओं में श्रृंगार रस के दोनों पक्षों संयोग और वियोग को दिखाया है। 'आँसू' उनका सबसे प्रसिद्ध विरह काव्य है, जिसमें उन्होंने प्रेमियों के बिछुड़ने पर होने वाले दर्द की पीड़ा को अपने शब्दों के माध्यम से लोगों के बीच साँझा किया है।

यथाः-

"इस करुणा कलित ह्रदय में,
एक विकल रागिनी बजती।
क्यों हाहाकार स्वरों में,
वेदना असीम गरजती।"6

प्रसाद जी आधुनिक काल के कवि हैं इसलिए उनकी रचनाओं में आधुनिक प्रश्नों के उत्तर तलाशने और सामाजिक वैषम्य पर सवाल उठाने की घटनाएं विशेष रूप से देखने को मिलेंगी। नारी सौंदर्य के साथ-साथ स्त्री-सम्मान की भावना भी इनके काव्य में हमें जगह-जगह पर दिखाई देती है। अतः प्रसाद जी ने तात्कालिक सामाजिक परिस्थितियों को आधार बनाकर स्त्री संबंधी आधुनिक सवाल उठाकर स्वयं की दूरदर्शिता का भी परिचय दिया है। इसलिए जयशंकर प्रसाद जी वे लिखते हैं कि श्रद्धा के बिना जीवन जीना असंभव है और उनकी 'कामायनी' भी यही कहती है। 'कामायनी' में श्रद्धा का प्रेम, सौदर्य और उसकी अतिरिक्त महत्ता विद्यमान् है। यथाः-

"नारी! तुम केवल श्रद्धा हो,
विश्वास रजत नग पगतल में।
पीयूष-स्त्रोत सी बहा करो,
जीवन के सुंदर समतल में।"7
"तुम भूल गए पुरुषत्व मोह में,
कुछ सत्ता है नारी की।
समरसता है संबंध बनी,
अधिकार और अधिकारों की।"
"मैं जभी तौलने का करती उपचार,
स्वयं तुल जाती हूं।
भुज लता फंसाकर नर-तरू से,
झूले-सी झोंके खाती हूं।"

Principal
Dyal Singh College
KARNAL

हिन्दी साहित्य में छायावाद के अन्य कवियों की तरह जयशंकर प्रसाद की सौंदर्य चेतना की अभिव्यिक्ति हमें कई स्तरों

पर दिखाई देती है। सौंदर्य जीवन के दोनों पक्षों में होता है चाहे वह सुखात्मक हो या दुखात्मक। इसीलिए इसमें नारी भी सुंदर है और उसके हृदय में उठने वाले भाव भी सुन्दर हैं, किन्तु इससे भी अधिक मानव सौंदर्य का स्तर सर्वोच्च है। प्रसाद जी के साहित्य में जिस नारी सौंदर्य का वर्णन किया गया है उसमें कहीं पर भी बनावटीपन दिखाई नहीं देता और न ही उसमें नग्नता व अश्लीलता दिखाई देती बल्कि उसमें संकोच व लज्जा दिखाई देती है। प्रसाद जी ने 'कामायनी' में दर्शाया हैः-

"हृदय की अनुकृति बाह्य उदार,
एक लंबी काया उन्मुक्त"

जयशंकर प्रसाद जी ने मानव प्रेम को बड़ी सहजता के साथ अपनाया है। वे मानवता के हमेशा प्रेमी और पक्षधर रहे हैं। इसलिए उनको संकुचित राष्ट्रीयता बिलकुल पसंद नहीं थी क्योंकि वे तो विश्व प्रेमी थे और समस्त मानवों के कल्याण की चाहत करते थे। वे विश्व बंधुत्व की भावना से प्रेरित होकर सच्चे मानव प्रेम को ही उन्होंने अपनी कविताओं में दर्शाया है। 'कर्म' सर्ग में श्रद्धा मनु को प्राणी-मात्र से प्रेम करने एवं सभी को सुखी बनाने का आग्रह करती है।8 श्रद्धा की इस विश्व बंधुत्व की भावना को मनु भी स्वीकार करते हैं और वे कहते हैं कि यहाँ का अणु-अण और कण-कण कण अपना ही हैं और द्वैत के लिए यहाँ कोई स्थान नहीं है।9 इस तरह संपूर्ण 'कामायनी' मानवता प्रेम और विश्व बंधुत्व की भावना से भरी पड़ी है। यथाः-

"ताल-ताल पर चलों नहीं लय छूटे जिसमें,
तुम न विवादी स्वर छेड़ो अनजाने इसमें।"10

सौंदर्य के बारे में जयशंकर प्रसाद जी मानते थे कि समस्त संसार में अनंत सौंदर्य विद्यमान् है। सृष्टि के इस अथाह सौंदर्य ने जयशंकर प्रसाद जी के हृदय को आंदोलित किया और उनके हृदय में अनेक भाव लहरियाँ उठाई हैं। यही भाव लहरियाँ मनुष्य के हृदय में सौंदर्य को जन्म देती हैं। सौंदर्य से परिपूर्ण कामायनी को पढ़कर कोई ऐसा हृदयहीन व्यक्ति ही होगा कि जिसके हृदय में उसके प्रति आकर्षण पैदा न हो। प्रसाद भी उभय पक्षीय सौंदर्य के समर्थक हैं और इसी कारण उन्होंने 'शिव-सूत्र विमर्शिनी' के आधार पर आत्मा के स्वरूप का वस्तु में परिमित रूप से प्रकटीकरण अथवा 'स्व' का संवित् वस्तुओं या प्रमाता में प्रक्षेपण को ही कला बतलाया है।11 इस प्रकार स्पष्ट रूप से कहा जा सकता है कि जयशंकर प्रसाद जी का प्रेम और सौंदर्य ऐसे दृष्टिकोण का प्रतिनिधित्व करता है जहाँ प्रेम और सौंदर्य की समस्त स्थूलताएँ नष्ट हो जाती हैं और उसके सूक्ष्म पक्ष हमारे सामने उभरने लगते हैं।

संदर्भ सूचीः-

डॉ. शिवकुमार शर्मा, हिन्दी साहित्य: युग और प्रवृत्तियाँ, पृष्ठ 456
वहीं, पृष्ठ 464
जयशंकर प्रसाद, कामायनी, आनंद सर्ग, पृष्ठ 215
जयशंकर प्रसाद, प्रेम पथिक, पृष्ठ 24
डॉ.रमाशंकर त्रिपाठी, काव्याायन, पृष्ठ 57
जयशंकर प्रसाद, आँसू, पृष्ठ 78
जयशंकर प्रसाद, कामायनी, संजय बुक सेंटर, वाराणसी, पृष्ठ 88
कामायनी, पृष्ठ 132-133
वही, पृष्ठ 287-289
वही, पृष्ठ 193
काव्य और कला तथा अन्य निबंध,पृष्ठ 43

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA

রবীন্দ্র ভারতী পত্রিকা

प्रेम और सौंदर्य के कवि जयशंकर प्रसाद

Authored By

डॉ. यशवन्ती देवी

असिस्टेंट प्रोफ़ेसर, दयाल सिंह कॉलेज, करनाल

Principal
Dyal Singh College
KARNAL

Published in

Rabindra Bharati Patrika: Rabindra Bharati University

ISSN No: 0937-0037

Impact Factor: 6.4

Vol.: XXVIII, No. : 8, May 2024

UGC CARE, Peer Reviewed and Refereed Journal

ज्ञान-विज्ञान विमुक्तये

Rabindra Bharati Patrika ISSN No: 0937-0037

Editor
Rabindra Bharati Patrika

देवानां भद्रा सुमतिर्ऋजूयताम्।। ऋ० १/८९/२

ISSN : 2395-7115
September 2023
Vol.-18, Issue-3

Impact Factor
7.523

Bohal Shodh Manjusha

AN INTERNATIONAL PEER REVIEWED, REFEREED MULTIDISCIPLINARY
& MULTIPLE LANGUAGES RESEARCH JOURNAL
UGC Valid Journal (The Gazette of India, Extraordinary Part III, Section 4, Dated July 18, 2018)

विश्व पटल पर हिंदी भाषा विशेषांक



प्रबंध सम्पादक :
डॉ. किरण आंगरा

विशेषांक सम्पादक :
डॉ. मंजु तोमर

सम्पादक :
डॉ. नरेश सिहाग
एडवोकेट

Publisher :
Gugan Ram Educational & Social Welfare Society (Regd.)
202, Old Housing Board, Bhiwani, Haryana-127021

Principal
Dyal Singh College
KARNAL

Bohal Shodh Manjusha

AN INTERNATIONAL REFEREED/REVIEWED AND INDEXED MULTIDISCIPLINARY & MULTIPLE LANGUAGES RESEARCH JOURNAL
ISSN 2395-7115

सम्पादकीय सम्पर्क :
डॉ. नरेश सिहाग एडवोकेट
202, पुराना हाऊसिंग बोर्ड,
भिवानी-127021 (हरियाणा)
Email : nksihag202@gmail.com
मो. 09466532152

Published by :
Gugan Ram Educational & Social Welfare Society (Regd.)
202, Old Housing Board,
Bhiwani-127021 (Haryana) INDIA
Email : grsbohal@gmail.com
Facebook.com/bohalshodhmanjusha
Website : www.bohalsm.blogspot.com
WhatsApp : 9466532152

All Right Reserved by Publisher & Editor

Principal
Dyal Singh College
KARNAL

Price

Individual/Institutional : 1100/-

Disclaimer :
1. Printing, Editing, Selling and distribution of this Journal is absolutely honorary and non-commercial.
2. All the Cheque/Bank Draft/IPO should be sent in the name of Gugan Ram Educational & Social Welfare Society payable at Bhiwani.
3. Articles in this journal do not reflect the Views or Policies of the Editor's or the Publisher's. Respective authors are responsible for the originally of their views/opinions expressed in their articles.
4. All dispute will be Subject to Bhiwani, Hry. Jurisdication only.

Printed by : Manbhawan Printers, Old Bus Stand Road, Naya Bazar, Bhiwani (Hry.)

क्र.	विषय	लेखक	पृष्ठ
1.	प्रस्तावना	डॉ. किरन आंगरा	12-12
2.	सम्पादकीय	डॉ. मंजु तोमर	13-14
3.	संदेश राज्यपाल हरियाणा	बंडारू दत्तात्रेय,	15-15
4.	संदेश मुख्यमंत्री हरियाणा	मनोहर लाल	16-16
5.	हिंदी भाषा : कल, आज और कल	डॉ. महाश्वेता, मिस. सोन किरण शर्मा	17-21
6.	विश्व भाषा की ओर अग्रसर होती हिन्दी	डॉ. अनीता रानी	22-25
7.	विदेशों में हिंदी शिक्षण	डॉ. सीमा शर्मा	26-30
8.	वैश्विक स्तर पर हिंदी	डॉ. मंजीत	31-34
9.	हिन्दी कल आज और कल हिन्दी भारत माता के भाल की बिंदी है	डॉ. नीलम	35-37
10.	हिन्दी का वैश्विक परिप्रेक्ष्य और चुनौतियाँ	डॉ. रमेश कुमार	38-42
11.	विश्व स्तर पर हिंदी और टेलीविजन	डॉ० रीना देवी गोरा	43-45
12.	विश्व स्तर पर संचार सूचना और हिंदी भाषा	कृष्ण कुमार	46-48
13.	हिन्दी भाषा कल, आज और कल	डॉ. प्रियंका घिल्ड़ियाल	49-51
14.	विश्व भाषा की ओर हिंदी के बढ़ते कदम	डॉ. रेनु भाटिया	52-55
15.	वैश्विक आर्थिक विकास में हिंदी भाषा की भूमिका	प्रा. डॉ. पवार विक्रमसिंह	56-59
16.	विश्व पटल पर हिन्दी भाषा	डॉ. मंजु तोमर	60-64
17.	वैश्विक परिदृश्य में समरसता की संवाहक राजभाषा हिन्दी	डॉ. मो. माजिद मियाँ	65-72
18.	विश्वभाषा की ओर हिन्दी के बढ़ते कदम	डॉ. यशवन्ती देवी	73-76
19.	विश्व भाषा की ओर हिंदी के बढ़ते कदम	डॉ. सुनील बाबुराव काळे	77-79
20.	विश्व भाषा की ओर हिन्दी के बढ़ते कदम	डॉ. दीपचंद	80-83

Principal
Dyal Singh College
KARNAL

21.	विदेशों में हिन्दी शिक्षण	डॉ. निशान सिंह	84-86
22.	मनुष्य के जीवन में सदाचरण लाने में संगीत की भूमिका	डॉ. तरूण जोशी	87-90
23.	सामाजिक समरसता में संगीत की भूमिका	डॉ. उज्जवल	91-94
24.	हिंदी भाषा कल आज और कल	श्याम कुमार	95-99
25.	वैश्विक परिदृश्य में समरसता की संवाहक हिंदी	जगबीर सिंह	100-104
26.	हिंदी की संभावनाएं एवं चुनौतियाँ	डॉ आशीष कुमार साव	105-109
27.	पं. लख्मीचंद जी की सांगीतिक रचनाओं में सामाजिक समरसता	रीनु शर्मा	110-113
28.	हिंदी राष्ट्रभाषा की गंगा से विश्वभाषा का गंगासागर	प्रा. डॉ. अशोक शामराव मराठे	114-117

Principal
Dyal Singh College
KARNAL

www.bohalshodhmanjusha.com
Impact Factor : 7.523
Bohal Shodh Manjusha
September 2023
ISSN : 2395-7115
Page No. : 73-76
AN INTERNATIONAL PEER REVIEWED, REFEREED MULTIDISCIPLINARY
& MULTIPLE LANGUAGES RESEARCH JOURNAL

विश्वभाषा की ओर हिन्दी के बढ़ते कदम

डॉ. यशवन्ती देवी

असिस्टेंट प्रोफेसर, दयाल सिंह कॉलेज, करनाल।

हिन्दी एक बड़ी भाषा होने के बाद भी कॉर्पोरेट जगत की एक ऐसी भाषा नजर आती है जिसमें विज्ञापन के माध्यम से ही से बड़ी संख्या तक पहुंचाया जाता है। हिन्दी जगत तो ये है उपभोक्ता बाजार हिन्दी की ओर कॉर्पोरेट जगत लाइक करता है। हिन्दी भाषा ने भी इस अवसर को हाथ से जाने नहीं दिया है इसलिए हिन्दी के पठन–पाठन में परिवर्तन देखा जा सकता है तथा देखते–देखते हिन्दी क्षेत्रों में पत्रकारिता सिखाने वाले ढेरों संस्थान है। वर्तमान समय में विद्यार्थी पत्रकारिता और जनसंचार पढ़ने में दिलचस्पी लेने लगे हैं। वैश्वीकरण, निजीकरण, उदारीकरण, भूमंडलीकरण व बाजारवाद इनमें से किसी भी एक नाम से पुकारो, भारत में यह प्रक्रिया उन्नीस सौ नब्बे के दशक में शुरू हो गई थी। इस युग में कोई सरहद, कोई सीमा, या कोई दीवार नहीं थी। वास्तव में भूमंडलीकरण ऐसी अवधारणा है जिसने पूरे संसार को एक गाँव में बदल दिया है। शुरुआती दौर में अंग्रेजी भाषा का ज्यादा महत्व था लेकिन धीरे–धीरे हिन्दी भाषा का महत्व ज्यादा हो गया और अंग्रेजी भाषा की गति धीमी हो गई। विश्व बाजार व्यवस्था की इस प्रकृति से भारत भी अछूता नहीं रह सकता था उसे भी वैश्विक मंडी में देर सबेर तो आना ही था। ये बात भी किसी से छुप नहींसकती कि भूमंडलीकरण ने जहाँ एक और मुक्त बाजार की दलील पेश है वहीं दूसरी और संसार में एक नई उपभोक्तावादी संस्कृति को भी हमारे सामने लाकर खड़ा कर दिया है।" ग्लोबलाइजेशन ने एक हिंदी ग्लोबल जमात और बाजार पैदा की है। हिंदी मीडिया की घरेलू बढ़त भी यही कहती है कि हिन्दी व किसी हद तक निचले विनिमय, विपणन और रोजगार की भाषा बन रही है।"[1]

नब्बे के दशक में हॉलिवुड के एक बहुत बड़े फिल्म निर्माता स्टीफन स्पिलबर्ग ने अपनी बहुचर्चित फिल्म "जुरासिक पार्क" कोजब हिन्दी में डब किया तो मानो वे एक कॉरपोरेट रणनीति के लिए नये दरवाजे खोल रहे थे। "जुरासिक पार्क" हिन्दी में "डब" होते ही देश के छोटे–छोटे कस्बों से होती हुई गाँव तक जा पहुँची इससे पहले किसी भी विदेशी फिल्म ने भारत में आकर इतना मुनाफा नहीं कमाया था। वर्तमान समय में संयुक्त राष्ट्र संसार की मुख्य भाषाओं में हिंदी को शामिल आवाज उठा रहा है। विश्व हिंदी सम्मेलनों के कार्यक्रम भी एक ऐतिहासिक परिवर्तन की आहट है। प्रसिद्ध भाषा वैज्ञानिक नोम चॉमस्की ने वैश्वीकरण का अर्थ अंतराष्ट्रीय एकीकरण माना है। इस एकीकरण में भाषा की भूमिका मुख्य होगी और जो भाषा व्यापक रूप से प्रयोग में रहेगी, उसी का स्थान संसार में सुनिश्चित हो जाएगा।

मीडिया ने हिन्दी भाषा को रातों–रात विश्व की भाषा बना दिया है। [illegible] बाजार में जो भाषा

Principal
Dyal Singh College
KARNAL

प्रयोग की जाएगी वहीं जीवित रह पाएगी। भारत में जब बहुत सारी विदेशी कंपनियां व्यापार के लिए आईं तो पहले उन्होंने हिंदी के साथ ज्यादती नहीं की लेकिन बाद में उनकी समझ में ये पूरी तरह से आ गया कि अगर हमें भारत की बहुसंख्य जनता को अपना सामान बेचना है तो हमें हिंदी को महत्व देना ही होगा। "हिंदी से संबंधि त सोलह लाख इन बीस हजार वेबसाइट हैं। भारत समेत 132 देशों की कुल 80 करोड़ से अधिक लोगों की जुबान है–हिन्दी। विश्व की सर्वाधिक बोली जाने वाली भाषाओं में तीसरे नंबर की भाषा है। हिन्दी अपनी जगह खुद बनाती है। यह विशेषता केवल हिन्दी की ही हो सकती है। हिन्दी का विश्वभाषा के रूप में बढ़ना इस बात का प्रमाण है। अंग्रेजी के वर्चस्व के बीच अपनी जगह बनाना वाकई बड़ी बात है।"[2]

रूपर्ट मर्डोक जब स्टार टीवी लेकर भारत में आये तो उनकी सबसे बड़ी पहल यही की थी कि सभी तरह के आयोजन हिन्दी में ही तैयार किये जाएँ। स्टार टीवी ने तो न केवल समाचारों और विदेशी कार्यक्रमों को ही हिन्दी में दिखाना शुरू किया बल्कि उसने पॉप संगीत के देशी संस्करण भी बना दिए। ऐसे ही बीबीसी और डिस्कवरी चैनल भी अपने कार्यक्रमों को हिन्दी में प्रसारित करने लगे। आज लगभग सभी मुख्य चैनलों पर बहुत संख्या हिन्दी कार्यक्रमों की है।" हिंदी एक सर्वेग्राही भाषा है। वह बढ़ रही है। बाजार में हिन्दी का बोलबाला है। अंग्रेजी के बड़े–बड़े सुरमा हिन्दी को नमन कर रहे हैं। अंग्रेजी के मानी गुमानी हिन्दी में अपनी किताब लाने छपने को तरसते हैं। नौकरशाह अंग्रेजी में बूँकते हैं, मगर रोते अपने–अपनी मातृभाषा में ही हैं। हिन्दी के नौकर साहा अंग्रेजी में टहलते हैं हाँ मगर सारण हिन्दी में ही बातें हैं। हिन्दी सब जानती–सहती–हँसती है।"[3] संसार के बाजार का हिन्दी भाषा के साथ बनने वाला संबंध एक नयी तरह का है।

पिछले एक दशक से साबुन और टूथपेस्ट जैसी सस्ते सामान से लेकर कार, फ्रिज, टीवी, वाशिंग मशीन, महंगे वस्त्रों, बचत और निवेश की योजनाओं, महँगी प्रसाधन सामग्री आदि के लिए भी हिन्दी में विज्ञापन तैयार हो रहे हैं। भागलपुर, बाराबंकी और भरतपुर में किसी सड़क के चौराहे पर अब आप वाशिंग मशीन या फ्रिज के लिए हिन्दी में बनी होर्डिंग्स देख सकते हैं। भारत में उपभोक्ता वस्तुओं के बाजार का लगातार फैलाव हो रहा है। उपभोक्ता वस्तुएँ बड़े शहरों से आगे निकलकर मध्यम दर्जे के शहरों, छोटे कस्बों और दूर–दराज के गाँवों तक पहुँच रही हैं। छोटे–छोटे कस्बों में ब्यूटी पार्लर खुल रहे हैं। रेबेन के चश्में पहने कस्बों के युवक इतरा रहे हैं तथा दूसरे दर्जे के रेल यात्रियों के लगेज का रूप बदल रहा है।" बहुराष्ट्रीय कंपनियों की प्रचार सामग्री का अनुवाद कौन करेंगे–हिन्दी वाले, तो फिर हिन्दी प्राइवेट क्षेत्र में भी धूम मच जाएगी।"[4] दूर–दराज के इलाकों में बैंकों के क्रेडिट कार्ड और 'एटीएम' सेंटर खुल रहे हैं।

एक समय था जब भारत ने विश्व बाजार में अपनी धाक जमाई थी। उस समय भारत अपने खुशबूदार इत्रों, रंगीन वस्त्रों तथा मशालों के लिए प्रसिद्ध था। भारत की इस प्रसिद्धि से रोम की संसद इतनी डर गई थी कि रोम के एक विधायक ने संसद में अपने देश के लोगों को भारतीय कपड़ों ख़रीदना इसीलिए मना किया कि उनके देश के सोने के सिक्के भारत में न जा सके। यही से भारत की वसुधैव कुटुंबकम् की भावना चरितार्थ होते है। विश्व स्तर पर सरकारी काम काज के लिए फ्रेंच, अंग्रेजी, स्पेनिश, चीनी, रूसी और अरबी भाषाओं को अंतर्राष्ट्रीय भाषाओं का स्थान प्राप्त है। हिंदी भी संयुक्त राष्ट्र संघ में अंतर्राष्ट्रीय भाषा का स्थान प्राप्त करने के लिए लगातार प्रयास कर रही है। आंकड़े दर्शाते हैं कि सवा सौ करोड़ की आबादी वाले इस राष्ट्र में चालीस करोड़ से अधिक लोगों की मातृभाषा हिंदी है।

Principal
Dyal Singh College
KARNAL

हिन्दी आज विश्व की दूसरे नंबर की भाषा है। हिन्दी से आगे सिर्फ चीनी भाषा है। पैंतीस करोड़ से ज्यादा लोग हिन्दी भाषा का प्रयोग दूसरी भाषा के रूप में करते हैं। लगभग तीस करोड़ ऐसे लोग हैं जिनका किसी न किसी रूप में हिंदी भाषा के साथ सरोकार जुड़ा हुआ है। "हिंदी के प्रसार में किसी वक्त में लता, रफी, मुकेश मन्नाडे की जैसी भूमिका रही, आज वैसी ही भूमिका अमिताभ बच्चन की है। हिन्दी वाले इसलिए उन पर ही मरते हैं, मीडिया उन पर मरता है और बाकी इसलिए मरते हैं क्योंकि अमिताभ उनके लिए भी गैर मामूली है। वे दुनियाभर के लोगों के चहेते हैं।"[5]

भारत देश की आबादी के लगभग तीन चौथाई से अधिक लोगों में संपर्क की भाषा हिन्दी है। हिंदी वैश्वीकरण का अर्थ व्यापक तौर पर बाजारीकरण है। आज मनुष्य जीवन का प्रत्येक क्षेत्र बाजारवाद से प्रभावित है। मुक्त व्यापार और वैश्वीकरण के युग में भारत में हिंदी भाषा संप्रेषण का एक बहुत बड़ा बाजार है। आज हिन्दी एक मजबूत भाषा बन चुकी है और वैश्विक स्तर पर वह एक मजबूत भाषा के रूप खड़ी है और यहाँ से उसे और मजबूत होना है और बहुत आगे जाना है। लेकिन इसके लिए उसे प्रयास करने होंगे। हिन्दी तब और भी मजबूत होगी जब हिन्दी भाषा–भाषी क्षेत्रों का पिछड़ापन दूर किया जाएगा। जिस दिन हिन्दी भाषियों का आर्थिक विकास हो गया उसी दिन से हिन्दी मजबूत होनी शुरू हो जाएगी और आर्थिक पिछड़ापन दूर होते ही हिन्दी की सभी बाधाएँ स्वतः ही दूर हो जाएंगे।" मीडिया संस्थान हिन्दी में कारोबार करके अच्छी आमदनी करने लगे हैं। इसका प्रमाण हिन्दी में आने वाले विज्ञापन है।"[6] टीवी चैनलों की अपनी ही अलग प्रकार की हिन्दी होती है। कहीं मात्रा है तो कहीं उच्चारण। टीवी का इतिहास बताता है कि हिंदी शुरू में सूचना समाचार का माध्यम बनते–बनते अचानक नब्बे के आसपास मनोरंजन का जबरदस्त जरिया बनती चली गयी। "भूमंडली व निजीकरण के चलते आज पूरे विश्व की निगाह भारत पर है क्योंकि भारत सबसे बड़ा बाजार है।"[7] ये बिलकुल सही बात है कि हिंदी को आगे बढ़ाने में मीडिया, बाजार और मनोरंजन की दुनिया ने बहुत बड़ी भूमिका निभाई है लेकिन उसे आगे ले जाने के लिए आर्थिक विकास तो करना ही होगा। आज देशी कंपनियों की लगभग सत्तर प्रतिशत से अधिक वस्तुएं हिंदी जरिए जन साधारण तक पहुँच रही हैं।

वर्तमान में हिन्दी भाषा के भाव बढ़ गये हैं। आज हिन्दी एक मजबूत भाषा के रूप में खड़ी है। भूमंडलीकरण में सांस्कृतिक व आर्थिक दोनों ही दृष्टि से हिंदी की भूमिका बढ़ी है। बाजारीकरण की इस व्यवस्था में हिंदी भाषा इसका एक बढ़िया जरिया बनकर उभरी है। इलैक्ट्रानिक मीडिया और टेलिविजन पर प्रस्तुत कार्यक्रम चाहे किसी भी विषय से संबंधित हों उन्हें व्यावसायिकता की दृष्टि से हिंदी एक बहुत बड़ा क्षेत्र उपलब्ध I कराती है। इस स्तर टेलीविजन ने हिंदी के भाषा वैविध्य और संप्रेषण क्षमता को सर्वथा नई दिशाएं प्रदान की हैं। "समकालीन मीडिया न केवल मारकेट से संचालित होता है, बल्कि मारकेट को भी संचालित करता है।"[8] यह हिंदी भाषा का ही कमाल है कि आज बहुराष्ट्रीय तथा राष्ट्रीय कंपनियों के उत्पादों को हम गांवों में भी प्राप्त कर सकते हैं। समाचार पत्रों तथा टीवी की विज्ञापन संस्कृति का इसमें बहुत बड़ा योगदान रहता है। "यह सर्वमान्य तथ्य है कि फिल्मों/मीडिया ने हिन्दी को विश्व की भाषा बना दिया है।"[9] कुल मिलाकर हम सकते हैं कि वैश्वीकरण बाजार के विकास तथा फैलाव में प्रिंट व इलैक्ट्रॉनिक माडिया पर प्रसारित विज्ञापनों की सर्वाधिक महत्वपूर्ण भूमिका है। स्टार टीवी ने हिंदी में कार्यक्रम प्रसारित करने आरंभ किए तो उसके दर्शकों में बहुत ज्यादा वृद्धि हुई है। भारत में अब डिस्कवरी, सोनी, कलर, आज तक, एनडीटीवी, ज... चैनल हिंदी में ...

Principal
Dyal Singh College
KARNAL

कार्यक्रम प्रसारित कर रहे हैं। "यह हिंदी के बाजार का, उसकी जनसंख्या की ताक़त है जो विज्ञापन खींचती है।"[10]

आज हिंदी समूचे भूमंडल की एक प्रमुख भाषा के रूप में उभरी है आज की बदलती परिस्थितियों में हिंदी भाषियों और भारत की शक्ति के नाते ही सही अमेरीकी सरकार के साथ–साथ कम्प्यूटर के किंग कहे जाने वाले बिल गेट्स भी हिंदी के उपयोग में दिलचस्पी दिखा रहे हैं। गूगल के प्रमुख अधिकारियों का मानना है कि भविष्य में स्पेनिश नहीं बल्कि अंग्रेजी और चीनी के साथ हिंदी ही इंटरनेट की प्रमुख भाषा होगी। वर्तमान में गूगल के जरिए अंग्रेजी भाषा से हिंदी भाषा में स्पीच से सीधा अनुवाद भी प्राप्त होने लग गया है। गूगल सॉफ्टवेयर के जरिए अंग्रेजी डाक्यूमेंट को हम हिंदी भाषा में तुरंत अनुदित कर सकते हैं। फिल्मों के माध्यम से भी हिंदी को वैश्विक स्तर पर सम्मान प्राप्त हो रहा है।

वर्तमान में हिंदी सिनेमा ऑस्कर तक पहुँच रहा है। सिनेमा ने हिंदी की लोकप्रियता और व्यावहारिकता दोनों ही बढ़ा दी है। "हिंदी मीडिया की घरेलू बढ़त भी यही कहती है कि हिंन्दी किसी हद तक नीचले विनिमय, विपणन और रोजगार की भाषा बन रही है।"[11] संचार माध्यम की भाषा के रूप में प्रयुक्त होने पर हिंदी समस्त ज्ञान–विज्ञान और आधुनिक विषयों से सहज रूप से ही जुड़ गई है। आज कंप्यूटर, मोबाइल, फेसबुक, ट्वीटर, ब्लॉक, वाट्सएप इत्यादि पर हिंदी के प्रयोग ने दुनिया को सचमुच मनुष्य की मुट्ठी में कर दिया है। अब वह दिन दूर नहीं जब हर जगह हिंदी भाषा का बोलबाला नजर आएगा। भारत की सदियों पुरानी उक्ति 'वसुधैव कुटुम्बकम्' एक बार फिर से चरितार्थ होती जा रही है। "सचमुच में हमारी हिन्दी सोने की तरह चमकती है, चंदन–सी महकती है। मलयानिल–सी बहती है, खाती–पीती है। कि चंगे हैं सचमुच में हिन्दी रंग–बिरंगी है।"[12]

संदर्भ सूची :-

1. हिन्दी का नया जनक्षेत्र, सुधीर पचौरी, वाणी प्रकाशन, नई दिल्ली, पृष्ठ 20, प्रथम संस्करण 2012
2. हिंदुस्तान दैनिक, श्री चौतन्य, सितम्बर 2003
3. हिन्दी का नया जन क्षेत्र, सुधीर पचौरी, वाणी प्रकाशन, नई दिल्ली, प्रथम संस्करण 2012, पृष्ठ 69
4. भूमंडलीकरण, निजीकरण व हिन्दी, डॉ. मणिका मृगेश, पृष्ठ 14
5. हिन्दी का नया जन क्षेत्र, सुधीर पचौरी, वाणी प्रकाशन, नई दिल्ली, प्रथम संस्करण 2012, पृष्ठ 11
6. भूमंडलीकरण, निजीकरण व हिन्दी, डॉ. मणिका मृगेश, पृष्ठ19
7. वही, पृष्ठ 17
8. हिन्दी का नया जन क्षेत्र, सुधीर पचौरी, वाणी प्रकाशन, नई दिल्ली, पृष्ठ 15, प्रथम संस्करण 2012
9. भूमंडलीकरण, निजीकरण व हिन्दी, डॉ. मणिका मृगेश, पृष्ठ 4
10. हिन्दी का नया जन क्षेत्र, सुधीर पचौरी, वाणी प्रकाशन, नई दिल्ली, प्रथम संस्करण 2012, पृष्ठ 19
11. वही, पृष्ठ 20
12. भूमंडलीकरण, निजीकरण व हिन्दी, डॉ. मणिका मृगेश, पृष्ठ 63

Principal
Dyal Singh College
KARNAL

Iranian Polymer Journal
https://doi.org/10.1007/s13726-024-01367-w

ORIGINAL RESEARCH

Cell viability assessment and physicomechanical characterization of *Juglans regia* leaf fiber-reinforced poly(hydroxybutyrate) films for biomedical uses

Simran Ahuja[1] · Neha Bansal[1] · Mahak Mittal[2] · Kapil Gulati[3] · Ashwani Mittal[4] · Sanjiv Arora[1]

Received: 30 January 2024 / Accepted: 12 June 2024
© Iran Polymer and Petrochemical Institute 2024

Abstract

The present study aims to explore the cytotoxicity, physicomechanical, thermal, and barrier properties of *Juglans regia* leaf fiber (J) reinforced PHB-based films, with a focus on evaluating their suitability for biomedical applications. In this work, scaffolds are developed by incorporating varying concentrations (0.5%, 1%, 1.5%, 2% and 2.5%) of J into poly(hydroxybutyrate)/poly(vinylacetate) matrix by solvent casting. These are characterized through Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), thermo-gravimetric analysis (TGA), differential scanning calorimetry (DSC), and dynamic mechanical analysis (DMA). The results indicated that the sample containing 1.0% (by weight) J (PJ1.0) results in maximum values of the tensile strength (25 MPa) and storage modulus (1.61 GPa) at – 20 °C. Moreover, this sample exhibited favorable thermal, water barrier, and wettability properties. The hydrolytic degradation behavior of the composites is also studied at pH 7.4 and 37 °C for 16 weeks. It is observed that PJ1.0 degrades by 45%, whereas PHB experiences 18% degradation. Furthermore, the cytotoxic nature of the scaffolds is also assessed using C2C12 mouse skeletal muscle cell lines. The results confirmed that PJ1.0 does not show any cytotoxic effects when compared to pure PHB. Thus, findings of this study suggested the potential of *Juglans regia* fiber for the development of sustainable and mechanically robust materials for biomedical applications.

Graphical abstract



Principal
Dyal Singh College
KARNAL

Keywords Biocompatibility · *Juglans regia* · Poly(hydroxybutyrate) · Scaffolds · Skeletal muscle cell line

Extended author information available on the last page of the article

Published online: 12 August 2024

Introduction

Scaffolds play a significant role in tissue engineering as they serve as 3-D frameworks for generating new tissues [1]. For the successful development of scaffolding materials, we must understand their chemical, physicomechanical, and biological characteristics. The 3D structure, mechanical stability, biocompatibility, wettability, and their breakdown inside the body in a therapeutically appropriate time are some prerequisite characteristics of scaffolds [2]. Scaffolds must also deliver biophysical stimuli that mimic the natural characteristics of the extracellular matrix and hence promoting cell differentiation [3]. Designing the scaffold is a multifaceted task as it includes the need for biocompatibility to prevent inflammatory reactions and biodegradability to facilitate the gradual replacement of the scaffold with new tissues [4, 5]. The mechanical strength of the scaffold is also crucial as it ensures integrity during handling [6]. Hence, the selection of polymer material plays a vital role during the scaffold design. The family of poly(hydroxyalkanoates) (PHAs) represents a group of polyesters that are favorable candidates for effective scaffold production [7]. Among all the biopolymers, poly(hydroxybutyrate) (PHB), a biodegradable and biocompatible polyester, has emerged as a promising candidate due to its environmentally friendly nature and suitable mechanical properties [8, 9]. However, the inherent brittleness and inadequate strength of PHB limit its widespread usage in various biomedical applications [10, 11].

To address these limitations, polymer blending and fiber reinforcement comes out as a cost-effective method that produces novel materials with desired properties. The integration of additional biopolymers such as poly(vinylacetate) (PVAc), poly(ethylene glycol) (PEG), poly(lactic acid) (PLA), and poly(ε-caprolactone) (PCL) into the PHB matrix has surfaced as a promising approach to maximize the capabilities of PHB to their utmost extent [12–14].

Besides this, different natural fibers, i.e., hemp, kenaf, agave, coir, palm, cellulose fiber, wood flour and jute as reinforcement materials have also been employed to overcome their shortcomings [15–18]. Kuciel et al. reported the synthesis of PHB based biocomposite reinforced with kenaf fibers (as 40% by wt) and wood flour (as 25% by wt) by melt mixing. The results of the study showed that PHB composite reinforced with kenaf fiber exhibited good mechanical properties as well as high water absorption capacity because the biopolymer begin to degrade in water [19]. Erica et al. have observed that the incorporation of agave fiber in PHB significantly improved the tensile modulus by 80%. The thermal stability of the composites was also improved [20]. In another study by Sarahi et al., nanoparticles derived from walnut shell (WS) were reinforced with PCL polymer matrix. It was observed that sample with 2% WS nanoparticles conc. was the optimum because of the excellent mechanical properties. The scaffolds made from these fibers showed excellent cell viability, growth [21]. Song et al. observed the effect of *Juglans regia* shell fiber (WS) and hydroxyapatite (HA) on the PLA matrix through fusion depositing and the results showed that incorporating WS resulted in higher tensile elongation, compressive strain, improved thermal stability and water absorption of PLA. Finally, scaffolds were manufactured and their structural features indicated that the PLA/WS/HA composites have the potential to be applied in structural parts, such as bone implants [22]. Consequently, it can be concluded that incorporating natural fibers such as hemp fiber, agave, *Juglans regia* fiber and kenaf fiber, etc., holds promise as a method for improving the mechanical, thermal, and permeation properties of biopolymers. Nonetheless, it is worth noting that the majority of these investigations did not primarily focused on composites using *Juglans regia* leaf fiber in poly(hydroxyalkanoates).

Juglans regia has gained considerable attention due to their inherent bioactivity and potential therapeutic effects [23]. The inedible components of the plant, such as unripe walnuts, the inner part, foliage, and outer covering shells, are utilized in traditional medicine and the cosmetic industry for addressing various health issues [24]. Among all the *Juglans regia*-derived products, *Juglans regia* leaves have been recognized for their rich content of bioactive compounds, including phenols, juglone, flavonoids, and antioxidants [25, 26]. The bioactive constituents of *Juglans regia* leaves offer potential benefits, such as antimicrobial, antioxidant and anti-inflammatory properties, which are desirable in tissue engineering applications. Moreover, *Juglans regia* leaf fiber (J) offers significant potential for enhancing the mechanical strength and toughness of PHB-based films, thereby expanding their biomedical applications [27]. Furthermore, the biodegradability of both J and PHB ensures the sustainability and environmentally friendly nature of the composite film. Such composites containing *Juglans regia* leaf fiber (J) are in high demand for scaffolding and tissue engineering [23, 28]. Therefore, reinforcing PHB with such components can be a suitable approach for developing biomaterial scaffolds with desired characteristics.

In this research, we have synthesized composites of PHB by incorporating PVAc, PEG, and tributyrin with *Juglans regia* leaf fiber as reinforcement material. These biocomposites were characterized in terms of their physicomechanical, thermal, morphological, and barrier properties. The hydrolytic degradation of the composites was also analyzed in a phosphate buffer saline (PBS) at pH 7.4 and 37 °C to assess their durability in the extracellular environment. To evaluate

Principal
Dyal Singh College
KARNAL

the cell viability, cytotoxicity was evaluated through in vitro tests on C2C12 mouse skeletal muscle cell lines. Thus, the present study aims to explore the cytotoxicity and physico-mechanical properties of *Juglans regia* leaf fiber-reinforced PHB-based films, with a focus on evaluating their suitability for biomedical applications. The results obtained from this study will pave the way for the development of novel PHB-based composite materials that exhibit the bioactive properties of *Juglans regia* leaves. These composites provide a promising pathway toward more effective and environmentally friendly biomedical solutions.

Experimental

Materials and methods

The pure PHB powder of natural origin, with a molecular weight of 10,000 g/mol and a density of approximately 1.25 g/cm^3 at 25 °C, was purchased from Sigma–Aldrich. Polyethylene glycol (PEG) with a molecular weight of 6000 g/mol and Tributyrin were Himedia products. Poly(vinylacetate) (PVAc) was obtained from the Central Drug House (CDH). Yellow *Juglans regia* leaves collected from Solan, Himachal Pradesh, India, were thoroughly cleaned and processed into a fine fiber to be used as reinforcement. The fiber was then washed several times with alkali, distilled water and chloroform to remove the impurities. This was later dried in a hot-air oven at 70 °C. Dulbecco's modified eagle's medium (DMEM) and fetal bovine serum (FBS), were purchased from Thermo-Fisher Scientific. Amphotericin, Ciprofloxacin, Chloroform, DMSO, and MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide] were obtained from Himedia.

PHB/PVAc/PEG/TB (PVET) blend preparation.

The solvent-casting technique was employed to prepare the blends of PHB and PVAc. Various compositions of PHB/PVAc/PEG/tributyrin were prepared with different weight ratios of PEG and tributyrin (as shown in Table 1). Initially, PHB and PVAc were separately dissolved in chloroform (15 mL each) under refluxing conditions at 55 °C. Subsequently, the PVAc solution was gradually added to the PHB solution, and the mixture was stirred for 1 h. Further PEG was introduced into this mixture, and further stirred for another 30 min. To enhance plasticity, the mixture was blended with tributyrin. This 30 mL solution containing all the components was cast onto glass dishes and dried at temperature of 40 °C for 24 h to obtain thin films.

Among all the prepared samples, PHB/PVAc matrix containing 10% PEG and 10% TB (abbreviated as PVET10) exhibited high tensile strength of 19.4 ± 0.0 MPa. Therefore, this film was chosen for further investigation of *Juglans regia* leaf fiber (J) loading.

PVET10/*Juglans leaf* fiber (PJ) composite preparation

The PVET10 film, which contained 10% PEG and 10% TB, was chosen as the base material for reinforcement with varying concentrations of *Juglans* leaf fiber (J) (as shown in Table 2). These composites were prepared by incorporating 0.5, 1, 1.5, 2 and 2.5% of fiber into the PVET10 blend. To ensure proper dispersion of the J fiber in chloroform, the solution mixture was subjected to sonication. Subsequently, the solution was cast onto Petri dishes and dried at 40 °C for 24 h, which resulted in films with a thickness ranging from 0.04 to 0.05 mm. These films were further analyzed to investigate the impact of the *Juglans regia* leaf fiber on various properties.

Table 1 List of blends prepared and their composition

Sample code	Polymer matrix composition % (wt/wt)	PEG content (% wt of total polymer weight)	Tributyrin content (% wt of total polymer weight)
PHB	100	–	–
PVAc	100	–	–
PHB/PVAc	70/30	–	–
PHB/PVAc/PEG 10	70/30	10	–
PHB/PVAc/PEG 20	70/30	20	–
PHB/PVAc/TB	70/30	–	10
PHB/PVAc/PEG/TB (PVET5)	70/30	10	5
PHB/PVAc/PEG/TB (PVET10)	70/30	10	10
PHB/PVAc/PEG/TB (PVET15)	70/30	10	15
PHB/PVAc/PEG/TB (PVET20)	70/30	10	
PHB/PVAc/PEG/TB (PVET30)	70/30	10	

Principal
Dyal Singh College
KARNAL

Table 2 Composites with different amounts of fiber loading

Sample code	Polymer matrix composition % (wt/wt)	PEG content (% wt of total polymer weight)	Tributyrin content (% wt of total polymer weight)	*Juglans regia* leaf fiber (J) (% wt of total polymer weight)
PVET10	70/30	10	10	–
PJ0.5	70/30	10	10	0.5
PJ1.0	70/30	10	10	1.0
PJ1.5	70/30	10	10	1.5
PJ2.0	70/30	10	10	2.0
PJ2.5	70/30	10	10	2.5

Characterization techniques

Fourier transform infrared spectroscopy (FTIR)

To examine effect of the plasticizer and the fiber on the polymer matrix, FTIR spectra of the composites were recorded on the IR affinity-1S FTIR instrument (Shimadzu, Japan) in transmission mode over the spectral range of 4000–600 cm^{-1}.

Scanning *electron* microscopy (SEM)

The discrepancy in surface and cross-section morphologies of films was studied by scanning electron microscopy, JSM 6100 (Jeol, Japan), operating at an accelerating voltage of 10 kV. To enhance the conductivity and to acquire resolved images, each film was sputter-coated with a thin gold layer.

X-ray diffraction (XRD)

XRD measurements of thin film samples were made on an X'Pert Pro PANalytical diffractometer system (The Netherlands) using CuKα radiation (40 mA; $\lambda = 0.154$ nm; 40 kV) at room temperature in the range of $2\theta = 10°$ to 80° at a scan speed of 0.200°/min. The proportion of crystallinity was computed by dividing the crystalline area (I_c) with the overall area of the diffraction pattern ($I_c + I_a$), where I_a represents the area of amorphous scattering.

Thermogravimetric analysis (TGA)

TGA of the samples was carried out on the Simultaneous Thermal Analyzer (STA) STA7200 (Hitachi) instrument at the uniform heating rate of 10 °C/min in nitrogen atmosphere. Samples (5 mg) were placed in ceramic pans and heated using TGA from room temperature to 500 °C.

Differential scanning calorimetry (DSC)

The crystallization and melting behavior of the composites were investigated through Differential Scanning Calorimeter (Perkin & Elmer, US) using nitrogen as a purging gas. During the first heating cycle, the sample (10 mg) was heated at a heating rate of 10 °C/min from − 50 °C to 200 °C, subsequently cooled down to − 50 °C at a cooling rate of 10 °C/min and then another run up to 200 °C.

Mechanical testing

The ultimate tensile strength (UTS) of composites was measured on the universal testing machine (Animatex Instruments and Services, New Delhi, India) at the cross-head speed of 10 mm/min. Samples conformed to ASTM D-882 standards, maintaining a 50 mm gauge length, thickness of 0.04–0.05 mm, and an average width of 10 mm were tested in triplicates for each category of tensile analysis, and average values are reported.

Dynamic mechanical analysis (DMA)

The dynamic mechanical properties were measured on a dynamic mechanical analyzer DMA 8000 (Perkin and Elmer, US). Measurements were carried out in tension mode at a heating rate of 3 °C/min within temperature range of − 25 °C to 150 °C at a frequency of 1 Hz.

Water contact angle measurement

Water contact angle of the specimens was measured using the sessile drop method by Drop Shape Analyzer—DSA100. Approximately 3 μL droplet volume was placed perpendicular to the film surface using a microsyringe, and the drop profile image was captured. Based on an analysis of the drop's height and width, the software automatically determined the value of the contact angle from the drop profile image. Three measurements were made on each sample surface.

Water vapor permeation test

The water vapor permeability of all the films was determined according to ASTM E96. Glass vials of a particular

Principal
Dyal Singh College
KARNAL

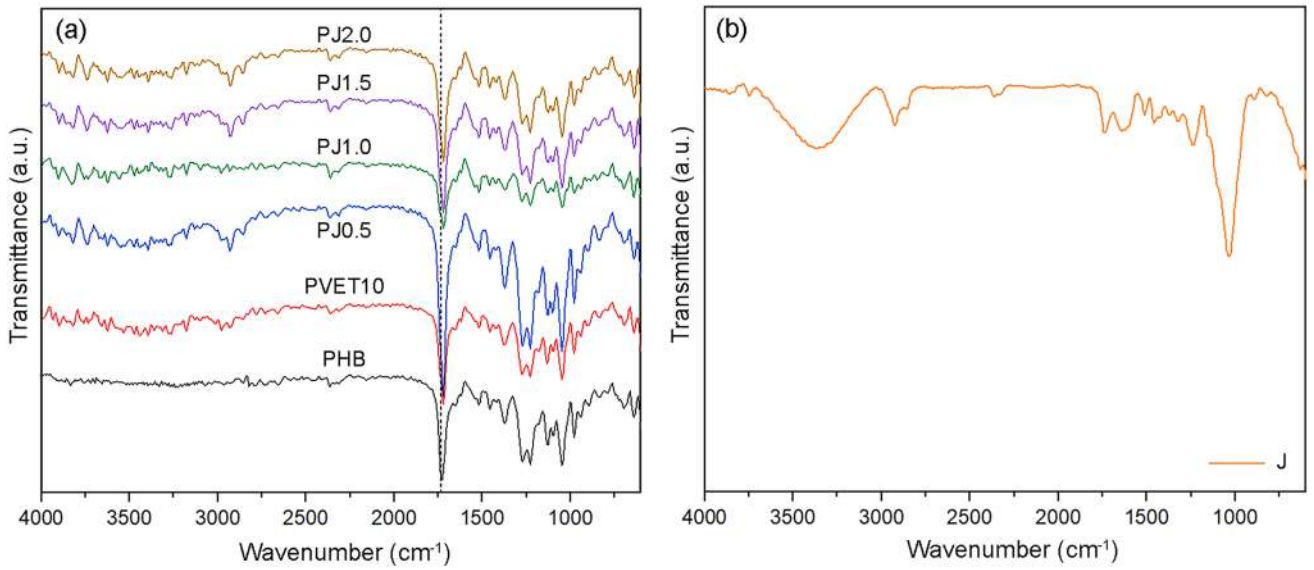


Fig. 1 **a** FTIR spectra of neat PHB, PVET10 and other fiber reinforced films of PJ0.5, PJ1.0, PJ1.5, PJ2.0 and **b** FTIR spectra of *Juglans regia* leaf fiber J

diameter were filled with 10 mL water and sealed with the film. The weight of these glass vials was taken initially and then placed inside a desiccator containing $CaCl_2$. This desiccator was kept in an oven at 30 °C. Further, the weights of these glass vials were taken every 24 h for 3 days. To obtain accurate results, the experiment was conducted in triplicates. Water vapor transmission rate (WVTR) (g/m^2.day) and water vapor permeation (WVP) ($g.mm/m^2$.day.kPa) were calculated by the formula given as (1) and (2):

$$WVTR = \frac{\Delta w}{A \times hours}, \tag{1}$$

$$WVP = \frac{WVTR \times thickness}{\Delta p}, \tag{2}$$

where Δp is the difference in partial vapor pressure (kPa) between both sides of the film, Δw (g) is the change in the weights of vials after 24 h and A is the cup mouth area in m^2.

Hydrolytic degradation

The hydrolytic degradation test was performed under the ASTM F1635-11 standards. To establish the hydrolytic degradation behavior of scaffold samples, these were incubated using 25 mM phosphate buffer saline at pH 7.4 and 37 °C in a thermostat for 16 weeks in triplicates. After every five days, the buffer was also replaced with the freshly prepared one, and films were taken out of the buffer, washed, dried, and weighed. A graph between weight percentage and time (weeks) was plotted which provides information about the durability of scaffolds in the extracellular environment.

Cytotoxicity of scaffolds

The cytotoxicity evaluation of the scaffolds was performed in accordance with ISO10993 guidelines. According to the guidelines, sold scaffold samples and their extracts were examined for cytotoxicity against mouse skeletal muscle cell lines.

(a) Cell culture Mouse skeletal muscle cell line (C2C12) was cultured in growth media (GM) i.e., Dulbecco's modified Eagle's medium (DMEM), supplemented with 20% fetal bovine serum (FBS), 5 µg/mL ciprofloxacin and 2.5 µg/mL amphotericin B at 37 °C in the presence of 5% CO_2. These cells (~90% confluency) were used to assess the cytotoxicity of the scaffolds.

(b) Sterilization of scaffolds First, PHB (the control) and PJ1.0 (optimum sample) with thickness of 0.04–0.05 mm were cut into square shapes of varying surface area (1×1 cm, 2×2 cm, 4×4 cm, and 8×8 cm). The cut samples from both scaffolds were placed in a Petri plate and sterilized with 70% ethanol for 30 min. Further, the samples were washed and autoclaved. These samples were divided into two groups. For the first group, cut samples (triplicates) were placed in the GM (300 µL) for 24 h to acquire leached of any components (used for the formation of these scaf-

Principal
Dyal Singh College
KARNAL

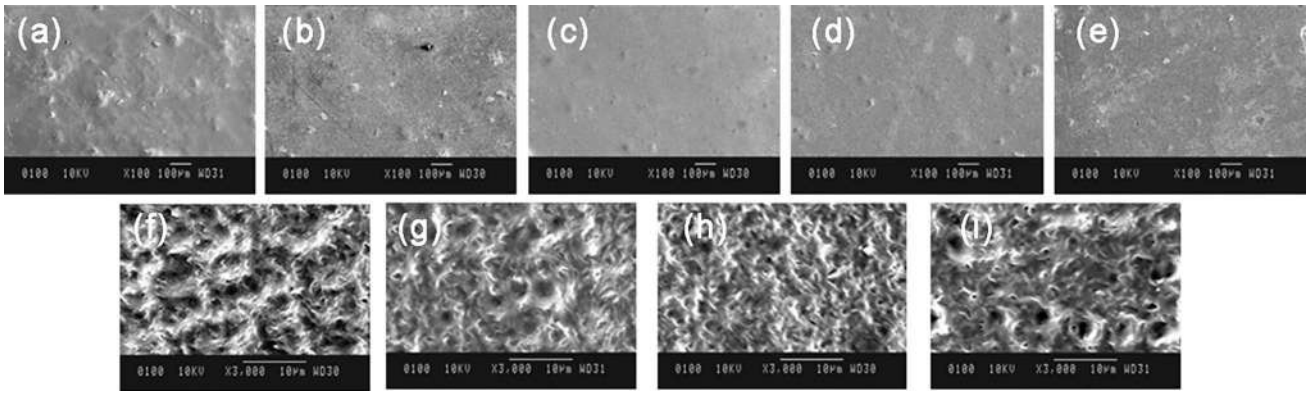


Fig. 2 SEM images of: **a** PHB, **b** PVET10, **c** PJ0.5, **d** PJ1.0, **e** PJ2.0 at 100X magnifications and 3000X magnifications of **f** PVET10, **g** PJ0.5, **h** PJ1.0 and **i** PJ2.0

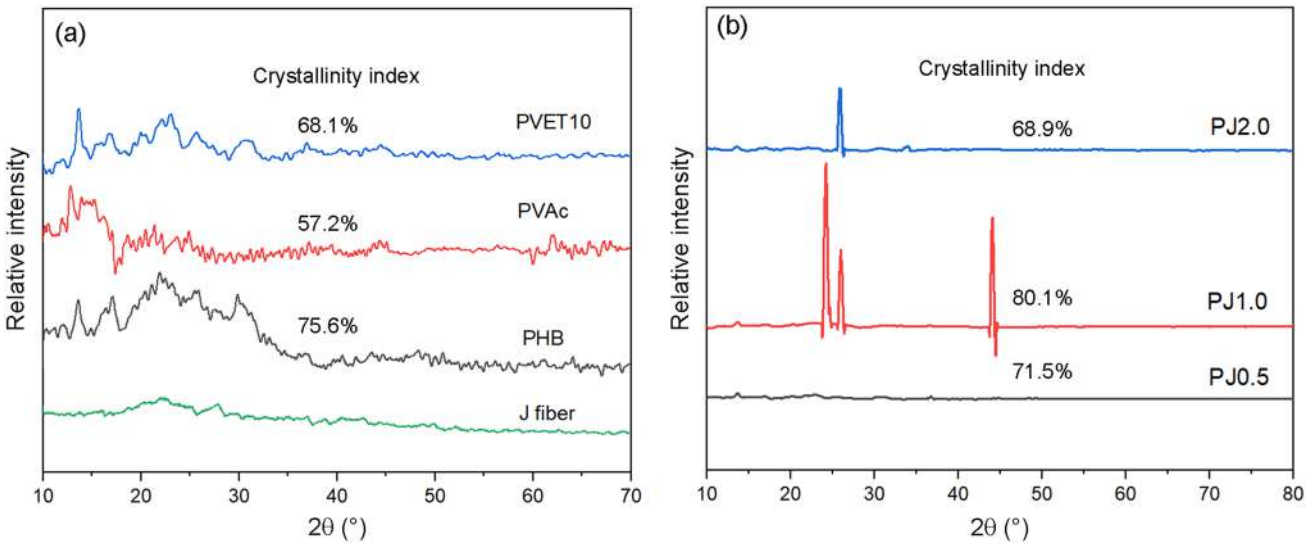


Fig. 3 **a** X-Ray diffractograms of J, PHB, PVAc, and their blend PVET10 and **b** X-ray diffractograms for PJ0.5, PJ1.0 and PJ2.0 composites

folds). Thereafter cells were treated with GM (300 µL) having leached components. This group was named as leached component containing group (Group I). The other set of cut samples (triplicates) were placed directly with C2C12 cells for cytotoxicity study without keeping them in the growth media for 24 h, known as Group II.

(c) Cytotoxic effect of Group I and Group II on C2C12 cells by MTT assay To study the possible cytotoxic effects, scaffolds and their leached components (Group II and Group I, respectively) were incubated with C2C12 cells for 24 h. Representative photographs of treated cells (viable/non-viable) were taken using a bright field microscope (Nikon) after 24 h. Thereafter, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-tetrazolium bromide (MTT) assay was carried out to quantify the viability of the cultured cells.

(d) MTT Assay: Assay is based on the reduction of the yellow tetrazolium salt (MTT) to purple formazan crystals by dehydrogenase enzymes secreted from the mitochondria of metabolically active (viable) cells. The amount of purple formazan crystals formed is directly proportional to the number of viable cells.

For the assay, group I and II treated cells were incubated with MTT solution (5 mg/mL in PBS) for 4 h at 37 °C followed by treatment with DMSO (150 µL). The absorbance was taken at 570 nm.

Statistical analysis

Statistical analysis was conducted on the data by performing each experiment in triplicates. The analysis of variance (ANOVA) method was utilized for this purpose. The data

Principal
Dyal Singh College
KARNAL

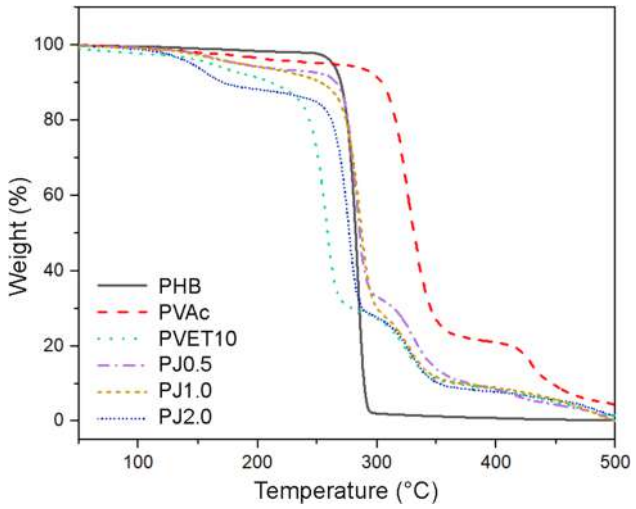


Fig. 4 TGA of PHB, PVAc, PVET10 and PJ0.5, PJ1.0 and PJ2.0 composites

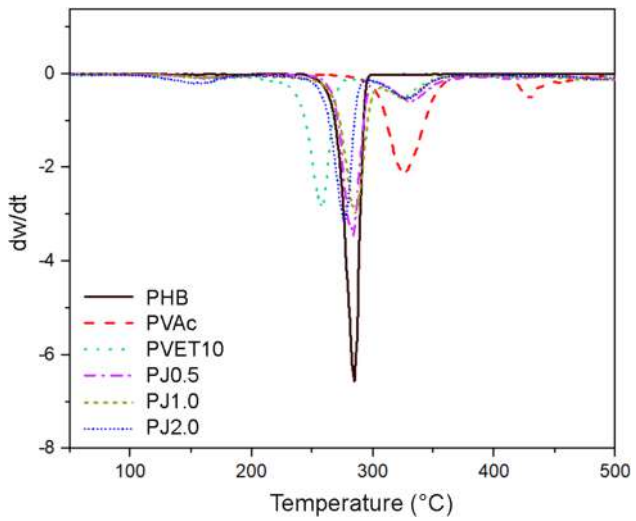


Fig. 5 DTG of PHB, PVAc, PVET10 and PJ0.5, PJ1.0 and PJ2.0 composites

were then presented as mean ± standard deviation (SD) values.

Results and discussion

FTIR

The FTIR spectra of PHB, PVET10, and other fiber reinforced films PJ0.5, PJ1.0, PJ1.5 and PJ2.0 are displayed in Fig. 1. In the spectra of PHB, major absorption peaks at 1730 and 2980 cm^{-1} are assigned to – C = O stretching of the ester functional group and C-H asymmetric stretching, respectively. For the film PVET10 and the other fiber reinforced films, the peak of the – C = O group shifts towards the lower wavenumber, i.e., up to 1720 cm^{-1}. The reason could be attributed to the dipole–dipole interactions between – C = O and $-CH_3$ groups present in the added components. The peak in the band region of 3000–3500 cm^{-1} was also observed for PVET10 which was attributed to the presence of number of –OH groups present in PEG polymer. The peak between regions of 1225–1285 cm^{-1} belongs to the stretching C-O and C–C bonds present in the added polymers.

After the inclusion of *Juglans regia* leaf fiber, the increase of intensity for O–H and C = O groups was observed. As the concentration of J particles increases, the intensity of the C = O peak and OH peak initially decreases until reaching 1.0% J, after which begins to increase again. This fluctuation might be attributed to optimal compatibilization which occurred through hydrogen bonding of – C = O group with OH group of polymers and cellulose present in *Juglans regia* leaf fiber (J) within the PJ1.0 composite. This association of OH group with other components is the major indication of the interaction between fiber and the polymers. Similar pattern of ester and hydroxyl groups was also reported during the reinforcement of cellulose nanocrystals into PHA matrix [29]. Further, the slight increase in intensity of OH band occurred due to the formation of agglomerates. Thus, these results demonstrated the presence of cross-links between all the components used for the synthesis of composites. Similar peaks were observed in a previous study where microcrystalline cellulose fiber was incorporated in PHB [30].

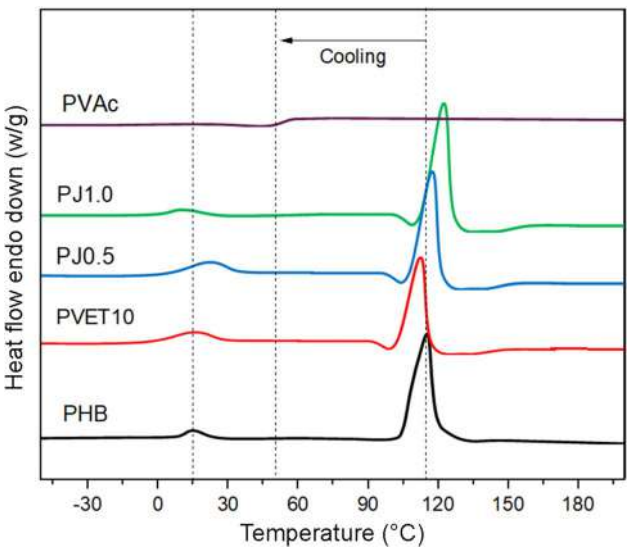


Fig. 6 The cooling cycle of DSC thermograms of PHB, PVAc, PVET10 and PJ0.5 and PJ1.0 composites

Principal
Dyal Singh College
KARNAL

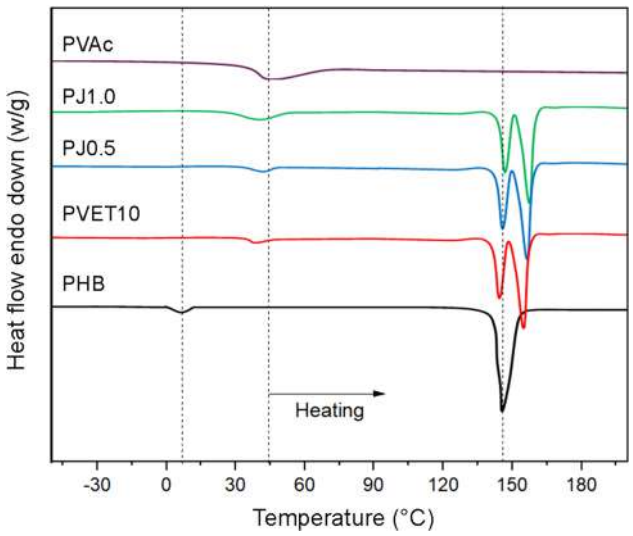


Fig. 7 The heating cycle of DSC thermograms of PHB, PVAc, PVET10 and PJ0.5 and PJ1.0composites

Scanning electron microscopy (SEM)

The detailed analysis of the surface morphology of the samples was done by SEM as shown in Fig. 2. Pure PHB film has micro-textures on its surface as shown in Fig. 2a. The film PVET10 in Fig. 2b exhibits a smooth surface and least number of pores due to the addition of plasticizer tributyrin [31]. After the incorporation of fiber, films tend to show high surface roughness Fig. 2c–e. The film containing 0.5% of fiber exhibits pores of size 1.26 µm in Fig. 2g while for PJ1.0 film, the homogeneous dispersion and reduced pore size of approximately 0.76 µm can be seen at higher magnifications in Fig. 2h. However, at further fiber loading (PJ2.0), the film showed greater inhomogeneity which might be associated with the entanglement of fiber particles that led to the larger pore size of 2.26 µm as indicated in Fig. 2i. Similar results were observed for the incorporation of graphene particles into the PHBV matrix [32] and carboxymethylcellulose in poly(vinyl alcohol) [33].

XRD analysis

X-ray diffraction was carried out to evaluate the crystallinity of the pure PHB, PVAc, J fiber, and their composites (Fig. 3). PHB is a highly crystalline polymer that showed the diffraction peaks at 2θ Bragg's angle = 13.5°, 17.0°, 21.8°, 25.8° and 29.8° as reported in the literatures [34, 35]. These peaks closely overlap with the two diffraction peaks of amorphous PVAc at 2θ = 12.81°, 15.32°, 21.40° and 24.92°. In PVET10, the appearance of two weak peaks at 22.96°, 30.5°, and 36.8° can be ascribed to the addition of PEG and TB in the polymer matrix.

Table 3 Mechanical parameters for PHB, PVAc, their blends, and PJ composites

Sample code	Tensile strength (σ) (MPa)	Elongation-at-break (ε) (%)
PHB	9.8 ± 0.0	2.5 ± 0.0
PVAc	17.9 ± 0.0	0.0 ± 0.0
PHB/PVAc/PEG/TB (PVET10)	**19.4 ± 0.0**	**33.0 ± 4.2**
PJ0.5	23.3 ± 1.3	19.3 ± 3.0
PJ1.0	**24.6 ± 0.2**	**18.4 ± 1.5**
PJ1.5	20.3 ± 0.5	15.5 ± 0.7
PJ2.0	14.6 ± 0.7	13.0 ± 1.0
PJ2.5	9.7 ± 0.4	8.5 ± 0.7

In the diffractograms of composite samples, the most intense peak of cellulose near 24.1° can be observed. Similar cellulosic peaks have been reported in a study where composites of cellulose with starch were prepared [36]. However, no significant displacements were detected in the peaks of PHB with the addition of other additives and fiber. Moreover, the values of crystallinity, X_c, decreased from 75.6% for pure PHB to 68.1% for the PVET10 blend which could be attributed to the interlamellar segregation in the polymer matrix. Even though the rise in X_c to 80.1% was found for PJ1.0, it indicates the regular arrangement of fiber particles in between the interlamellar region of the matrix. A similar phenomenon has been detected when cassava/sugar palm fiber reinforced cassava starch hybrid composites were synthesized [37]. The entanglement of fiber particles at high fiber loading (PJ2.0) can be the reason for 68.9% crystallinity. An analogous phenomenon was observed when no change in crystallinity was noticed even after increasing the concentration of bamboo fiber in PHBV [38].

Thermogravimetric analysis (TGA)

The thermal profiles for PHB and its composites at the heating rate of 10 °C/min are displayed in Figs. 4 and 5. The neat polymers did not show any mass loss until 200 °C. Pure PHB displayed a single-step pyrolysis, resulting in approximately 98.7% weight loss up to 266 °C. This degradation process primarily involved the ester cleavage of PHB through a β-elimination reaction [39]. On the other hand, pure PVAc decomposed in two stages, with weight losses of 78.3% up to 303.2 °C and 17.2% up to 420.5 °C. The first stage of thermal degradation was attributed to deacetylation, while the second stage resulted from the structural degradation of the polyene backbone [40].

For all other samples, degradation occurred in three stages associated with moisture loss. The blending of polymers slightly decreased the thermal stability which could be explained by the formation of i

Principal
Dyal Singh College
KARNAL

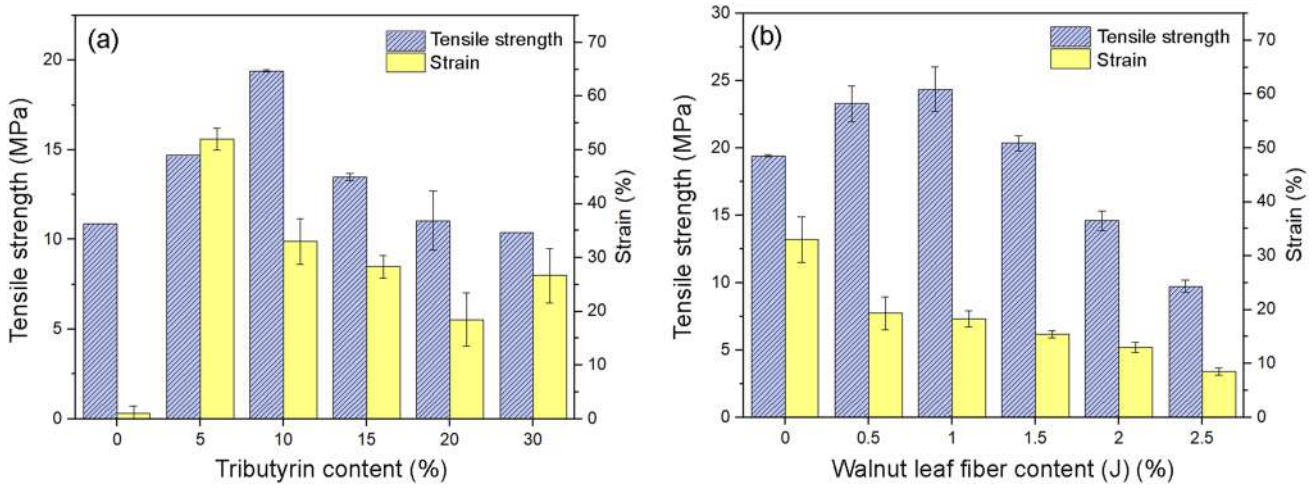


Fig. 8 **a** Effect of plasticizer (tributyrin) on the mechanical properties of PHB/PVAc/PEG blends and **b** effect of J (*Juglans regia* leaf fiber) on the mechanical properties of PVET10 blends

to the added plasticizer. These gaps facilitate the escape of produced gaseous molecules at lower temperatures [31].

After the addition of fiber, improved thermal stability was observed for PJ0.5 and PJ1.0 compared to PVET10. This primarily occurred due to the homogeneous dispersion of the fibers and enhanced crystallinity [41]. However, at higher concentration, PJ2.0 showed poor thermal stability due to the uneven distribution of fibers and reduced adhesion between the fiber and matrix.

Differential scanning calorimetry (DSC)

It is of great interest to study the melting and crystallization behavior of polymer composites since it affects not only the microscopic but also the macroscopic properties of materials. Therefore, PHB and its composites were analyzed through DSC technique (Fig. 6). On cooling the melt, neat PHB showed the peak crystallization temperature (T_c) of 116 °C. Similar value of T_c of 112 °C was reported by Pracella et al. where PHB/PVAc blends were reinforced with cellulose particles [29]. However, PVET10 blend caused T_c to decrease to 113 °C due to the amorphous nature of the miscible polymer blend. For PJ1.0, T_c shifts towards higher temperature of 120 °C which inferred that fiber particles accelerate the crystallization process. As well, little sharpening of the crystallization peak demonstrated the homogeneous dispersal of fiber; hence, more sites are available for efficient nucleation and crystallization. An analogous nucleation effect has been reported earlier for other fillers like coir fibers and micro fibrillated cellulose in PLA matrix [18, 42].

The heating scan obtained after the cooling run is presented in Fig. 7. A single melt peak was developed for pure PHB at a peak melting temperature (T_m) of 146 °C, as also reported by a study where PHB was mixed with PLLA [43]. While PVET10 and other composites exhibit bimodal behavior. In PVET10, the first endotherm at $T_{m1} = 143$ °C arises when the original miscible phase melts, while the other arises at $T_{m2} = 155$ °C due to the melting of crystals formed as a result of restructuring phenomena. After the incorporation of fiber into the matrix, the position of endotherms has shifted towards higher temperatures. This could be attributed to the strong fiber-matrix interactions, i.e., hydrogen bonds formed between the hydroxyl groups of the fibers and the carbonyl groups of polymer matrix that restricted polymer chain mobility [44]. A similar effect has been described by Pascual et al. where ZnO particles were reinforced into the PHB-*co*-HV matrix [45]. A close analysis of glass transition temperature (T_g) was also made using these DSC scans. Neat PHB and PVAc showed a T_g value near 6 °C and 45 °C, respectively. A marked decrease in T_g value was observed for PVET10 at 36 °C [29]. Moreover, in composites, a noticeable increase of T_g was visible, from 36 °C to 41 °C for PJ1.0. Similar effects were also observed by Cheng et al. when PEG was absorbed into cellulose nanocrystals [46].

Mechanical testing

As depicted in Table 3, tensile testing indicated that pure PHB and PVAc are brittle materials with lower elongation-at-break [47]. PVAc exhibited a tensile strength (σ) of 18.0 MPa, which is twice the value of PHB. When comparing the values of pure polymers with blends (Fig. 8), it was observed that the PVET10 blend showed an increase in the σ value from 9.8 MPa (PHB) to 19.4 MPa. Furthermore, the PVET10 demonstrated the value of 33.4% elongation-at-break which is quite higher than PHB (2.5%). This improvement in mechanical properties can be attributed to

Principal
Dyal Singh College
KARNAL

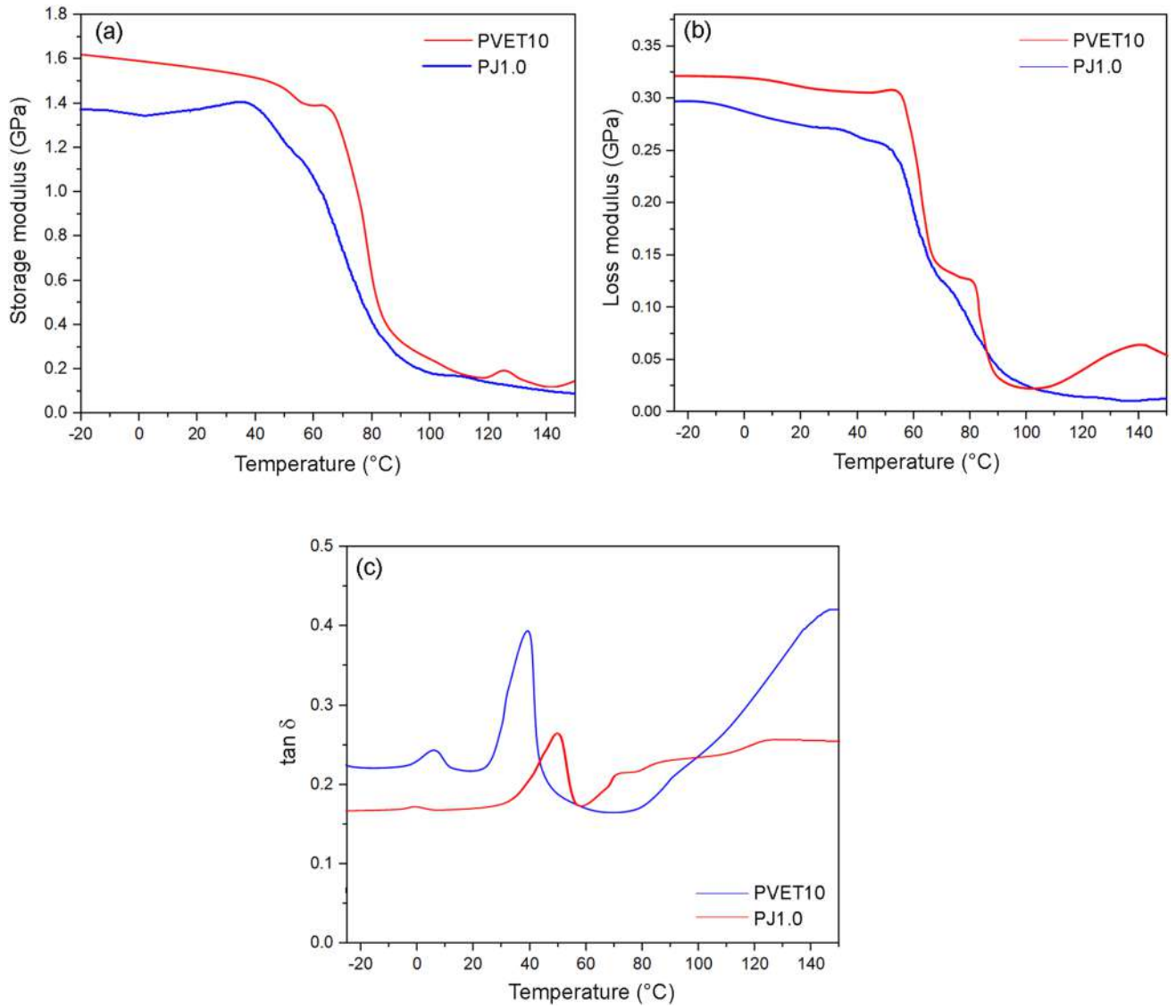


Fig. 9 DMA measurements of: **a** storage modulus of PVET10 and PJ1.0 as a function of temperature, **b** loss modulus of PVET10 and PJ1.0 as a function of temperature, and **c** tan δ PVET10 and PJ1.0 as a function of temperature

the interfacial interaction between different polymer chains present in the blend. These interactions are likely to be enhanced through hydrogen-bonding involving free OH groups of PEG. A previous study also detected the enhanced mechanical performance for PHB/PEG fiber mats than pure PHB [48]. In addition, tributyrin occupies intermolecular gaps within the polymeric chains, thereby altering the three-dimensional molecular association of the polymers. This situation resulted in increased molecular mobility [49, 50].

The inclusion of *Juglans regia* leaf fiber results in an improvement in the tensile strength (σ) from 19.4 MPa for PVET10 to 25.0 MPa for PJ1.0. This enhancement could be attributed to the homogeneous dispersion of the small-sized *Juglans regia* leaf particles, which probably led to increased fiber-matrix interaction and crystallinity, as confirmed by XRD analysis. However, when the fiber content exceeds 1%, both tensile strength and elongation-at-break begin to decrease. This happened due to the agglomeration of fibers which reduced the contact area between the fiber and matrix, consequently limiting the transfer of stress [51].

Dynamic mechanical analysis (DMA)

Figure 9 shows the mechanical performance of PVET10 and PJ1.0 (the optimized film) under refrigerated to heating conditions. The temperature dependence of storage modulus, loss modulus, and damping factor (Tan δ) was accessed by dynamic mechanical analysis. Neat PHB film gave very poor DMA thermogram and therefore was not displayed. At − 20 °C, high storage modulus values can be observed for

Principal
Dyal Singh College
KARNAL

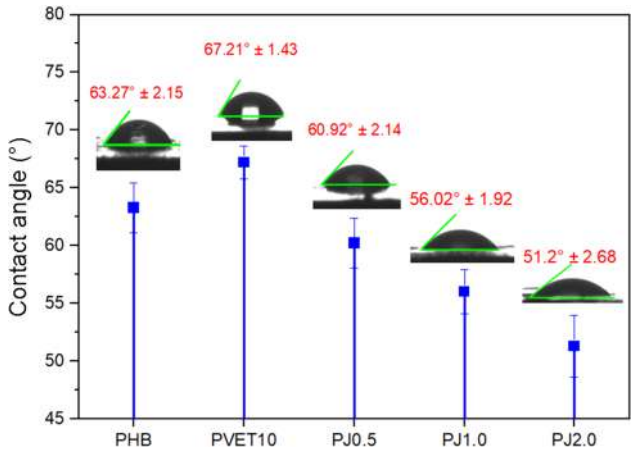


Fig. 10 Contact angle measurement of pure polymer PHB, PVAc, their blends PVET10 and PJ0.5, PJ1.0 and PJ2.0 composites

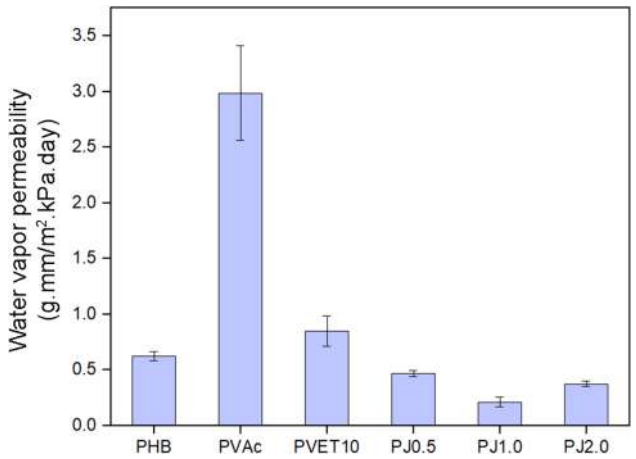


Fig. 11 Water vapor permeability values of PHB, PVAc, PVET10 and PJ0.5, PJ1.0, and PJ2.0 composites

PJ1.0. The first major transition related to T_g was appeared near 37 °C and 44 °C for PVET10 and PJ1.0, respectively (Fig. 9c). The high value of storage modulus and T_g indicated that the reinforcement of fiber particles restricted the motion of large segments of polymer chains in the composites [52, 53]. These results are consistent with the tensile testing, where the significant reinforcing effect of such natural fibers was described.

Moreover, the introduction of J broadened the Tan δ peak and also reduced its peak height [54]. This might be attributed to the least imperfections in the matrix that appeared

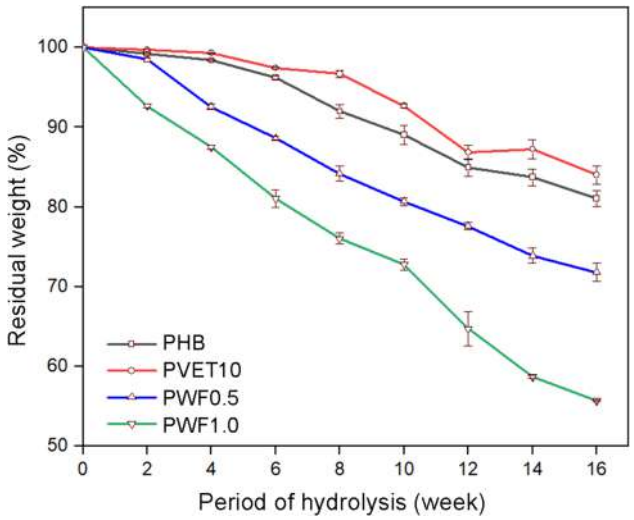


Fig. 12 Hydrolytic degradation of the PHB, PVET10, PJ0.5, PJ1.0 under physiological conditions

due to its hampered motion [45]. Overall, DMA demonstrated that the developed biocomposites exhibited higher stiffness compared to the neat film under heating and freezing conditions.

Water contact angle measurement

To study the effect of addition of fiber on surface wettability, contact angle for the pure polymer and its composites was determined and presented in Fig. 10. Pure PHB has a contact angle (CA) value of 63.27° ± 2.15, and PVET10 blend showed the value of 67.21° ± 1.43. This increase in CA could be attributed to the smoother surface of the plasticized blend. Moreover, the inclusion of *Juglans regia* leaf fiber (J) resulted in increased surface roughness and enhanced hydrophilicity, as indicated by the reduction in the contact angle of more than 10° for PJ1.0. The rough surface of the composite makes it easier for the droplets to penetrate easily onto its surface. Along with this, the inclusion of fiber enhances the abundance of hydrophilic elements such as OH groups, consequently enhancing the wettability of the composite. Similar results were also reported by the studies where the wettability nature of the PLA/palm fiber and PLA/*Juglans regia* shell flour composite was examined [55, 56].

Water vapor permeation test

The water vapor permeability (WVP) of PHB composites is shown in Fig. 11. WVP of PVAc films was found to be higher due to its slight hydrophilic nature [57]. The permeation value was increased from 0.62 for PHB to 0.84 g.mm/m^2.day.kPa for PVET10. This was due to the addition of plasticizing additives which induced molecular motion and

Principal
Dyal Singh College
KARNAL

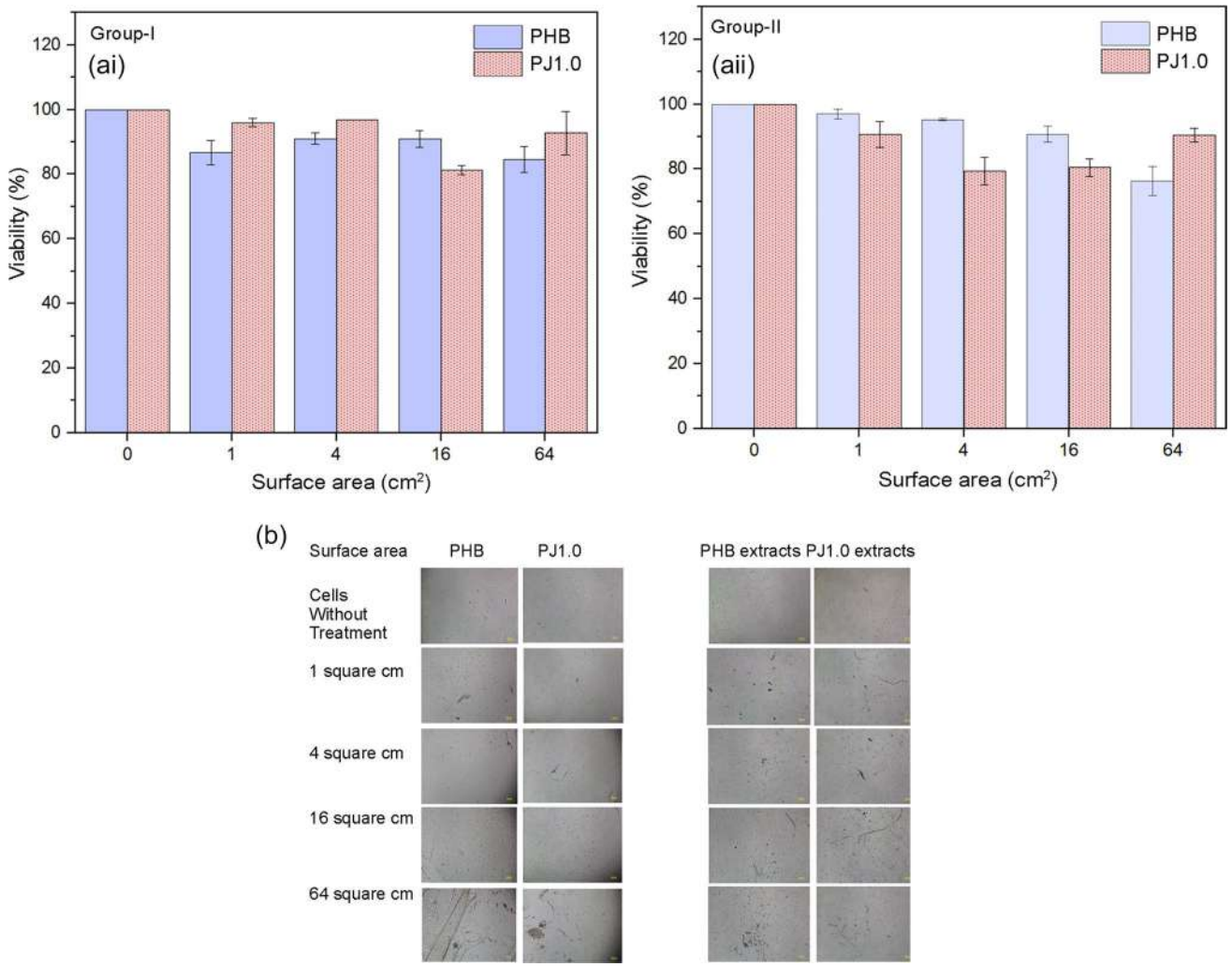


Fig. 13 Cell cytotoxicity study by MTT assay for PHB and PJ1.0 scaffolds with varying surface area (1×1 cm, 2×2 cm, 4×4 cm, and 8×8 cm—group II); their leachable components (group I). **a** i-ii quantification and **b** bright-field images

hence increase in WVP. These findings are similar to the results obtained when tributyl citrate was used as an effective plasticizer [31]. The films reinforced with the fiber were permeating less water than other films. The PJ1.0 sample showed the least permeability (0.21 g.mm/m^2.day.kPa) due to its high crystallinity. This caused the polymer chains to be fitted with each other which eventually leads to low WVP [58]. However, an increase of 76% in WVP was observed for PJ2.0 film, which happens due to agglomeration of excess fiber particles. Similar results were indicated when apricot and *Juglans regia* shells were utilized as reinforcement materials in starch-based films [59].

Hydrolytic degradation

The hydrolytic degradation of PHB, PVET10, PJ0.5 and PJ1.0 was carried out in phosphate buffer saline of pH 7.4 at 37 °C over 16 weeks. There was no significant weight loss observed for PHB within the first 2 weeks of hydrolysis period (Fig. 12). After 16th week of hydrolytic degradation, the total weight loss of 18.4% was marked. This might be due to the random cleavage in PHB chain segments. However, the addition of PVAc, tributyrin and PEG led to an overall slow degradation of about 15%. This could be explained by contact angle measurements where the incorporation of these additives enhanced the hydrophobic nature and hence the hydrolytic stability. An analogous effect has been observed when hydrolytic degradation of PHB, PLA and their derivatives was investigated [60].

On the other hand, the addition of *Juglans* leaf fiber led to the accelerated degradation of the composites. This happened due to the enhanced water uptake by the hydroxyl groups present in fiber. As the amount of fiber particles increases, the composites PJ0.5 and PJ1.0 degraded much

Principal
Dyal Singh College
KARNAL

easily. PJ1.0 degraded about 44.6% in 16 weeks compared to 18.4% degradation of neat PHB. A decrease in contact angle value due to the hydrophilic nature of the fiber was also observed. These results are analogous to the study of PLA with short jute fibers, hemp fibers [15, 61]. Therefore, the addition of natural fiber comes across as an effective method for the accelerated degradation of natural PHB. Such robust as well as degradable polymers show a wide range of applications in everything from sutures to implants to drug delivery.

Cytotoxicity of scaffolds

The potential of PJ1.0 (optimum sample) as a scaffold material for cells was evaluated through the MTT cytotoxicity assay using C2C12 mouse skeletal muscle cell lines. PHB (control) and PJ1.0 (optimum sample) scaffolds with different surface areas (1×1 cm, 2×2 cm, 4×4 cm, and 8×8 cm), as well as their leached components, were used to check the cell cytotoxicity as described in Materials and methods. The viability of cells in direct contact with the scaffolds and their leached components was compared to the viability of cells cultured without any treatment. Figure 13a–b represent the cytotoxicity data of PHB, PJ1.0 scaffolds (with varying surface areas), and their leached components. Data demonstrate that PJ1.0 (optimum sample) scaffolds with different surface areas and their leached components are non-toxic to C2C12 cells. The bright field photomicrographs also show that leachable components (group I) and direct scaffold (group II) did not show any toxic effect on C2C12 cells even after 24 h incubations with C2C12 cells. These results depict not only the non-toxic behavior of scaffolds but also illustrate that other components which are used in making these scaffolds, if leached, are also non-toxic to cells. Such data strongly support the compatibility of the scaffolds under study to animal cells.

The findings of other available reports with natural fibers (i.e., flex and jute) also suggested that composites used in natural fibers are compatible with human cells [62, 63].

Overall cytotoxicity data confirm that composites used under study exhibit the potential to be used as sustainable and mechanically robust materials for further biomedical applications.

Conclusion

The purpose of this study was to prepare materials with tunable properties for biomedical applications. In this work, *Juglans regia* leaf fiber (J)-reinforced PHB/PVAc/PEG composites were prepared by the solvent-casting method. The optimum concentration of fiber in composites was analyzed based on their mechanical, thermal, and water barrier properties. On this account, 1% (by weight) concentration of fiber was found to be the optimum concentration for PHB/PVAc/PEG. The incorporation of 1% (by weight) *Juglans* leaf fiber into the PHB matrix (PJ1.0) offered several advantages, including improved tensile strength, storage modulus, water barrier properties, and hydrolytic degradation. In addition, these biocomposites showed accelerated degradation in 16-week hydrolysis under physiological conditions. Due to enhanced hydrolytic degradation than PHB, the incorporation of fiber could be a means of producing biomaterials with controlled hydrolytic stability. Moreover, by assessing the cytotoxicity, it is evidenced that PJ1.0 and its extract were not toxic for C2C12 cells. Thus, the findings of this study showed that these biocomposites have significant potential for the development of sustainable and mechanically robust materials for biomedical applications. Overall, this research endeavors to contribute to the field of biomaterials by exploring the potential of PHB/*Juglans regia* leaf reinforced films as a sustainable alternative for biomedical uses.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13726-024-01367-w.

Acknowledgements One of the authors, Simran Ahuja is thankful to the Council of Scientific and Industrial Research (CSIR), New Delhi, for Senior Research Fellowship, Ref. No.-16/06/2019. Acknowledgment is also due to Chairperson, Chemistry Department, Kurukshetra University, Kurukshetra. We are thankful to CRF-IIT Delhi for providing us with the facilities for water contact angle measurements and IIT Indore for providing DSC facilities. MNIT-MRC (Jaipur) is also acknowledged for DMA measurements. Thanks are also due to Prof. Puneet Tandon (IIITDM, Jabalpur) for helpful discussions regarding Tensile testing.

References

1. Chen GQ, Wu Q (2005) The application of polyhydroxyalkanoates as tissue engineering materials. Biomaterials 26:6565–6578
2. Alamán-Díez P, García-Gareta E, Napal PF, Arruebo M, Pérez MÁ (2022) In vitro hydrolytic degradation of polyester-based scaffolds under static and dynamic conditions in a customized perfusion bioreactor. Materials (Basel) 15:2572
3. Amaro L, Correia DM, Marques-almeida T, Martins PM, Leyre P, Vilas JL, Id GB, Lanceros-mendez S (2018) Tailored biodegradable and electroactive poly(hydroxybutyrate-co-hydroxyvalerate) based morphologies for tissue engineering applications. Int J Mol Sci 19:2149
4. Rezwan K, Chen QZ, Blaker JJ, Boccaccini AR (2006) Biodegradable and bioactive porous polymer/inorganic composite scaffolds for bone tissue engineering. Biomaterials 27:3413–3431
5. Kendre PN, Gite M, Jain SP, Pote A (2022) Nanocomposite polymeric materials: State of the art in the development of biomedical drug delivery systems and devices. Polym Bull 79:9237–9265
6. O'Brien FJ (2011) Biomaterials and scaffolds for tissue engineering. Mater Today 14:88–95
7. Dhania S, Bernela M, Rani R, Parsad M, Grewal S, Kumari S, Thakur R (2022) Scaffolds the backbone of tissue engineering:

Principal
Dyal Singh College
KARNAL

Advancements in use of polyhydroxyalkanoates (PHA). Int J Biol Macromol 208:243–259
8. Pulingam T, Appaturi JN, Parumasivam T, Ahmad A, Sudesh K (2022) Biomedical applications of polyhydroxyalkanoate in tissue engineering. Polymers (Basel) 14:2141
9. Degli Esposti M, Chiellini F, Bondioli F, Morselli D, Fabbri P (2019) Highly porous PHB-based bioactive scaffolds for bone tissue engineering by in situ synthesis of hydroxyapatite. Mater Sci Eng C 100:286–296
10. Yeo JCC, Muiruri JK, Thitsartarn W, Li Z, He C (2018) Recent advances in the development of biodegradable PHB-based toughening materials: approaches, advantages and applications. Mater Sci Eng C 92:1092–1116
11. Zubir NHM, Sam ST, Zulkepli NN, Omar MF (2018) The effect of rice straw particulate loading and polyethylene glycol as plasticizer on the properties of polylactic acid/polyhydroxybutyrate-valerate blends. Polym Bull 75:61–76
12. Lai S-M, Sun W-W, Don T-M (2015) Preparation and characterization of biodegradable polymer blends from poly(3-hydroxybutyrate)/poly(vinyl acetate)- Modified corn starch. Polym Eng Sci 55:1321–1329
13. Ahuja S, Mittal M, Aggarwal NK, Arora S (2024) Enhancing the potentialof poly(hydroxybutyrate)/poly(lactic acid) films with olive oil and zinc oxide for active food packaging. Macromol Chem Phys 2300437:1–11
14. Ahuja S, Verma A, Arora S (2024) Evaluation of mechanical, permeation, and degradation properties of poly(hydroxybutyrate) blends for sustainable packaging. Asia-Pacific J Chem Eng e3073
15. Mazzanti V, Salzano de Luna M, Pariante R, Mollica F, Filippone G (2020) Natural fiber-induced degradation in PLA-hemp biocomposites in the molten state. Compos Part A Appl Sci Manuf 137:105990
16. Moura S, Demori R, Miranda R, Luis C, Frankenberg C, Marlene R, Santana C (2019) The influence of the coconut fiber treated as reinforcement in PHB (polyhydroxybutyrate) composites. Mater Today Commun 18:191–198
17. Wu CS, Liao HT, Cai YX (2017) Characterisation, biodegradability and application of palm fibre-reinforced polyhydroxyalkanoate composites. Polym Degrad Stab 140:55–63
18. Běhálek L, Maršálková M, Lenfeld P, Habr J, Bobek J, Seidl M (2013) Study of crystallization of polylactic acid composites and nanocomposites with natural fibres by DSC method. NANOCON Conf Proc 10:1–6
19. Kuciel S, Liber-Kneć A (2011) Biocomposites based on PHB filled with wood or kenaf fibers. Polimery/Polymers 56:218–223
20. Torres-Tello EV, Robledo-Ortíz JR, González-García Y, Pérez-Fonseca AA, Jasso-Gastinel CF, Mendizábal E (2017) Effect of agave fiber content in the thermal and mechanical properties of green composites based on polyhydroxybutyrate or poly(hydroxybutyrate-co-hydroxyvalerate). Ind Crops Prod 99:117–125
21. Sharahi M, Hivechi A, Bahrami SH, Hemmatinejad N, Milan PB (2021) Co-electrospinning of lignocellulosic nanoparticles synthesized from walnut shells with poly(caprolactone) and gelatin for tissue engineering applications. Cellulose 28:4943–4957
22. Song X, Guan W, Qin H, Han X, Wu L, Ye Y (2022) Properties of poly(lactic acid)/walnut shell/hydroxyapatite composites prepared with fused deposition modeling. Sci Rep 12:1–13
23. Altan E, Karacelebi Y, Saatcioglu E, Ulag S, Sahin A, Aksu B, Croitoru AM, Codrea CI, Ficai D, Gunduz O, Ficai A (2022) Fabrication of electrospun Juglans regia (Juglone) loaded poly(lactic acid) scaffolds as a potential wound dressing material. Polymers (Basel) 14:1971
24. Chamorro F, Carpena M, Lourenço-Lopes C, Taofiq O, Otero P, Cao H, Xiao J, Simal-Gandara J, Prieto MA (2022) By-products of walnut (Juglans regia) as a source of bioactive compounds for the Formulation of nutraceuticals and functional foods. Biol Life Sci Forum 12:35
25. Croitoru A, Ficai D, Ficai A, Andronescu E (2019) Evaluation and exploitation of bioactive compounds of walnut, Juglans regia. Curr Pharm Des 25:119–131
26. Al-Snafi AE (2018) Chemical constituents, nutritional, pharmcological and therapeutic importance of Juglans regia: a review. IOSR J Pharm 8:1–21
27. Zheng H, Sun Z, Zhang H (2020) Effects of walnut shell powders on the morphology and the thermal and mechanical properties of poly(lactic acid). J Thermoplast Compos Mater 33:1383–1395
28. Jouyandeh M, Vahabi H, Rabiee N, Rabiee M, Bagherzadeh M, Saeb MR (2022) Green composites in bone tissue engineering. Emergent Mater 5:603–620
29. Pracella M, Mura C, Galli G (2021) Polyhydroxyalkanoate nanocomposites with cellulose Nanocrystals as biodegradable coating and packaging materials. ACS Appl Nano Mater 4:260–270
30. El-Hadi AM (2013) Influence of microcrystalline cellulose fiber (MCCF) on the morphology of poly(3-hydroxybutyrate) (PHB). Colloid Polym Sci 291:743–756
31. Chaos A, Sangroniz A, Gonzalez A, Iriarte M (2019) Tributyl citrate as an effective plasticizer for biodegradable polymers: effect of the plasticizer on the free volume, transport and mechanical properties. Polym Int 68:125–133
32. Barrett JSF, Abdala AA, Srienc F (2014) Poly(hydroxyalkanoate) elastomers and their graphene nanocomposites. Macromolecules 47:3926–3941
33. Shin JY, Lee DY, Yoon JI, Song YS (2020) Effect of CMC concentration on cell growth behavior of PVA/CMC hydrogel. Macromol Res 28:813–819
34. D'Amico DA, Iglesias Montes ML, Manfredi LB, Cyras VP (2016) Fully bio-based and biodegradable polylactic acid/poly(3-hydroxybutirate) blends: use of a common plasticizer as performance improvement strategy. Polym Test 49:22–28
35. Mittal M, Ahuja S, Yadav A, Aggarwal NK (2023) Development of poly(hydroxybutyrate) film incorporated with nano silica and clove essential oil intended for active packaging of brown bread. Int J Biol Macromol 233:123512
36. González K, Retegi A, González A, Eceiza A, Gabilondo N (2015) Starch and cellulose nanocrystals together into thermoplastic starch bionanocomposites. Carbohydr Polym 117:83–90
37. Edhirej A, Sapuan SM, Jawaid M, Zahari NI (2017) Cassava/sugar palm fiber reinforced cassava starch hybrid composites: physical, thermal and structural properties. Int J Biol Macromol 101:75–83
38. Singh S, Mohanty AK, Sugie T, Takai Y, Hamada H (2008) Renewable resource based biocomposites from natural fiber and polyhydroxybutyrate-co-valerate (PHBV) bioplastic. Compos Part A Appl Sci Manuf 39:875–886
39. Sharhan O, Yahaya AH, Nasef MM (2015) Preparation and characterization of poly(3-hydroxybutyric acid)/poly(vinyl acetate) blend films. Asian J Chem 27:979–983
40. Troitskii BB, Razuvaev GA, Khokhlova LV, Bortnikov GN (1973) On the mechanism of the thermal degradation of polyvinyl acetate. J Polym Sci Polym Symp 42:1363–1375
41. Gulati K, Lal S, Arora S (2019) Synthesis and characterization of PVA/starch/CMC composite films reinforced with walnut (*Juglans regia* L.) shell flour. SN Appl Sci 1:1–12
42. Bin Y, Yang B, Wang H (2018) The effect of a small amount of modified microfibrillated cellulose and ethylene–glycidyl methacrylate copolymer on the crystallization behaviors and mechanical properties of polylactic acid. Polym Bull 75:3377–3394
43. Cao K, Liu Y, Olkhov AA, Siracusa V, Iordanskii AL (2018) PLLA-PHB fiber membranes obtained by solvent-free electrospinning for short-time drug delivery. Drug Deliv Transl Res 8:291–302

Principal
Dyal Singh College
KARNAL

44. Mlhem A, Abu-Jdayil B, Tong-Earn T, Iqbal M (2022) Sustainable heat insulation composites from date palm fibre reinforced poly(β-hydroxybutyrate). J Build Eng 54:104617
45. Díez-Pascual AM, Díez-Vicente AL (2014) ZnO-reinforced poly(3-hydroxybutyrate-co-3-hydroxyvalerate) bionanocomposites with antimicrobial function for food packaging. ACS Appl Mater Interf 6:9822–9834
46. Cheng D, Wen Y, Wang L, An X, Zhu X, Ni Y (2015) Adsorption of polyethylene glycol (PEG) onto cellulose nano-crystals to improve its dispersity. Carbohydr Polym 123:157–163
47. El-Hadi A, Schnabel R, Straube E, Müller G, Henning S (2002) Correlation between degree of crystallinity, morphology, glass temperature, mechanical properties and biodegradation of poly(3-hydroxyalkanoate) PHAs and their blends. Polym Test 21:665–674
48. Thanh NH, Olekhnovich R, Sitnikova V, Kremleva A, Snetkov P, Uspenskaya M (2023) PHB/PEG nanofiber mat obtained by electrospinning and their performances. Technologies 11:48
49. Vieira MGA, Da Silva MA, Dos Santos LO, Beppu MM (2011) Natural-based plasticizers and biopolymer films: a review. Eur Polym J 47:254–263
50. Lal S, Kumar V, Jagdeva G, Arora S, Kumar P, Gulati K, Singh O (2022) A sustainable approach to the development of highly degradable packaging films of pectin/guar gum/polyvinyl pyrrolidone: thermal, biodegradation, and mechanical studies with statistical optimization. J Appl Polym Sci 139:1–13
51. Robledo-Ortíz JR, González-López ME, Martín del Campo AS, Pérez-Fonseca AA (2021) Lignocellulosic materials as reinforcement of polyhydroxybutyrate and its copolymer with hydroxyvalerate: a review. J Polym Environ 29:1350–1364
52. Lim JS, Il PK, Chung GS, Kim JH (2013) Effect of composition ratio on the thermal and physical properties of semicrystalline PLA/PHB-HHx composites. Mater Sci Eng C 33:2131–2137
53. Srithep Y, Ellingham T, Peng J, Sabo R, Clemons C, Turng LS, Pilla S (2013) Melt compounding of poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate)/nanofibrillated cellulose nanocomposites. Polym Degrad Stab 98:1439–1449
54. Wei L, Liang S, McDonald AG (2015) Thermophysical properties and biodegradation behavior of green composites made from polyhydroxybutyrate and potato peel waste fermentation residue. Ind Crops Prod 69:91–103
55. Akindoyo JO, Hossen Beg MD, Ghazali S, Islam MR (2016) The effects of wettability, shear strength, and Weibull characteristics of fiber-reinforced poly(lactic acid) composites. J Polym Eng 36:489–497
56. Mazur KE, Bazan P, Liber-Kne A, St J (2022) Analysis of the effect of photo and hydrodegradation on the surface morphology and mechanical properties of composites based on PLA and PHI modified with natural particles. Materials (Basel) 15:878
57. Novoa GAG, Heinämäki J, Mirza S, Antikainen O, Iraizoz Colarte A, Suzarte Paz A, Yliruusi J (2005) Physical solid-state properties and dissolution of sustained-release matrices of polyvinylacetate. Eur J Pharm Biopharm 59:343–350
58. Ahuja S, Bains O, Mittal M, Kamal R, Aggarwal NK, Arora S (2023) Multifunctional chromone-incorporated poly(hydroxybutyrate) luminescent film for active and intelligent food packaging. Int J Biol Macromol 246:125625
59. Ali A, Ali S, Yu L, Liu H, Khalid S, Hussain A, Qayum MMN, Ying C (2019) Preparation and characterization of starch-based composite films reinforced by apricot and walnut shells. J Appl Polym Sci 136:1–10
60. Bonartsev AP, Boskhomodgiev AP, Iordanskii AL, Bonartseva GA, Rebrov AV, Makhina TK, Myshkina VL, Yakovlev SA, Filatova EA, Ivanov EA, Bagrov DV, Zaikov GE (2012) Hydrolytic degradation of poly(3-hydroxybutyrate), polylactide and their derivatives: kinetics, crystallinity, and surface morphology. Mol Cryst Liq Cryst 556:288–300
61. Jiang N, Li Y, Li Y, Yu T, Li Y, Li D, Xu J, Wang C, Shi Y (2020) Effect of short jute fibers on the hydrolytic degradation behavior of poly(lactic acid). Polym Degrad Stab 178:109214
62. Wróbel-Kwiatkowska M, Czemplik M, Kulma A, Zuk M, Kaczmar J, Dymińska L, Hanuza J, Ptak M, Szopa J (2012) New biocomposites based on bioplastic flax fibers and biodegradable polymers. Biotechnol Prog 28:1336–1346
63. Rahman MM, Afrin S, Haque P, Islam MM, Islam MS, Gafur MA (2014) Preparation and characterization of jute cellulose crystals-reinforced poly(l-lactic acid) biocomposite for biomedical applications. Int J Chem Eng 1:842147

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

Authors and Affiliations

Simran Ahuja[1] · Neha Bansal[1] · Mahak Mittal[2] · Kapil Gulati[3] · Ashwani Mittal[4] · Sanjiv Arora[1]

✉ Sanjiv Arora
sarora@kuk.ac.in

[1] Department of Chemistry, Kurukshetra University, Kurukshetra, Haryana 136119, India

[2] Department of Microbiology, Kurukshetra University, Kurukshetra, Haryana 136119, India

[3] Department of Chemistry, Dyal Singh College, Karnal, Haryana 132001, India

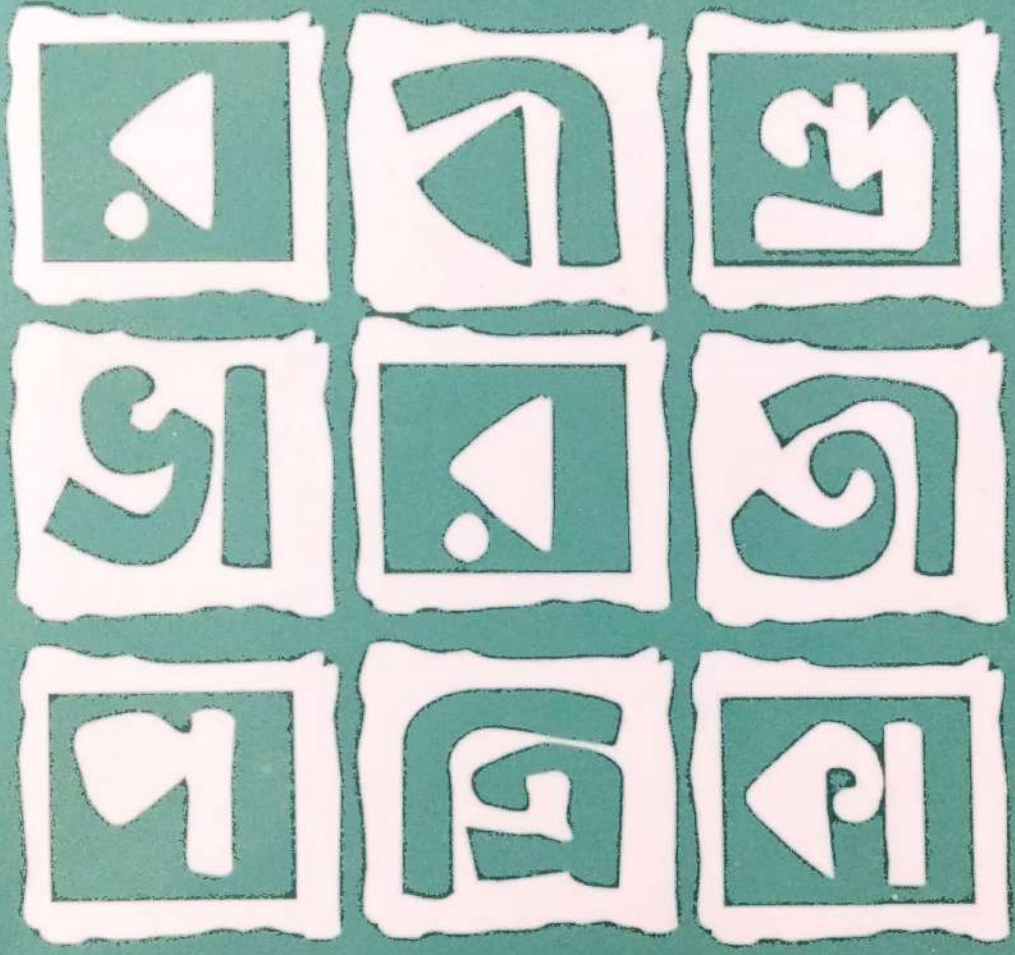
[4] Skeletal Muscle Laboratory, Institute of Integrated and Honors Studies, Kurukshetra University, Kurukshetra, Haryana 136119, India

Principal
Dyal Singh College
KARNAL

ISSN 0937-0037

রবীন্দ্রভারতী পত্রিকা

Volume Twenty Seven | January - March 2024



Rabindra Bharati Patrika

Principal
Dyal Singh College
KARNAL

রবীন্দ্রভারতী পত্রিকা
Rabindra Bharati Patrika

দ্বিভাষিক

Bilingual

Volume Twenty Seven | January - March 2024

রবীন্দ্রভারতী বিশ্ববিদ্যালয়
Rabindra Bharati University
৫৬এ, বি. টি. রোড, কলকাতা - ৭০০০৫০
56A, B. T. Road, Kolkata - 700050

Principal
Dyal Singh College
KARNAL

ISSN 0937-0037
A Refereed Journal
[Enlisted in UGC Care List, Serial No.127]

New Series | Volume Twenty-Seven | January-March 2024

Chief Editor
Dr. Kanika Mukhopadhyay
Vice-Chancellor, Rabindra Bharati University

Editors
Swati Mohan
Paul Sen Gupta
Debalina Ganguly

Manager
Aditya Prasad Niyogi

Printer
Print-It, Rabindra Bharati University

Publisher
J.B.S. International
Kolkata - 700049

Principal
Dyal Singh College
KARNAL

Chief Editor
Dr. Kanika Mukhopadhyay



Rabindra Bharati University
Emerald Bower Campus, 56A,
B.T. Road, Kolkata - 700050

Greetings

This issue, containing articles on various topics by renowned teachers and researchers, will undoubtedly attract readers. We hope that this special issue of Rabindra Bharati Patrika will be warmly received by the readers.

Dr. Kanika Mukhopadhyay
Vice-Chancellor

Principal
Dyal Singh College
KARNAL

Content

• The reservation of women including individuals from more vulnerable segments	Kanika Kumari	1
• Smart Contracts and the Indian Contract Act: Examining Legal Foundations in Contract Formation	Jaswinder Singh Kuldeep Chand	11
• The Mythical Archetypes in Greek Tragedies: A Comparative Analysis	Jyoti	18
• FROM LAB TO COURTROOM: THE ROLE OF POSTMORTEM REPORTS IN THE INVESTIGATION OF THE CRIMINAL JUSTICE SYSTEM	Ms. Neha Prof. (Dr.) Shipra Gupta	33
• Global environmental issues and concern	Jitender Kumar	46
• A Comparative Study of Feminist Perspectives in the Short Stories of Katherine Mansfield and Kamala Das	Nidhi Malik	56
• वृद्ध विमर्श एक परिदृश्य : साहित्य और वर्तमान के परिप्रेक्ष्य में	डॉआरती .	60
• भारत अफगानिस्तानः व्यापार एवं वाणिज्य	नरेश कुमार	64
• Assessing Complainant Credibility and Legal Efficacies in Addressing Rape Offences within the Indian Judicial System	Akshay Kumar Co-author - Prof. (Dr.) Preeti Jain	71
• Challenges Facing People with Disabilities and Possible Solutions in India	Dr. Saroj kumari	78
• समकालीन कलाकार इंदर सलीम एवं उनके कला कार्यों व समीक्षा	प्रोफेसर राम विरंजन अनु शर्मा	84
• वाल्मीकि रामायण के आलोक में रामराज्यः एक समीक्षात्मक अध्ययन	प्रो. सुभाष चन्द्र गुप्ता प्रवीन कुमारी	95
• डा0 अंबेडकर का नारी मुक्ति हेतु योगदान	डा0 अंजना रानी	104
• THE MEDICAL TERMINATION OF PREGNANCY ACT	Rajesh Kumar Dr. Ramesh Kumar	110
• पाणिनीयाष्टाध्याय्यां वर्णितस्य स्थानिवद्भावप्रकरणस्य महाभाष्यसम्मतं विश्लेषणम्	दीपकः कुमारः	117

Principal
Dyal Singh College
KARNAL

• Law Relating To Surrogacy: A Comparative Analysis	Anup Dr. C.R. Jilova	124
• Changing Agrarian Relations in Haryana	Chand Dr Atul Kumar	133
• अष्टांगहृदयम् (सूत्रस्थानम्) में प्रयुक्त समास	गीता देवी डॉ. हरिओम	137
• Traumatic Experiences and Haunting Memories in Anuradha Roy's *The Folded Earth*	Babita Dr Krishna Chaudhary	140
• बालचित्रण : अभिज्ञाशाकुन्तलम् के परिप्रेक्ष्य में	डॉ० सुमन	147
• जे॰ कृष्णमूर्ति के 'स्व–बोध' की अवधारणा का दार्शनिक विवेचन	जयविन्द्र	151
• Emerging Trends and challenges in English Literature	Parvesh Devi	157
• ANALYSIS OF RIGHTS OF WOMEN PRISONERS	Ms. Mehak Rajpal Dr. Indu Bharti Jain	163
• स्वप्नवासवदत्तम् नाटक एक समीक्षा	अनुराधा आर्या डा0 सोनम	168
• Online technology based gender violence: a developing technique of E-crime and misdemeanors acts against women in India	Rupaksh Sharma Dr. Sushant Kumar Shadangi	170
• Evolution and current status of legal framework on human rights of disabled persons	Dr. Promila	177
• AN OVERVIEW OF ROLE OF SFIO AS CONTROLLER OF CORPORATE FRAUDS IN INDIA	Ms. Mansi Sharma Dr. Archana Sharma	186
• संगीत शिक्षण में रोज़गार प्रदान करने वाले संस्थान : एक अध्ययन	ओम प्रकाश	195
• सौभाग्यनुपुरं महाकाव्यम् मे माधव्या की नृत्यशिक्षा	किरण देवी डॉ. सोनम	201
• AN OVERVIEW OF LABOUR WELFARE MEASURES IN INDIA IN RESPONSE TO GLOBALIZATION	DR. Ramesh Kumar Bhardwaj Dr. Gian Mehra	204
• Unveiling the Social Media Effect on Consumer Purchasing Decisions: Navigating the Digital Marketplace	Dr. Vandana Sabharwal	218

Principal
Dyal Singh College
KARNAL

• Changing Dimensions of Feminism: A Study of Roxane Gay's *Bad Feminist*	Sukeerti Dr. Sheetal Nandal	223
• मानव संस्कृति और प्रकृति	डॉ. प्रमिला देवी	227
• INDIA IN THE LANDSCAPE OF CLIMATE FINANCE: PROSPECTS AND CHALLENGES	Dr. Chanchal Gupta Dr Komal Gupta	232
• VOLATILITY AND RISK ASSESSMENT IN CRYPTOCURRENCY ASSETS VALUATION	Sarita Dr. Ramanjeet Dr. Amit Kumar	236
• The Legal Implications of Digital Identity Theft (DIT) and Privacy Invasion in India	Garima Chuphal Prof. (Dr.) D.K.Bhatt	244
• Evaluating the Impact of the Organized Hotel Industry on Tourism Growth in Haryana	Dr. Gaurav Tyagi	250
• The development of the picture of women in African literature	Radhika	257
• Deciphering Knowledge Management Dynamics in the Context of Management Education	Ashun Malik	261
• The centralized units of an organization that cater to the stakeholder demands through conducting specialized	Anita	268
• Assessing Economic Viability and Policy Implications for Rooftop Solar Photovoltaic Adoption in India: A Comparative Analysis	Nidhi	272

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

पाणिनीयाष्टाध्याय्यां वर्णितस्य स्थानिवद्भावप्रकरणस्य महाभाष्यसम्मतं विश्लेषणम्

दीपकः कुमारः
सहायकाचार्यः संस्कृतविभागाध्यक्षश्च, दयाल–सिंह–महाविद्यालयः,करनालनगरम्

शोध–सारांशः –
ममास्मिन् शोधपत्रे महर्षिणा पाणिनिना स्थानिवद्भावस्य कृते **स्थानिवदादेशोऽनल्विधौ** (1.1.56) इत्यत आरभ्यो **द्विर्वचनेऽचि** (1.1.59) इति पर्यन्तं यानि चत्वारि सूत्राणि उल्लेखितानि तेषां महर्षेः पतञ्जलेरनुसारं किं तात्पर्यमभिप्रायं वा वर्तते– एषा वार्ता विशेषरूपेणोस्थापिता कृता मया। चतुर्णां सूत्राणां विश्लेषणं कृत्वा किं, कथं, कुत्र, कदा इत्यादीनां प्रश्नानां माध्यमेन रुचिवर्धनाय प्रयासः कृतः। अहम् एतत् प्रकरणं महाभाष्यानुसारम् एतदर्थमपि लिखितवान् यतोहि महाभाष्यकारस्य महर्षेः पतञ्जलेर्मतं सर्वाधिकः प्रमाणिको मन्यते विद्वद्भिः। कथितं यथा – **यथोत्तरं मुनीनां प्रामाण्यम्।** एतानि चत्वारि सूत्राणि अतिदेश–सूत्राणि सन्ति। अतिदेशसूत्रं किं भवति? अस्य प्रश्नस्य उत्तरमपि अतीवसरलविधिना प्रदत्तं शोधेऽस्मिन्। अस्य शोधस्य पठस्यानन्तरं स्थानिवद्भावतः सम्बन्धिताः प्रायः सर्वा आशंकाः समाप्ता भविष्यन्ति इति मे मतः।

मुख्य–शब्दाः – स्थानिवत्, अतिदेशम्, अनल्विधिः, अल्विधिः, परस्मिन्, पूर्वविधिः, महाभाष्यम्, पतञ्जलिः, पदान्तः।

प्रस्तावना :

जगत्यस्मिन् संस्कृतव्याकरणे मुनित्रयं प्रसिद्धाः सन्ति। सूत्रकारः पाणिनिः, वार्तिककारः कात्यायनः, महाभाष्यकारः पतञ्जलिश्च। महर्षिः पाणिनिः संस्कृतव्याकरणे 'अष्टाध्यायी' इति ग्रन्थे केवलं सूत्राणां रचनामकरोत्। तदनन्तरं शब्दभण्डारस्य शल्यचिकित्सायै अर्थात् शब्दस्य सम्पूर्णं प्रकृतिप्रत्ययोर्ज्ञानाय यदि कस्यापि सूत्रस्य अभावोऽनुभूतोऽभवत्तु महर्षिकात्यायनो वार्तिकानां माध्यमेन एनमभावं पूर्णमकरोत् ।तत्पश्चाद् एनयोर्लेखनस्य पश्चादपि यदि किमपि अभावम् अथवा त्रुटियुक्तमनुभूतमभवत् तथा च मुख्यरूपेण एतयोर्महर्ष्योः कथनान् अतीव–सरलविधिना सुंदर–सुंदर–उदाहरणानां माध्यमेन तथा विस्तृतेन, सुबोधेन, सुगम्येन व्याख्यानेन शेषनागस्य अवतारो भगवान् पतञ्जलि र्व्याख्यातुं यथाशक्ति प्रयतितवान् तथा च अस्य ग्रन्थो महाभाष्यम् इति नाम्ना प्रसिद्धो बभूव। त्रिमुनि–व्याकरणे पातञ्जल–महाभाष्यस्य उच्चैस्तमं स्थानमस्ति। ग्रन्थेऽस्मिन् लेखकः पस्पशा इति नाम्ना आह्निकसहितं पञ्चाशीतिः (85) आह्निकानि लिखितवान्। महाभाष्यस्य अष्टमे आह्निके महर्षिणा पतञ्जलिना स्थानिवद्भावप्रकरणं लिखितम्। यस्य कृते महर्षिणा पतञ्जलिना अष्टाध्याय्या आहत्य चतुर्भिः सूत्रै र्मिलित्वा उत्तरं दीयते। एतेषामेव चतुर्णां सूत्राणां महाभाष्यसम्मतं परिशीलनं ममास्मिन् शोधपत्रे विद्यते। प्रस्तूयते मया इदानीं पृथक्–पृथक् चतुर्णां सूत्राणां महाभाष्यसम्मतं विस्तृतं विवेचनम् :–

1. स्थानिवदादेशोऽनल्विधौ :

'स्थानिवदादेशोऽनल्विधौ'[1] इति अतिदेशसूत्रमस्ति। अतिदेशसूत्रमित्युक्ते–यत् तथा नास्ति तत् तथा स्वीकरणमतिदेशमस्ति। यथा–शिष्यो यो गुरुर्नास्ति इदानीं तं गुरुतुल्यो मन्यताम्। अतिदेश–शब्दस्य व्युत्पत्तिरस्ति– **अतिदिश्यन्ते तुल्यतया विधीयन्ते कार्याणि येन सोऽतिदेशः।** अर्थाद् येन समानता प्रदीयते तदतिदेशसूत्रं कथ्यते।

महाभाष्यकारो महर्षिः पतञ्जलिः सूत्रे वत्करणस्य प्रयोजनं कथयति – **स्थान्यादेशोऽनल्विधौ इतीयत्युच्यमाने संज्ञाधिकारोऽयम्। तत्र स्थानी आदेशस्य संज्ञास्यात्।**[2] अर्थाद् वति प्रत्ययस्य प्रयोगं न अकरिष्यत् तदा सञ्ज्ञाधिकारोऽभविष्यत्। **'हनो वध लिङि'**[3] सूत्रेण **हनः** स्थाने भावको वधादेशस्य स्थानी – 'हन' संज्ञा भविष्यति। शास्त्रे संज्ञाया विधानं संज्ञीनां ज्ञानं कारयितुं भवति। अत **'आङो यमहनः'**[4] सूत्रेण यत्र **'आङ्'** इत्यस्मात् परे **यम** एवं **हन्** धातू आत्मनेपदं भवति तत्र हन् संज्ञया **'वध'** इत्यस्य ग्रहणे सति **'वध'** अनेनैव

Principal
Dyal Singh College
KARNAL

आत्मनेपदं भविष्यति **'हन्'** इत्यनेन आत्मनेपदं नैव भविष्यति। एतदस्य संज्ञाधिकारे भवने दोषोऽस्ति। परन्तु यदा वत्करणं कुर्मस्तदाऽयं दोषो न भवति।

पुन आचार्यः प्रश्नं करोति – **अथादेशग्रहणं किमर्थम् ?**[6] अस्योत्तरे कथयति यद् 'आदेश' इति पदस्य ग्रहणं न कुर्मस्तर्हि **'अनल्विधौ स्यात्'** एतावद् अर्थो भविष्यति स्थानेस्तुल्यो कः स्यात् ? प्रत्ययः स्यात्, आगमः स्यात्, धातुः स्यात् आदेशः स्याद् इत्थं तुल्यताया विस्तारो भविष्यति। एवं विस्तारो न भवेद् अतएव कथितम् आदेशमात्रं स्थानिवत् स्याद् अर्थात् केवलम् आदेश एव स्थानेस्तुल्यं भवेद् अन्या नैव। एतदर्थं आदेशपदस्य ग्रहणम्।

अग्रे महाभाष्यकारोऽनल्विधौऽइति पदस्योपादानस्य प्रयोजनं लिखन् कथयति–

न तु स्थान्यलाश्रयविधौ अर्थात् प्रकृतसूत्रेण भावकः स्थानिवद्भावः स्थानीरूप–अलाश्रयविधौ न भवति। अलाश्रयविधौ चतुर्विधः समासाः कथिताः –

(क) अला विधिः

अत्र तृतीयतत्पुरुषः समासः। अर्थाद् अला कोऽपि विधिः करणीयोऽस्ति तु आदेशः स्थानिवद्भावं न प्राप्नोति। यथा – **'व्यूढोरस्केन'** इत्यस्मिन् उदाहरणो सकारादेशस्य स्थानिवद्भावं कृत्वा विसर्गो मन्यामहे तु णत्वं भवितुं शक्नोति। अयोगवाहविसर्गस्य गणना अट्–प्रत्याहारे भवति तथा च अट् प्रत्याहारस्य व्यवधाने सत्यपि **'अट्कुप्वाङ्नुम्व्यवायेऽपि'**[8] अनेन सूत्रेण णत्वं भवितुं शक्नोति किन्तु अत्र विसर्जनीयस्य **अल्** वर्तते तथा च अस्य कारणनैवणत्व–प्राप्तोऽभवत्। अतः **'अला विधिः'** समासस्यानुसारम् एतद् घटितं भवति। फलतोऽलाश्रितविधि–र्भवनात् स्थानिवद्भावो नाभवद् णत्व–अपि नाभवद्– **व्यूढोरस्केन।**

(ख) अलो विधिः –

पञ्चमीतत्पुरुषसमासोऽत्र। अर्थाद् यदि स्थानीभूतअलः परे कोऽपि विधिः (कार्यम्) करणीयोऽस्ति तर्हि आदेशः स्थानिवद्भावं न प्राप्नोति। यथा 7 **'दिव+सु'** इत्यत्र **"दिव औत्"**[7] इत्यनेन सूत्रेण वकारस्य स्थाने औत् इत्यादेशे सति यणो भूत्वा 'द्यौ स्' इति जातम्। औकारादेशं यदि स्थानिवत् स्वीकुर्मस्तदा हल् मत्वा तस्मात् परे सु इत्यस्य अपृक्त–सकारस्य **'हल्ङ्याब्भ्यो दीर्घात् सुतिस्यपृक्तं हल्'**[8] इति सूत्रेण लोपो भवितुं शक्नोति किन्तु अलः परे विधिरयम्। अस्य कर्तव्यतायां स्थानिवद्भावो न भविष्यति। अतो हलत्वमिति धर्मो नागमने सति सस्य लोपो न भवति – **'द्यौ'** इति विसर्गयुक्तो भवति।

(ग) अलः परस्य विधिः

षष्ठीतत्पुरुषसमासोऽयम्। अत्र 'अल्' इति प्रातिपदिकस्य पञ्चम्यन्ते तथा च षष्ठयन्ते 'अलः' समानरूपे भवने सति असन्देहार्थो महाभाष्यकारेण परस्य इति शब्दस्य निर्देशः कृतः। अत्रार्थोऽयमस्ति यद् यदि स्थानीभूत–अलः स्थाने कोऽपि विधिः कर्तव्योऽस्ति तु आदेशं स्थानिवद्भावो न भवति। उदाहरणमाध्यमेन एवमवगच्छामः – 'द्युकामः' अस्यां सिद्धौ 'दिवः कामः' विग्रहेऽस्मिन समासादि भूत्वा दिव+काम इति जातम्। **"दिव उत्"**[9] सूत्रेण वकारस्य स्थाने उकारादेशो भूत्वा 'दि उ काम' इति जातम्। अत्र उकारादेशं स्थानिवद्भावोऽभविष्यत्। तदा वकारं मत्वा **"लोपो व्योर्वलि"**[10] सूत्रेण उकारस्य लोपो भवितुं शक्नोति परञ्च अलः स्थाने भावको विधिर्भवने सद् स्थानिवद्भावो नाभवत्। अतो **'द्युकामः'** इति सिद्धम्।

(घ) अलि विधिः

सप्तमीतत्पुरुषसमासोऽयम्। अर्थाद् यदि अलः परे भवने सति तस्मात् पूर्वं कोऽपि विधिः करणीयोऽस्ति तदाऽपि आदेश स्थानिवद्भावो न भवति। यथा – 'क इष्टः' इत्यत्र यज्–धातुतः क्तप्रत्ययो भूत्वा 'यज्+त' इति जातम्। धातो र्यकारं **'वचिस्वपियजादीनां किति'**[11] सूत्रेण सम्प्रसारण–इकारो भूत्वा तदनन्तरं पूर्वरूपैकादेशो भूत्वा **'इज्+त'** इति जातौ जकारं षकारो **'व्रश्चभ्रस्जसृजमृजयजराजभ्राजच्छशां षः'**[12] सूत्रेण तथा तस्मात् परे तकारं टकारो **'ष्टुना ष्टुः'**[13] सूत्रेण भूत्वा तदनन्तरं स्वादिकार्यं भूत्वा 'इष्टः' इति निर्मितम्। तस्मात् पूर्वं किम् शब्दात् सु प्रत्ययो, अनुबन्धलोपस्तथा च **"किमः कः"**[14] सूत्रेण किम् इत्यस्य स्थाने 'क' इति आदेशो भूत्वा 'क स्+इष्टः' सस्य रुत्वे, अनुबन्धलोपे **'कर्+इष्टः'** इति निर्मितम्। अत्र यदि धातौ विद्यमान–सम्प्रसारणेन निष्पन्न–इकारं

Principal
Dyal Singh College
KARNAL

स्थानिवद्भावोऽभविष्यत् तु यकारं मत्वा तस्य परे भवने **'हशि च'**[16] सूत्रेण 'कर्' इत्यस्य रेफस्य स्थाने उकारादेशो प्राप्तो शक्नोति परञ्च एतद् उत्वं हशः परस्य भवनस्य कारणाद् अलः परे भावको विधिरस्ति, अतः अलाश्रयविधिर्भवनस्य कारणात् स्थानिवद्भावो न भवति। फलतो रेफम् उत्वमपि न भवति किन्तु तस्य स्थाने **'भो भगो अघोऽपूर्वस्य योऽशि'**[16] सूत्रेण यकारादेशे तस्य **'ढलि सर्वेषाम्'**[17] सूत्रेण लोपो भूत्वा **'क इष्टः'** इति निर्मितं भवति।

इत्थम् अनल्विधौ इत्यस्मात् पदाद् अलाश्रयविधौ स्थानिवद्भावस्य निषेधो भवति। अतएव अस्य सूत्रवृत्तौ अपि कथितं यद् **'आदेशः स्थानिवत्स्यात्, न तु स्थान्यलाश्रयविधौ।'**[18] एवमस्य सूत्रस्य प्रत्येक–पदशो व्याख्या कृता महाभाष्यकारेण श्रीभगवत्पाद–पतञ्जलिना। इत्थमस्य प्रकरणस्य द्वितीयस्य सूत्रस्यापि – व्याख्या प्रस्तूयते मया महाभाष्यसम्मतम् –

2. अचः परस्मिन पूर्वविधौ :

'अचः परस्मिन पूर्वविधौ'[19] इत्यतिदेशसूत्रम्। पूर्वस्य विधिः पूर्वविधिः, पूर्वस्मादपि विधिः, पूर्वविधिस्तस्मिन् पूर्वविधौ। अचः षष्ठयन्तं, परस्मिन् सप्तम्यन्तं, पूर्वविधौ सप्तम्यन्तं, त्रिपदमिदं सूत्रम्। **'स्थानिवदादेशोऽनल्विधौ'** सूत्राद् 'आदेशः' तथा च 'स्थानिवत्' इत्यनयोरनुवृत्तिरागच्छति।

सूत्रमिति कथयति – **'परनिमित्तोऽजादेशः स्थानिवत् स्यात्।**[20] अर्थात् परं निमित्तं मत्वा भूतः अचः स्थाने भूतो योऽजादेशः, स स्थानिवद्भावं प्राप्नोति, यदि आदेशस्य स्थानीभूत–अचः पूर्वत्वेनदृष्टविधेः कर्तव्यता वर्तते अर्थादुक्त–अचः पूर्वो यो वर्णः तत्सम्बन्धितं कार्यं करणीयमस्ति चेत्। प्रकृतसूत्रे प्रत्येकं पदानाम् आवश्यकताः पदकृत्यस्य माध्यमेन एवमवगन्तुं शक्नुमः।

'अचः परस्मिन् पूर्वविधौ' सूत्रस्य व्याख्याने महाभाष्यकारो महर्षिः पतञ्जलिः प्रश्नं करोति – **अच इति किमर्थम्?**[21] अस्य प्रश्नस्योत्तरे बहवः प्रश्नोत्तरं करोति परञ्च निष्कर्षरूपेण इत्थं कथयति – **इदं तर्हि प्रयोजनम्– आगत्य। अभिगत्य। अनुनासिकलोपः परनिमित्तकः; तस्य स्थानिवद्– भावाद् ध्रस्वस्येति तुङ् न प्राप्नोति। 'अच' इति वचनाद् भवति।'**[22] कथनस्याभिप्रायोऽयमस्ति यद अजादेशं स्थानिवद्भावो भवेद् हलादेशं नैव; नो चेत् समस्या भविष्यति, का समस्या? पश्यामः।

'आ+गम्+क्त्वा' इत्यत्र समासे कृते, क्त्वा प्रत्ययस्य स्थाने ल्यप् आदेशानन्तरम् – **'अनुदात्तोपदेशवनतितनोत्यादीनामनुनासिक लोपो झलि क्ङिति'**[23] सूत्रेण मकारस्य लोपे सति **'आ+ग+य' इति जातम्।**अत्र हलादेश– मकारलोपस्य स्थानिवद्भावं भवनाद् मकार – दर्शनस्य कारणाद् अन्ते **ह्रस्ववर्णो** न अद्रक्ष्यत् किन्तु **'गम' इति** अद्रक्ष्यत्। फलतो **'ह्रस्वस्य पिति कृति तुक्'**[24] सूत्रेण तुगागमो न भवितुं शकितः। अचः इति पदस्य भवने सति अजादेशमेव स्थानिवद्भावो भवति हलादेशं नैव। अतः स्थानिवद्भावाभावे ह्रस्वं तुगागमो भूत्वा 'आगत्य' इति कृदन्तपदं सिद्धयति।

अस्यानन्तरमाचार्यः प्रश्नं करोति – **अथ परस्मिन्निति किमर्थम्?**[25] उत्तरे कथयति – **युवजानिः। वधूजानिरिति, जायया निङ् न परनिमित्तकः। तस्य स्थानिवद्भावाद् वलीति यलोपो न प्राप्नोति। परस्मिन्निति वचनाद् भवति।**[26]

अर्थात् प्रकृतसूत्रे **'परस्मिन्' इति पदं नाभविष्यत्** तर्हि परनिमित्तकस्य अतिरिक्तस्थलेषु अपि कथमपि प्रकारेण अजादेशे स्थानिवद्भावोऽभविष्यत्। यथा – **'युवतिर्जाया यस्य स'** विग्रहे बहुव्रीहिसमासस्य पश्चात् सुपोलुकि **युवति** इति शब्दे पुंवद्भावे भवने सति **'युवन्+जाया'** इति जातम्। **'जायाया निङ्'**[27] सूत्रेण जाया शब्दस्य अन्त्य–आकारस्य स्थाने निङ् आदेशे, अनुबन्धलोपे **'युवन्+जाय्+नि'** इति अभवत्। पूर्वपदस्य नकारस्य **'नलोपः प्रातिपदिकान्तस्य'** सूत्रेण **लोपः** तथा च उत्तरपदस्य **यकारस्य 'लोपो व्योर्वलि'** सूत्रेण लोपो भूत्वा **'युवजानि'** शब्दो निर्मितो भवति। इत्यत्र अज्वर्ण आकारस्य स्थाने निङादेशो जातः स परनिमित्तको नास्ति अर्थात् परवर्ण निमित्तं मत्वा नाभवत्। यदि प्रकृतसूत्रे परस्मिन् इति पदं न स्यात् तु स्थानेऽस्मिन् स्थानिवद्भावो भविष्यति। फलतो मध्ये आ–बुद्धिर्भवनेन अर्थाद् आकारस्य दर्शनेन **'लोपो व्योर्वलि'** सूत्रेण यकारस्य लोपो न भवितुं शक्नोति। प्रकृतसूत्रे 'परस्मिन्' इति पदस्य भवने सति निङादेशं स्थानिवद्भावं नाभवत्। अतो यकारस्य

Principal
Dyal Singh College
KARNAL

लोपो भूत्वा स्वादिकार्यं भूत्वा **'युवजानिः'** इति रूपं सिद्ध्यति।

अग्रे लिखितं भाष्यकारेण – **अथपूर्वविधाविति किमर्थम्?**[28] उत्तरे कथितमेवम् – **'हे गौः' इति प्रयोजनम्।**[29] अर्थाद् **'गो+स्'** इत्यवस्थायां **'गोतो णित्'**[30] सूत्रेण 'सु' इति प्रत्ययस्य णिद्भावे **'अचो ञ्णिति'**[31] सूत्रेण ओकारस्य स्थाने औकारे वृद्धौ **'गौ+स्'** इति जातम्। अत्र वृद्धिरूप – 'औ' इत्यजादेशोऽस्ति तथा च परनिमित्तकोऽपि। अतः अत्रापि स्थानिवद्भावे सति **'एङ् ह्रस्वात्सम्बुद्धेः'**[32] सूत्रेण **सकारलोपस्य** कर्तव्यतायाम् **'ओ'** इत्येव दर्शितो भूयते येन सकारलोपस्य भवनेन **'हे गौः'** इति इष्टरूपं सिद्धं न भवितुम् अशक्यत्। सूत्रे 'पूर्वविधौ' इति पदं भवनेन इयमापत्तिर्न भविष्यति यतोहि प्राप्त–सकारलोपो स्थानिभूत–अचः परविधिरस्ति पूर्वविधि–नैव।

इत्यासीद् महाभाष्यसम्मतं **'अचः परस्मिन् पूर्वविधौ'** इति सूत्रस्य व्याख्यानम्। इदानीं प्रस्तुतमस्ति तृतीयसूत्रस्य विवेचनम् –

3. **न पदान्तद्विर्वचनवरेयलोपस्वरसवर्णानुस्वारदीर्घजश्चर्विधिषु –**

"न पदान्तद्विर्वचन वरेयलोपस्वरसवर्णानुस्वारदीर्घजश्चर्विधिषु"[33] सूत्रस्य पदच्छेद इत्थमस्ति – न इति अव्ययं तथा च **पदान्त–द्विर्वचन–वरे– यलोप स्वर–सवर्ण–अनुस्वार–दीर्घ–जश्–चर्–विधिषु–** इत्यत्र सप्तमी बहुवचनम्। सूत्रार्थ एवमसित –

अच्–वर्णानां स्थाने कृतोऽजादेशः परनिमित्तकोऽस्ति चेत् स आदेशः (1) पदान्तकार्यार्थम् (2) द्वित्वकार्यार्थम (3) 'वरच्' प्रत्ययस्य कार्यार्थम् (4) यकारलोपार्थम् (5) स्वरविध्यर्थम् (6) सवर्णकार्यार्थम् (7) अनुस्वारविध्यर्थम् (8) दीर्घादेशकार्यार्थम् (9) जश्त्वकार्यार्थम् (10) चर्त्वकार्यार्थम् – स्थानिवत् कार्यं न करोति।

यत्र कस्यचन स्थानिनः कश्चन आदेशो विधीयते, तत्र–स्थानिनो गुणधर्मा आदेशे अपि अतिदिश्यन्ते वा? इति प्रश्ने जाते, अष्टाध्याय्याम् आहत्य चतुर्भिः सूत्रैर्मिलित्वा अस्य उत्तरं दीयते। **स्थानिवदादेशोऽनल्विधौ– (1.1. 56)** इत्यत आरभ्य **द्विर्वचनेऽचि (1.1.59)** इति यावन्ति एतानि चत्वारि सूत्राणि **'स्थानिवद्भावप्रकरणम्'** इति नाम्न ज्ञायन्ते। अस्य प्रकरणस्य इदं तृतीयं सूत्रम्। **"अचः परस्मिन् पूर्वविधौ"** इत्यनेन सूत्रेण उक्तः स्थानिवद्भाव आहत्य दशसु पूर्वविधिषु प्रकृतसूत्रेण निषिध्यते। इत्युक्ते परनिमित्तकोऽजादेशः पदान्तादिषु दशसु पूर्वविधिषु कर्तव्ये स्थानिवत् नैव भवति – इति प्रकृतसूत्रस्यार्थः। प्रत्येकं स्थानिवद्भावनिषेधस्य महाभाष्यानुसारं क्रमशोविवेचनमित्थमस्ति सोदाहरणम्:–

(क) पूर्वपदस्य अन्ते जायमानस्य कार्यस्य कृते परनिमित्तकोऽजादेशः स्थानिवद् न भवति। उदाहरणानि –कानि सन्ति, यानि सन्ति, कौ स्तः, यौ स्तः इति।

(ख) पूर्वस्य द्वित्वे कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा –सु ध् य् + उपास्यः, मधु+अरिः।

(ग) वरच् – प्रत्ययान्तस्य रूपसिद्धौ पूर्वविधौ कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा–यायावरः।

(घ) यकारलोपः पूर्वविधिरस्ति चेत् परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा–यातिः, वाय्वोः, अध्वर्य्वोः।

(ङ) स्वरविशिष्टे पूर्वविधौ कर्तव्ये परनिमितकोऽजादेशः स्थानिवद् न भवति। उदाहरणानि–आकर्षिकः, चिकीर्षकः, जिहीर्षकः।

(च) सवर्णसंज्ञया निर्दिष्टे पूर्वविधौ कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् भवति। यथा – शिण्ढि।

(छ) अनुस्वारादेशरूपिणि पूर्वविधौ कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा – शिंषन्ति, पिंषति।

(ज) दीर्घादेशविशिष्टे पूर्वविधौ कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा–प्रतिदीन्ना, प्रतिदीन्ने, प्रतिदीन्नः।

(झ) जश्त्वविशिष्टे पूर्वविधौ कर्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा – संग्धि।

(ञ) चर्त्वविशिष्टे पूर्वविधौ कर्त्तव्ये परनिमित्तकोऽजादेशः स्थानिवद् न भवति। यथा –जक्षतुः, जक्षुः।

इत्थमुदाहरणसहितं प्रकृतसूत्रस्य वर्णनं कृतं भगवत्पादपतञ्जलिना। इदानीं वर्ण्यते स्थानिवद्भावप्रकरणस्य अन्तिमं सूत्रम्।

4. **द्विर्वचनेऽचि :**

Principal
Dyal Singh College
KARNAL

'द्विर्वचनेऽपि'[34] इति द्विपदमिदं सूत्रम्। **'द्विर्वचने'**[35] इत्यत्र सप्तम्येकवचनं तथा अचि इत्यत्रापि प्तम्येकवचनम्। सूत्रमित्यापि अतिदेशसूत्रं, यतोहि स्थानिवद्भावप्रकरणस्य चतुर्थं सूत्रम्। **यस्य द्विवचनस्य निमित्तमजादिरस्ति तस्मिन् द्वित्वे कर्तव्ये अजादेशः स्थानिवद् भवति**[36] उदाहरणमाध्यमेन एवमवगन्तुं शक्नुमः **'गोपायाम् कृ अतुस्'** इत्यत्रअतुस् द्वित्वस्य निमित्तमजादिप्रत्ययोऽस्ति यतोहि लिट्–परे द्वित्वो भवति तथा च अयं लिटः स्थाने आदेशोऽभवत्, अतः स्थानिवद्भावाद् लिडस्ति, अस्य परे भवने सति अजादेशोऽस्ति। अतः द्वित्वकरणात् पूर्वम् अत्र यणादेशो न भविष्यति। यदि द्वित्वो भवनात् पूर्वं यणादेशोऽभविष्यत् तु ऋकारं रेफे भवने 'क्र्' इति जातम्। एतद् एकाच् नास्ति। अच् अस्मिन् नास्त्येव। अज्रहितं भवनाद् एकाज् नास्ति, तदा द्वित्वो न भवितुं शक्नोति। प्रकृतसूत्रम्, अजादेशस्य अपेक्षा द्वित्वं पूर्वविधानस्य अनुमतिं प्रददाति। द्वित्वस्यानन्तरं यथाप्राप्ताजादेशा भवितुं शक्यन्ते।

अतएव अत्र द्वित्वे सति अभ्यासकार्यं तथा च अजादेश–यण् भविष्यति, रुत्वे विसर्गे च भवने सति **'गोपाञ्चक्रतुः'** इतिरूपं सिद्धयति। एतत् सर्वं तु आसीत् प्रकृतसूत्रस्य सम्यगर्थं ज्ञातुम्।

आचार्यः पतञ्जलिः **'द्विर्वचनेऽचि इति किमर्थम्'**[37]

इत्युक्तिं प्रतिपादयति :

'कृत्येजन्तदिवादिनामधातुष्वभ्यासरूपं न सिद्धयति। कृति–अचिकीर्तत्। एजन्त–जग्ले, मम्ले। दिवादि–दुद्यूषति, सुस्यूषति। नामधातु–भवनमिच्छति भवनीयति, भवनीयतेः सन् बिभवनीयिषति।[38]

आचार्यः कथयितुमिच्छति यद् अन्यकार्याणां कृते अजादेशः स्थानिवद् न भवति। यथा – **ग्लै धातोर्भावे** लिट्–लकारस्य प्रथमपुरुषैकवचनस्य रूपसिद्धौ आकारलोपो वृद्धिकार्यस्य कृते स्थानिवद् न भवति।यथा – **'जग्ले'** अस्मिन् रूपसिद्धौ **'ग्ला गला +ए'** अत्र **'आतो लोप इटि च'**[39] सूत्रेण द्वितीया 'ग्ला' धातो **आकारस्य लोपे 'ग्ल ग्ल ए'** इति जातम्। अत्र यदि लोपादेशस्य स्थाने आकार इति स्वीकुर्मस्तदा **'वृद्धिरेचि'**[40] सूत्रेण वृद्धिरिति भवितुं शक्नोति परञ्च प्रकृतसूत्रस्य **'द्विवचने'** इति पदग्रहणात् केवलं स्थानिवद् द्वित्वकार्यार्थमेवास्ति। अन्यकार्याणां कृते नैव। अतः प्रकृतसिद्धौ हल्लोपः, ह्रस्वः, **'कुहोश्चुः'**[41] सूत्रेण चुत्वादि भूत्वा 'जग्ले' इति रूपं सिद्धयति।

'इदानीम् 'अचि इति किमर्थम्' कथनमेतत् प्रतिपादयति अज्ग्रहणं तु ज्ञापकं रूपस्थानिवद्भावस्य। यदयमज्ग्रहणं करोति तज्ज्ञापयत्याचार्यो रूपं स्थानिवद् भवतीति। कथं कृत्वा ज्ञापकम्? अज्ग्रहणस्यैतत् प्रयोजनम् – इह मा भूज्जेघ्रीयते देघ्मीयते इति।'[42]

अर्थाद् यत्र द्वित्वस्य निमित्तम् अजादि–नास्ति,तत्र प्रकृतसूत्रेण उक्तः स्थानिवद्भावो नैव प्रवर्तते। **जेघ्रीयते, देघ्मीयते** इत्यत्र घ्रा–ध्मा धातुभ्यां यङ्–प्रत्यये परे द्वित्वो भवति।

इष्टरूपसिद्धयर्थं प्रकृतसूत्रस्य प्रयोगः कुत्र–कुत्र आवश्यको वर्तते। इति प्रश्नोऽत्रोपतिष्ठति। भाष्यकारोऽस्मिन् सन्दर्भे इत्थं स्पष्टी करोति –

'आल्लोपोपधालोपणिलोपणिलोपयणयवायावादेशाः प्रयोजनानि।'[43]

इत्युक्ते, भाष्यकारस्य मतेन प्रकृतसूत्रस्य प्रयोग आहत्य पञ्चसु स्थलेषु आवश्यकोऽस्ति – **आकारलोपः, उपधालोपः, णिलोपः, यणादेशः, अयाद्यादेशः** – इति एतेषां पञ्चानां स्थलानां क्रमेण उदाहरणानि एतानि –

1. **द्वित्वे कर्तव्ये आकारलोपः स्थानिवद् भवति।** यथा–पपतुः।
2. **द्वित्वे कर्तव्ये उपधालोपः स्थानिवद् भवति।** यथा–जघ्नतुः।
3. **द्वित्वे कर्तव्ये णिलोपः स्थानिवद् भवति।** यथा–आटिटत्।
4. **द्वित्वे कर्तव्ये यणादेशः स्थानिवद् भवति।** यथा–चक्रतुः।
5. **द्वित्वे कर्तव्ये अय्/अव्/आय्/आव्– आदेशाः स्थानिवद् भवन्ति।** यथा –निनय, निनाय, पुपव, पुपाव।

एतेषु पञ्चसु स्थलेषु परनिमित्तकोऽजादेश आदौ क्रियते चेद् अनिष्टं रूपं सिद्धयति, अतोऽत्र एतेषां विषये प्रकृतसूत्रम् उपयुज्य द्वित्वमादौ क्रियते। अन्येषु स्थलेषु परनिमित्तकोऽजादेश आदौ क्रियते चेदपि रूपसिद्धौ न कश्चन दोषो जायते; परञ्च तत्रापि प्रकृतसूत्रमनुसृत्य द्वित्वमेव आदौ करणीयम्।

इत्यासीत् स्थानिवद्भावप्रकरणस्य चतुर्थं सूत्रं महाभाष्यसम्मतं व्याख्यानम्।

Principal
Dyal Singh College
KARNAL

अनेन प्रकारेण महाभाष्यस्य अष्टमे आह्निके स्थानिवद्भावस्य भगवतः पतञ्जलेरनुसारं सम्पूर्णं मुख्यञ्च व्याख्यानं सरलेन सुबोधेन च विधिना प्रस्तुतम्मया।

संदर्भ सूचिका :

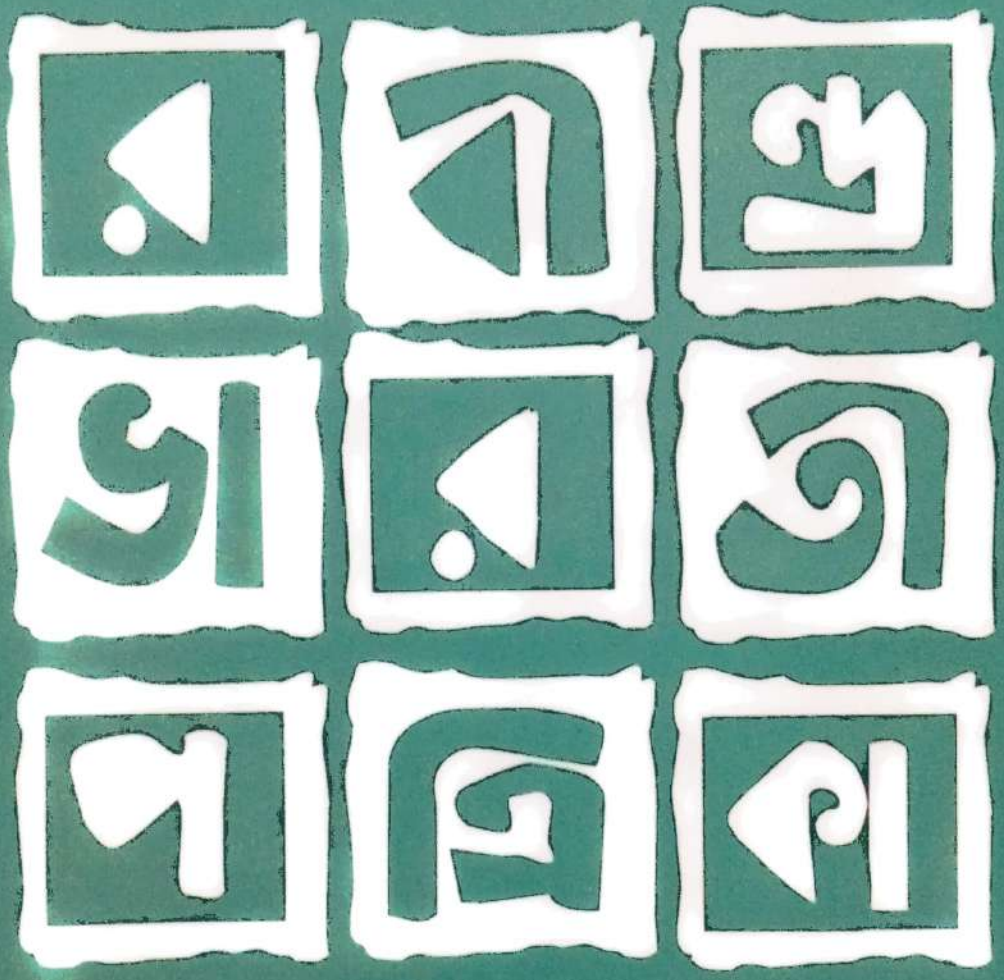
1. अष्टाध्यायी, 1.1.56
2. महाभाष्यम्, अष्टममाह्निकम्
3. अष्टाध्यायी, 2.4.42
4. तदेव, 2.3.28
5. महाभाष्यम, अष्टममह्निकम्
6. अष्टाध्यायी, 7.4.2
7. तदेव, 8.1.14
8. तदेव, 6.1.67
9. तदेव, 6.1.131
10. तदेव, 6.1.66
11. तदेव, 6.1.15
12. तदेव, 7.2.36
13. तदेव, 7.4.41
14. तदेव, 8.2.103
15. तदेव, 6.1.114
16. तदेव, 7.3.18
17. तदेव, 7.3.18
18. तदेव, 7.3.22
19. वैयाकरणसिद्धान्त–कौमुदी–सूत्र–संख्या 47 इत्यस्य सूत्रवृत्तिः।
20. तदेव, संख्या 50
21. महाभाष्यम्, अष्टममाह्निकम्
22. तदेव
23. अष्टाध्यायी, 6.4.38
24. तदेव, 6.1.81
25. महाभाष्यम, अष्टममाह्निकम्
26. तदेव
27. अष्टाध्यायी, 5.4.134
28. महाभाष्यम्, अष्टममाह्निकम्
29. तदेव
30. अष्टाध्यायी, 7.1.60
31. तदेव, 7.2.115
32. तदेव 6.1.66
33. अष्टाध्यायी 1.1.57
34. तदेव, 1.1.59
35. वैयाकरणसिद्धान्तकौमुदी सूत्रसंख्या 2243 इत्यस्य पदच्छेदः
36. तदेव, सूत्रवृत्तिः।
37. महाभाष्यम्, अष्टममाह्निकम्
38. तदेव

Principal
Dyal Singh College
KARNAL

39. अष्टाध्यायी 6.4.64
40. तदेव, 6.1.77
41. तदेव, 8.4.62
42. महाभाष्यम्, अष्टममाह्निकम्
43. तदेव

Principal
Dyal Singh College
KARNAL

Rabindra Bharati Patrika



Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA

রবীন্দ্র ভারতী পত্রিকা

पाणिनीयाष्टाध्याय्यां वर्णितस्य स्थानिवद्भावप्रकरणस्य महाभाष्यसम्मतं विश्लेषणम्

Authored By

दीपकः कुमारः

सहायकाचार्यः संस्कृतविभागाध्यक्षश्च, दयाल–सिंह–महाविद्यालयः,करनालनगरम्

Published in

Rabindra Bharati Patrika: Rabindra Bharati University

ISSN No: 0937-0037

Impact Factor: 6.4

Vol.: XXVII, No. : 7, March 2024

UGC CARE, Peer Reviewed and Refereed Journal

Principal
Dyal Singh College
KARNAL

ज्ञान-विज्ञान विमुक्तये

Rabindra Bharati Patrika ISSN No: 0937-0037

Editor
Rabindra Bharati Patrika

Educational Administration: Theory and Practice
2024,30(2), *776-781*
ISSN:2148-2403
https://kuey.net/

Research Article

War Is Unseen Legacy Exploring The Impact Of Science And Technology In WWII Through The English Patient And Black Rain

Dr Jyoti Syal[1*], Kiran Kumar[2]

[1*]Assistant Professor, Department of Humanities & Social Sciences, Maharishi Markandeshwar Engineering College, MM(DU), Mullana(Ambala- 133203), Jyoti.syal7@gmail.com
[2]Research Scholar, Department of Humanities & Social Sciences, Maharishi Markandeshwar Engineering College, MM(DU), Mullana(Ambala- 133203), Kirandoliyar.1986@gmail.com

***Corresponding Author:** Dr Jyoti Syal
*Assistant Professor, Department of Humanities& Social Sciences, Maharishi Markandeshwar Engineering College, MM(DU), Mullana(Ambala- 133203), Jyoti.syal7@gmail.com

Citation: Dr Jyoti Syal, et al. (2024), War Is Unseen Legacy Exploring The Impact Of Science And Technology In WWII Through The English Patient And Black Rain, Educational Administration: Theory And Practice, 30(2), 776-781, Doi:10.53555/kuey.v30i2.2056

ARTICLE INFO

Received: 09 Mar 2024
Accepted: 16 Apr 2024

ABSTRACT

The emergence of the modern state, accompanied by its technological advancements, was celebrated as a new era for humanity. The promises of enlightenment seemed to have come to fruition, with scientific innovations poised to propel humanity towards a universal culture. Long-standing issues such as disease, ignorance, and poverty appeared destined to fade into obscurity, given that science and industrialization had bolstered human intellect and productivity. However, amidst this optimistic narrative, dissenting voices have emerged to critique the shortcomings of modernism and its overarching narrative. Critics lament the tendency of modernist ideologies to mechanize human existence, stifling individual creativity and moral sensibilities. Through coercion and conformity, the modern state supplants individual cultural assessment and fosters violence and intellectual apathy, thereby impeding progress. This research paper delves into the lesser-explored aspects of World War II (WWII) by examining the profound impact of science and technology during this tumultuous period. Through a comparative analysis of Michael Ondaatje's *The English Patient* and Masuji Ibuse's *Black Rain*, this study seeks to uncover how advancements in science and technology shaped the wartime experience and left a lasting legacy on post-war society. By scrutinizing the narratives of these two literary works, we aim to shed light on the multifaceted consequences of scientific progress and innovation in the context of WWII.

Keywords: Nuclear bomb, Japan, WWII, Black Rain

Introduction:

"A bundle of enriched-uranium fuel rods that could fit into a two-bedroom apartment in Hell's Kitchen would power [New York City] for a year: furnaces, espresso machines, subways, streetlights, stock tickers, Times Square, everything-even our cars and taxis, if we could conveniently plug them into the grid."
Max Schulz, 2006 p.60.

World War II has been valued as the most transformative period in human history, marked by unprecedented levels of destruction, suffering, and technological innovation. While the military and strategic dimensions of the conflict have been extensively studied, the impact of science and technology on the human experience of war remains a relatively underexplored area of research. This research paper delves into the unseen legacy of war, particularly focusing on the profound impact of science and technology during WWII as portrayed in Michael Ondaatje's *The English Patient* and Masuji Ibuse's *Black Rain*. Through a comparative analysis of these literary works, alongside historical context and scholarly insights, this paper aims to uncover the multifaceted dimensions of how science and technology shaped the wartime experience and legacies on individuals and societies.

Principal
Dyal Singh College
KARNAL

Copyright © 2024 by Author/s and Licensed by Kuey. This is an open access article distributed under the Creative Com License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is pr

Literature Review:

Previous research has highlighted the pivotal role of science and technology in shaping the outcome of WWII, from the development of atomic weapons to advancements in communication and transportation. However, scholars have paid limited attention to the humanistic implications of these technological innovations and their lasting impact on individual lives and societal norms. By examining literary representations of WWII, such as *The English Patient* and *Black Rain*, we can gain a deeper understanding of the human experiences behind the scientific and technological advancements of the era.

Methodology:

This research employs a comparative analysis of two seminal works of literature, *The English Patient* and *Black Rain*, to explore the impact of science and technology on WWII. Drawing on close readings of these texts, we will identify key themes and motifs related to scientific innovation, technological warfare, and their repercussions on human society. Additionally, we will examine secondary sources, including scholarly articles and historical analyses, to contextualize our findings within the broader discourse on WWII and its aftermath.

Findings and Discussion:

Our analysis reveals that both *The English Patient* and *Black Rain* offer nuanced portrayals of the intersection between science, technology, and human agency during WWII. In The English Patient, set against the backdrop of WWII, Ondaatje skillfully weaves together the narratives of four disparate characters whose lives converge in an abandoned Italian villa. Central to the novel's exploration is the character of the titular English patient, a severely burned man whose identity and past gradually unfold. Through the patient's recollections, readers are transported to the North African desert, where the protagonist, a Hungarian cartographer, becomes entangled in a doomed love affair and the perilous world of espionage. The novel juxtaposes the beauty of the desert landscape with the destructive power of war, symbolized by the ominous presence of the German army's technological superiority. From the use of advanced weaponry to the development of clandestine intelligence operations, *The English Patient* underscores how science and technology profoundly shape the lives of individuals caught in the chaos of war, leaving behind indelible scars on both the landscape and the human psyche. Joudar quoted for Ondaatje as:

Ondaatje has faced the problem of not being able to reach any community outside his family because he left his homeland at the age of eleven. Therefore, he describes the path into time and place because his memory of Ceylon is not sufficient to cover all the stories about the community. Thus, his identity is linked to things larger than himself. Despite his family history being different from social history, Ondaatje uses it to investigate social history.(Joudar, 2020, p 162)

Ibuse's work chronicles the aftermath of the atomic bombing of Hiroshima through the eyes of a survivor, Shigematsu. Despite their disparate narrative contexts, both novels underscore the transformative impact of scientific and technological advancements on individual identities, moral frameworks, and societal structures. Similarly, "Black Rain" by Masuji Ibuse offers a harrowing depiction of the aftermath of the atomic bombing of Hiroshima. Through the experiences of the protagonist, Shigematsu Shizuma, and his family, Ibuse examines the far-reaching consequences of nuclear warfare on both a personal and societal level. As the characters grapple with the immediate effects of the bombing, including the titular black rain contaminated with radioactive fallout, they also confront the invisible yet pervasive legacy of radiation sickness and the looming specter of long-term environmental devastation. Ibuse masterfully captures the tension between the awe-inspiring advancements in nuclear science and the catastrophic human toll wrought by its application as a weapon of war. Through vivid imagery and meticulous attention to detail, "Black Rain" serves as a haunting reminder of the ethical and existential dilemmas posed by the unchecked pursuit of scientific progress in the context of warfare.

Ibuse's *Black Rain* is a factual novel depicting the aftermath of the atomic bomb dropped on Japan towards the end of World War II. The author vividly portrays the devastating impact of the bomb on Hiroshima, emphasizing its use as a tool of American domination over Japan. Through carefully chosen language, the novel serves as a condemnation of the bomb, a product of the modernist vision. Ibuse's narrative style, devoid of explicit moralizing, aligns with postmodernist sensibilities, allowing him to connect the bomb's destructive effects to everyday life experiences. Structured around five personal journals, the novel provides intimate insights into the lives of its characters. Initially, Yasuko's journal, rewritten by her uncle Shigematsu, serves as a conduit to her intended fiancé, who plans to abandon her upon learning of her presence in Hiroshima during the bombing. Shigematsu's own journal follows, detailing the horrors unleashed by the bomb. Another perspective is offered through Shigeko's journal, focusing on wartime food shortages, while Yasuko's diary chronicles her illness resulting from exposure to nuclear radiation. Finally, Iwatake's journal recounts his struggles with atomic disease. In essence, Black Rain is a poignant exploration of the pitfalls of modern statehood and technology. On the other hand, set against the backdrop of war-torn Europe, *The English Patient* navigates the lives of four individuals whose paths converge in an abandoned Italian villa. Among t eponymous English patient, a man whose identity is shrouded in mystery and whose body bears t

Principal
Dyal Singh College
KARNAL

war's brutality. Through the intricate narrative woven by Ondaatje, the reader is transported into a world where the ravages of conflict are juxtaposed with the marvels of scientific progress.

The modern nation-state represents humanity's innovation, facilitating collective actions beyond individual capabilities. Concealed within the structure of governmental authority, vast sums of money are allocated toward the development of destructive technologies, contradicting moral principles. This aspect is illustrated in "Black Rain" through the portrayal of two modern nations: Japan and the United States. The plight of the Japanese people unfolds following the establishment of the modern state, wherein a state of "organized immorality" culminates under Emperor Hirohito's leadership. Ibuse criticizes the emperor for harboring expansionist ambitions that lead to societal calamity and ruin. One character, Ueda, remarks on the consequences of pursuing ideals such as the Greater East Asia Co-Prosperity Sphere. Swan (1996) argues that the Greater East Asia Co-Prosperity Sphere (GEACP) served as a strategy by the Japanese state to oust Western powers from East Asia and establish a self-sufficient protectorate (p. 139). Following Ueda's critique in "Black Rain," certain individuals in the audience rebuke him, advising him to refrain from expressing defeatist sentiments (p. 130). The Japanese government displayed initial indications of "collective immorality" with the formulation of the Tanaka Memorial in 1927. One of the most significant manifestations of science and technology in World War II was the development of weaponry. The English patient's fate is inextricably linked to the advancements in warfare, as he becomes a victim of a plane crash, a result of the aerial bombardments that characterized the conflict. The destructive power of these machines mirrors the dark side of scientific innovation, where progress is often accompanied by devastation and loss. However, amidst the chaos of war, science and technology also served as catalysts for salvation and redemption. In *The English Patient*, the character of Hana, a young nurse, embodies this duality. She harnesses the advancements in medical science to tend to the wounded and alleviate their suffering. The makeshift hospital in the villa becomes a sanctuary where modern medicine confronts the horrors of war, offering a glimmer of hope amidst the despair. The characters in the novel utilize cognitive maps as a tool to encode and retrieve spatial information. (Joseph, 2020)

According to Crow, Japan demonstrated its aspiration for global dominance by seizing Manchuria, China, and Asia, aiming ultimately to conquer Western powers (Crow, 1942, p 8-9). From 1927 to 1934, Japan initiated a series of military campaigns inflicting immense suffering upon Chinese civilians in pursuit of its vainglorious ambitions. Japan's deep-seated animosity towards Western nations is evident in the Tanaka Memorial, where the premier laments the perceived erosion of Japan's rights and privileges in Manchuria and Mongolia due to treaties such as the Nine Power Treaty, which he argues jeopardizes the nation's very existence (Crow, 1942, p. 8). Crow's analysis also sheds light on Japan's destruction of British colonies like Singapore.

The Japanese empire, hiding under the guise of a modern state, perpetrates heinous acts that individuals like Shigematsu would not engage in. Operating collectively as the "Japanese empire," they exhibit a disturbing audacity to violate moral principles such as the value of life and respect for others' property, as well as overarching narratives like societal advancement and universal truths. Acting as a group, the Japanese demonstrate a mob mentality by targeting British interests in Asia, leaving Shigematsu bewildered. At the root of this conflict lie cultural disparities between Japanese Buddhist traditions and Western secular ideologies. The Western world has long marginalized Japanese immigrants, dating back to their migration to the United States before World War I. Despite Japan's support for the Allies during the war, Japanese people faced segregation in Western nations. This highlights the failure of the modernist notion of a uniform global culture and strengthens the postmodernist argument for embracing diversity.

Under the guise of imperial expansion, the Japanese government engages in conflict with the West as a response to the racial marginalization of its citizens in those nations, thereby exposing the fallacy of cultural universalization. Throughout the novel, Ibuse highlights elements that emphasize the distinctiveness of Asian culture, challenging modernist ideals. In contrast to Western practices of Christian burial rites, the novel depicts bomb victims being cremated following customary prayers. Shigematsu documents his experiences during various Japanese festivals, such as the mass emergence of insects, rice planting festivities, and the Iris festival, as well as the River Imp festival on the 15th and the bamboo cutting festival on the 20th.

To sustain wartime momentum, the Japanese government regulates food distribution and employs propaganda to mislead the populace regarding its purported noble intentions in the war effort. Ibuse notes, "[u]nder control of ordinances in force at the time, rice, rice substitutes, fish and vegetables were all rationed" (p. 63). Through a calculated propaganda apparatus, citizens are coerced into supporting the state's violent campaign against other human beings. The state utilizes district notice boards and commissions artists to create plays and songs that promote its destructive agenda. The modern Japanese government, by co-opting artists to bolster its war efforts, has subverted culture and placed it at risk. The rampant inflation, scarcity of goods, and the bombing of Hiroshima serve as symbols of the collapse and dissolution of the modernist vision in Japan.

The contemporary government also restricts citizens' freedoms, particularly their freedom of speech, in order to garner public support for its policies. Mrs. Miyaji, who criticizes the government for altering student textbooks to reduce the number of meals from four to three, faces police interrogation and is cautioned to refrain from her dissenting remarks. She is viewed as a rebellious citizen for exercising her critical thinking to expose the flaws and inadequacies of the Japanese government. Conversely, the passive citize
Miyaji's actions is praised as responsible and honorable. Mrs. Miyaji's advocacy for four m

Principal
Dyal Singh College
KARNAL

portrayed as subversive, and she is warned of potential punishment for violating national laws. The ethical dilemma of altering Kenji Miyazawa's poem to justify the reduction in meals is silenced by legal enforcement.
Ibuse describes in the novel that the contemporary notion of "disciplined forces" is a deliberate strategy aimed at eroding soldiers' self-esteem and rationality, molding them into obedient machines to serve the collective immorality. Through robotic compliance to authority figures, the unscrupulous leaders of modern states can pursue their selfish agendas. It's notable how military superiors violate moral principles, such as reverence for the elderly, within Iwatake's barracks. Despite Constable Nakamura's advanced age, Lieutenant Yoshikawa persistently kicks him in the stomach, demonstrating a disregard for basic decency. Iwatake observes this behavior with interest. “[i]t was as though a man were to be kicked by his own offspring, somehow transformed into an unmanageable ruffian” (p. 241). Nakamura cannot report Yoshikawa’s cruel acts of immorality because the modern state recognizes Yoshikawa’s seniority and hence the right to oppress a man old enough to be his father.
Ibuse also highlights the shortcomings of modernism through a lens that includes the United States of America. The US military is depicted as highly mechanized to the extent that they unquestioningly follow orders from the president, even if it involves deploying nuclear weapons. The United States has armed its military with the primary objective of seeking vengeance for Japanese attacks in the Pacific. Moreover, despite claims by many modern scientists that technological advancements, including nuclear power, are intended for the greater good, Heidegger argues that such innovations are actually a revealing of being, serving subjective ends. Indeed, scientists in the United States developed nuclear technology primarily to create weapons for the purpose of defeating their adversaries, such as Japan. Ibuse writes:
It is said the enemy used what is referred to as a new weapon on his attack of Hiroshima, which instantly plunged hundreds of thousands of blameless residents of the city into a hell of unspeakable torments. A member of the Patriotic Service Corps who escaped with his life from Hiroshima has told me that at that moment when the new weapon wiped out the city, he heard countless cries for succour-the voice of those hundreds of thousands of souls-seemingly welling up from beneath the earth (p. 12).

Ibuse implies that the technology was specifically created to produce a deadly weapon intended for use against Japan. A witness, a member of the Patriotic Service Corps, affirms that the "new weapon" devastates Hiroshima, leaving thousands of innocent citizens buried underground, crying out in agony. While scholars like Hore-Lacy (2007) argues, “fission/atomic bomb concept was provided in 1939 by Francis Perrin who introduced the concept of the critical mass of uranium required to produce a self-sustaining release of energy”(Hore-Lacy, 2007, p 4) in 1939. Indeed, 1939 marked Hitler's declaration of war against Poland, prompting Western scientists to utilize their expertise to aid the war effort. Perrin's project in 1939 was deliberately sidelined due to a lack of perceived immediate political threats. However, as Japan and Germany made advancements in Asia and Europe, respectively, a committee was established to assess the feasibility of the nuclear project. Hore-Lacy observes:
The final outcome of the MAUD Committee was two summary reports in July 1941. One was on 'Use of Uranium for a Bomb' and the other was on 'Use of Uranium as a Source of Power'. The first report concluded that a bomb was feasible and that one containing some 12 kg of active material would be equivalent to 1,800 tons of TNT and would release large quantities of radioactive substances which would make places near the explosion site dangerous to humans for a long period (p. 7).
Ibuse portrays the dangers posed by advancements in science and technology to the perceived "enemy" of the United States. When the atomic bomb struck Hiroshima, soldiers rejoicing in their barracks were blinded by its illumination. The bomb's deafening roar and scorching heat weakened structures, causing them to collapse. Iwatake, struck by the bomb, loses consciousness until a comrade inadvertently steps on his neck. Ibuse succinctly encapsulates the drawbacks of modernity and technological progress with the statement, "[e]verything had been flattened and scattered in disorder [...]. The destructive power was fantastic" (p. 244), echoing the chaotic modern world where science and technology fail to bring order.
Throughout the novel, Ibuse portrays the futility of the modernist ideal by candidly depicting the chaos and devastation inflicted upon innocent Japanese individuals. Ibuse describes Hiroshima as a "burnt out city, a city of ashes, a city of death, a city of destruction, the heaps of corpses a mute protest against the inhumanity of war" (p. 18), highlighting how modern states perpetrate acts of vengeance that individuals would not. This raises questions about Western nations' commitment to human rights, particularly the right to life, amidst their pursuit of power. Furthermore, the character of Caravaggio, a former intelligence operative, embodies the intersection of science, technology, and espionage during the war. His experiences illuminate the clandestine operations and covert innovations that shaped the course of history. From code-breaking to sabotage, the shadowy realm of espionage epitomizes the fusion of intellect and ingenuity in the service of conflicting ideologies.
Through the lens of *The English Patient*, we are reminded that the impact of science and technology in World War II extends far beyond the battlefield. As **Bhoi** writes, “this novel covers almost 1930s to 1945 and more period. Element of memory and its explanation also matters a lot. Because our mind is not having that sharp memory to store everything in as it is formation. Due to that here characters tell the story in a flash-back mode which has no chronological order of life as well as narration pattern” (Bhoi, 2020, p 33). It aspect of human existence, from the intimate struggles of individuals to the grand sweep of

Principal
Dyal Singh College
KARNAL

we navigate the complexities of our modern world, it is essential to heed the lessons of history and recognize the profound implications of scientific progress on the human experience. The radioactive ash from the bomb not only pollutes the environment but also poses health risks to Japanese citizens. It causes radiation sickness when entering Yasuko's body through a blister and contaminates rivers, leading to the death of fish years later. Ibuse suggests that these are the consequences of prioritizing technological development over humanity. The bombing of Hiroshima results in the violent destruction of property, exemplified by characters like Iwatake. Such actions, when carried out by individuals, are labeled as terrorism, yet when executed by states, they're justified as self-defense. The bombings of Hiroshima and Pearl Harbor illustrate this collective immorality, where leaders like Harry Truman and Emperor Hirohito sanction atrocities for the pursuit of state interests.

Conclusion

Although most citizens naively believe in the objective intentions of nuclear power, it is evident that it was invented specifically to meet Western military conquest of Japan. It is also evident that although the modern state claims to bolster aspects of culture, it deals a death blow to its practice. The state offers for an opportunity for individuals to violate cultural norms and taboos. Any evils can be committed as long as they are legalized by the state. This research paper demonstrates the importance of examining the impact of science and technology on WWII through literary representations such as *The Remains of the Day* and *Black Rain*. By illuminating the complex interplay between scientific progress, human agency, and moral responsibility, these novels offer valuable insights into the enduring legacy of war on individual lives and societal values. Moving forward, further research in this area can contribute to a more comprehensive understanding of the human dimensions of technological warfare and the ethical dilemmas it poses for contemporary society.

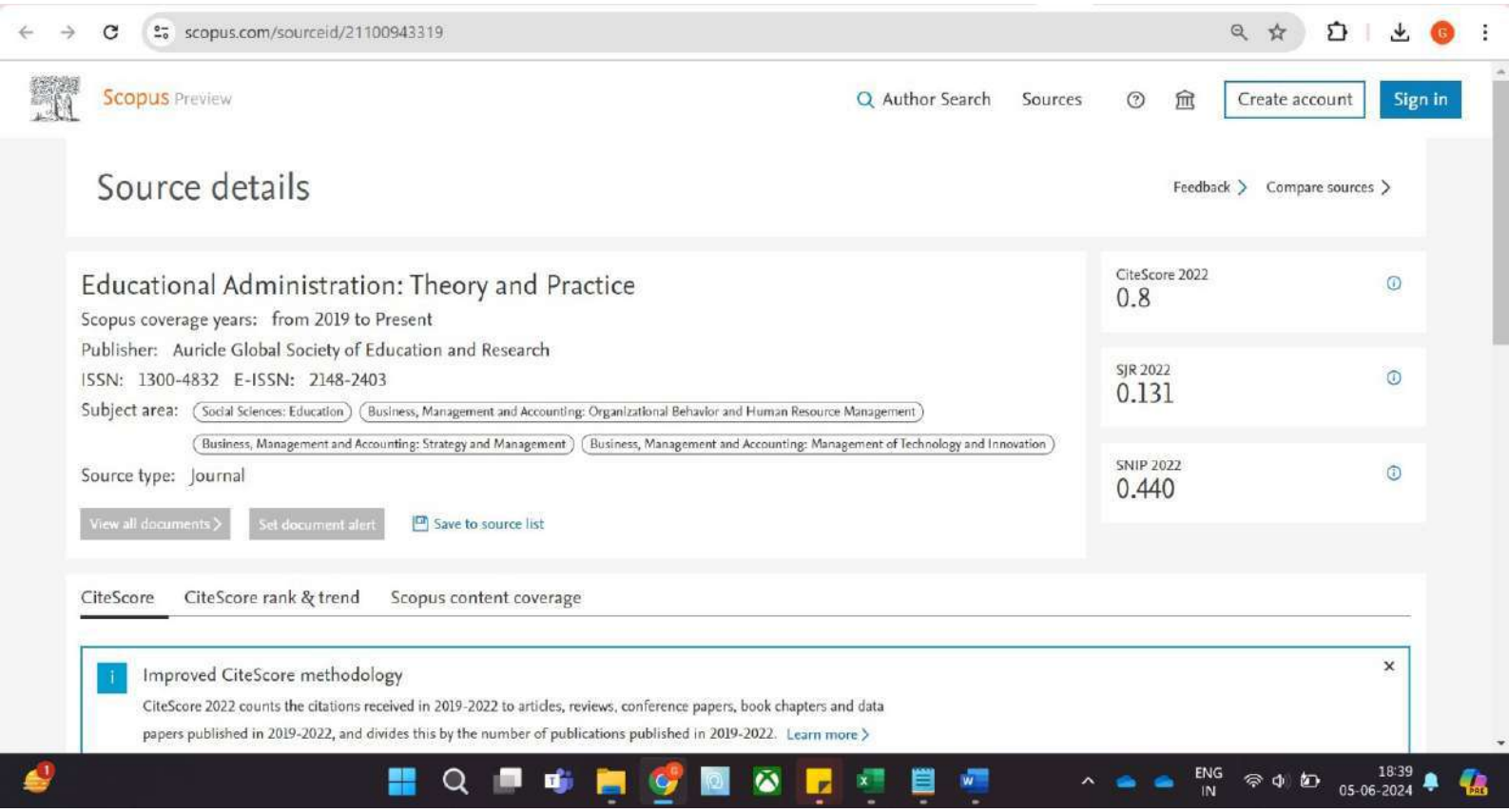
References:

1. Bhoi, Ranjitsing Raysing. (2019). An Indefinable Relationship etween Almasy- Katharian and Hana-Kirpalsingh in Ondaatje's *The English Patient*.https://idees.acs.ac.in/wp-content/uploads/2020/02/Ranjitsing-Raysing-Bhoi-2.pdf
2. Crow, C. (1942). *Japan's dream of world empire: the Tanaka memorial*. Harper Brothers. Dar-Khalil, A. K., & Alshetawi, M. F. (2020). What the Survivors are Telling: Nuclear Trauma and Narratives of Toxicity in Japan. *International Journal of Liberal Arts and Social Science*, *8*(11), 41-50. https://ijlass.org/articles/8.11.5.41-50.pdf
3. Hore-Lacy, I. (2007). *History of Nuclear Energy*. https://www.researchgate.net/publication/302449730_9_HISTORY_OF_NUCLEAR_ENERGY
4. Ibuse, M. (1969). *Black Rain*. Kodansha International. Jerrold, M. (2002). *Killing in the Name of God*. Air University.
5. Joseph, Justy & Dr. Nirmala Menon. (2020). Memory Anchored by Place Attachment and Cognitive Maps in Michael Ondaatje's Warlight and The Cat's Table. https://rupkatha.com/V12/n6/v12n618.pdf
6. Joudar, Ahmed. (2020). The temporary return to the homeland in Michael Ondaatje's Running in the Family. Journal of Language and Cultural Education https://intapi.sciendo.com/pdf/10.2478/jolace-2020-0027
7. Kamanzi, A. (2011). Modernity: foundation for universal environmental degradation. *Journal of the College of Humanities and Social Sciences*, *10*(3), 204 – 213. https://www.researchgate.net/publication/261548678_ Modernity_Foundation_for_Universal_Environmental_Degradation
8. Kangune, Babasaheb. (2018). Study of Love, Mystery and History in Michael Ondaatje's Novel 'The English Patient'. https://www.researchgate.net/publication/341640951_Study_of_Love_Mystery_and_History_in_Michael_Ondaatje's_Novel_'The_English_Patient'
9. Kanimozhi. A. (2020). The Portrayal of Mass Graves in Michael Ondaatje's Anil's Ghost. https://www.jetir.org/papers/JETIR2005342.pdf Top of Form
10. Kaur, Harneet. (2020). Traumatic Reverberations in Michael Ondaatje's Anil's Ghost https://www.igncollege.ac.in/wp-content/uploads/2022/07/Traumatic_Reverberations_in-Michael-ondaatje_Anils-Ghost_Harneet_Kaur.pdf
11. Lakshmi, A. (2020). Rejuvenation Vs Contradiction in Michael Ondatjee's The English Patient.https://marymathacollege.edu.in/wp-content/uploads/2021/06/B8T15953-LAKSHMI.pdf
12. Ondaatje, Michael. The English Patient: New York: Knopf, 1992. Print.
13. Pownika, M. (2020). Cultural and Identity Crisis In Michael Ondatjee's Anil's Ghost https://marymathacollege.edu.in/wp-content/uploads/2021/06/B8T15955-POWNIKA-M-merged.pdf
14. Schulz, M. (2006). Nuclear Power is the Future. *The Wilson Quarterly*. http://blogs.evergreen.edu/chernobyl/files/2010/07/Schulz-Nuc-power-is-future-Wilson-Q-20061.pdf
15. Selwyne, N. (2008). Developing the technological imagination: theorising the social shaping and consequences of new technologies. *Theorising the benefits of new technology for youth: Controversies of learning and development, 19-29.* http://eprints.lse.ac.uk/33821/1/Theorising_the_benefits_of_new_techn ology_for_youtl

Principal
Dyal Singh College
KARNAL

16. Swan, L. W. (1996). Japan's Intentions for its Greater East Asia Co-Prosperity Sphere as indicated in Its Policy Plans for Thailand. *Journal of South East Asian Studies,* 27(1), 139-149. https://www.jstor.org/stable/20071764.

Principal
Dyal Singh College
KARNAL



Principal
Dyal Singh College
KARNAL

Educational Administration: Theory and Practice
2024, 30(5), 3624 - 3630
ISSN: 2148-2403
https://kuey.net/

Research Article

Delving Into The Dynamic Cultural Transitions Within Kazuo Ishiguro's Masterpiece: An Artist Of The Floating World

Dr Jyoti Syal[1], Kiran Kumar[2*]

[1]Assistant Professor, Department of Humanities & Social Sciences, Maharishi Markandeshwar Engineering College, MMDU, Mullana
Email: Jyoti.syal7@gmail.com
[2*]Research Scholar, Department of Humanities & Social Sciences, Maharishi Markandeshwar Engineering College, MMDU, Mullana
Email: Kirandoliyar.1986@gmail.com

Citation: Dr Jyoti Syal, Kiran Kumar, (2024), Delving Into The Dynamic Cultural Transitions Within Kazuo Ishiguro's Masterpiece: An Artist Of The Floating World, *Educational Administration: Theory and Practice, 30(5),* 3624 - 3630
Doi: 10.53555/kuey.v30i5.3500

ARTICLE INFO
Received: 12-04-2024
Accepted: 09-05-2024

ABSTRACT

In a dynamic world characterized by perpetual change, culture emerges as the conductor of humanity's narrative, weaving a symphony of traditions and beliefs handed down through generations. When different cultures converge, it can create a complex blend that shapes our perspectives and influences who we are. This clash of cultural identities is a recurring theme in cultural studies, which critically analyzes the impact of societal power structures and ideologies, political interventions etc. on societies, economies, and identities. Japan, deeply affected by World War II, provides a poignant backdrop for exploring these themes. Kazuo Ishiguro's novel, An Artist of the Floating World, vividly portrays post-World War II Japan through the experiences of its central character, Masuji Ono. His personal struggles reflect the broader challenges faced globally in the aftermath of the war. As the only nation to endure the devastation of two atomic bombs, Japan still bears the scars of that tumultuous era. The story delves into themes of social, political, and cultural transformation. Masuji Ono's journey mirrors the broader national experience shaped by the upheavals of global conflict. An Artist of the Floating World illustrates the intricate interplay between culture and crisis, revealing the enduring resilience of the human spirit to adapt, grow, and find equilibrium amidst life's trials. The narrative underscores the universal human capacity to navigate challenges, portraying a poignant reflection on the lasting impact of war and cultural shifts.

Key words: Modernity, political, culture, social, America, Japan, World War II

Introduction:

Kazuo Ishiguro's An Artist of the Floating World stands as a captivating exploration of Japan's cultural and political landscape in the aftermath of World War II. Set against the backdrop of post-World War II Japan, the narrative unfolds in a society grappling with the aftermath of colonial pursuits and the transformative impact of global conflict. Through the lens of New Historicism, this paper seeks to illuminate the novel's engagement with history and its implications for understanding the complexities of cultural shifts in post-war Japan. New Historicism invites us to deeply explore the impact of power legacies, cultural shifts, spanning historical periods and our modern world. This concept, widely discussed in academic circles, delves into former colonial territories locally and globally, where echoes of imperial domination persist. By considering the ways in which An Artist of the Floating World intersects with broader socio-political and cultural dynamics, this paper seeks to uncover the complexities of historical representation and memory in Ishiguro's work. Within the dynamic and diverse discourse of new historicism, the novel unfolds many narratives encompassed a broad spectrum of themes, ranging from the haunting specter of slavery to the intricate tales of migration, the ominous shadow of oppression, the unwavering spirit of resistance, the celebration of diversity, the nuances of racial dynamics, the subtle exploration of gender complexities, and the influence of geography on societal narratives.

Copyright © 2024 by Author/s and Licensed by Kuey. This is an open access article distributed under the Creative Co License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is

Principal
Dyal Singh College
KARNAL

Methodology:

As we discussed earlier that this paper seeks to uncover the complexities of historical representation and memory in Ishiguro's novel An Artist of the Floating World with the help of New Historicism. New Historicism, as a literary theory, has profoundly influenced the study of literature by emphasizing the inseparable relationship between texts and their historical contexts. As discussed by Xiaotang Lyu as, "Not dealing with a text in isolation from its historical context, new historicists pay more attention to the historical and cultural context of the literary text". (Xiaotang, 2021) Emerging in the late 20th century as a response to the limitations of formalism and structuralism, New Historicism seeks to unravel the complex interplay between literature and history, viewing texts as products of specific socio-political conditions and cultural discourses. By examining how power, ideology, and historical contingency shape literary production and reception, New Historicism offers a dynamic framework for understanding the ways in which literature reflects and refracts the complexities of the past. Central to New Historicism is the practice of contextual reading, which involves situating texts within their historical, cultural, and political contexts. Rather than seeking to uncover the author's intentions or the text's inherent meaning, New Historicist critics examine how literature reflects and refracts the discourses of its time. This approach often involves drawing connections between literary texts and contemporary historical events, cultural practices, and ideological formations. Moreover, New Historicism emphasizes the importance of intertextuality, viewing texts as dialogues with other texts and discourses that shape and inform their meaning.

Background Study of the Novel

"Mentioned or not, cultural and historical factors guide the human activities and so does the literature, and at the same time literature inherently becomes the part of the historical and cultural heritage. The history provides the foundation of writing literature and literature gives the way out to the history to be exposed" as quoted by Keshav Raj Chalise in his research article Ranahar: Textuality of History, Culture and Politics. Dealing with the historical incident & war theme numerous authors have delved with, but Kazuo Ishiguro, an Anglo-Japanese writer, holds a significant place. Originally hailing from Nagasaki, Japan, Ishiguro embarked on a personal journey, migrating to England at the tender age of six. In this way, he became a living embodiment of the themes he would later explore in his literary works, adding his unique voice to the chorus of postcolonial narratives. The world shaped in An Artist of the Floating World is Japan. For Ishiguro, its shape is

A narrative, most literary critics agree, is a meaning-making activity, a highly deliberate rhetorical construct. It is a way we give shape to the world around us and the world of our experience. By creating a narrative out of these experiences, we impose an order and a structure on thoughts and ideas that otherwise would be uncontrollable. (Burton, 2007)

As the narrative unfolds, Ishiguro's aim is to cast a revealing light upon the pivotal years between 1948 and 1950, a time when Japan stood on the precipice of recovery, its collective psyche still haunted by the haunting specter of the war's indelible scars. During this tumultuous era, Japan found itself at the crossroads of history, where the echoes of its past met the dawn of a new global influence—the irresistible spread of American culture. To fully appreciate this juncture, we must journey back to a time when Japan, with astonishing swiftness, had metamorphosed into Asia's first industrialized and independent nation, asserting its identity from 1853 to 1895. In its relentless pursuit of regional dominance, Japan seized Taiwan following the Sino-Japanese war of 1894-1895 and, following in the footsteps of its European imperial counterparts, sought to expand its dominion within China.

Ishiguro's focus spans Japan's pivotal years from 1948 to 1950, post-war recovery intertwined with the influence of American culture. To understand this era, it's essential to revisit Japan's rapid industrialization and expansion from 1853 to 1895, culminating in its emergence as a major Asian power. Japan's ambitions led to conflicts like the Sino-Japanese War and the Russo-Japanese War, establishing its influence in the region. However, Japan's expansionist dreams were thwarted by the defeat in World War II, leading to occupation by the United States until 1952. This period saw profound transformations in Japanese society politically, socially, and economically. On intervene of this imperial power in Japanese democracy, Ishiguro mentions in the novel as:

Democracy is a fine thing. But that doesn't mean citizens have a right to run riot whenever they disagree with something. In this respect we Japanese have been shown to be like children. We've yet to learn how to handle the responsibility of democracy. (Ishiguro, 1986, p.120)

The identical formation of the Japan shattered in every field whether it was culture, power, economy etc. Shunya asserts, "...the ideal of postwar Japanese home life flowed explicitly from the model of the "American way of life" of the 1950s. People wanted to buy all kinds of home electric appliances and live in American type suburban houses. In the field of design and advertising, "American" influences were more evident. American films and TV dramas were quite popular especially during the 1950s..." (Shunya, 2008, p.83). He describes American occupation by dividing it into two categories: "effects consciously pursued as a part policy and effects that arose unconsciously through the interaction of occupier and occupied" (p.84).

Principal
Dyal Singh College
KARNAL

Discussion

Ishiguro explores the complex cultural identity of post-war Japan, where traditional Japanese values collide with Western influences during the process of reconstruction. Masuji Ono grapples with the tension between preserving traditional art forms and embracing modern Western values. The novel reflects power dynamics within Japanese society as it transitions from a militaristic regime to a democratic nation under Allied occupation. Masuji Ono's struggle to reconcile his past actions, aligned with imperialist ideologies, with the changing political landscape illustrates the power shifts within the nation. The profound influence of American culture casts a long shadow over the lives of the Japanese populace. This cultural collision lays at the heart of the protagonist, Ono's, inner turmoil, his sense of displacement, and the estrangement that plagues him. Ono, a retired artist who has tragically lost his son in the ravages of war, now resides with his two daughters. Setsuko, one of his daughters, is married, while Noriko remains single. In the later stages of his life, Ono gazes into the rearview mirror, conjuring the specters of his history and attempting to unravel the transformations in Japanese society before and after the devastating war, juxtaposing these different eras through a collage of memories. Ishiguro by portraying the character of Ono says that Rebecca Walkowitz, in her illuminating article titled “Ishiguro’s Floating Worlds," astutely observes that An Artist of the Floating World intricately complicates the structure of displaced narratives by weaving together a palimpsest of memories, recounting and juxtaposing multiple stories simultaneously. Ishiguro mentions in an interview:

I’m interested in people who, in all sincerity, work very hard and perhaps courageously in their lifetimes towards something, fully believing that they’re contributing to something good, only to find that the social climate has done a topsy-turvy on them by the time they reach the ends of their lives. (Mason, 1989.)

This literary technique adds layers of depth to the narrative, allowing readers to delve into the multifaceted psyche of the characters and the evolving societal backdrop. This sentiment encapsulates the essence of Ono’s journey, as he grapples with the disorienting shifts in the cultural and social landscape of Japan. Through Ono's introspective lens, Ishiguro masterfully paints a canvas that bridges the past and present of Japan. According to Burton, the name of the novel relates both to traditional Japanese art but

The floating world also refers more broadly to an elaborate web of memories and epiphanies spun by narrators who are caught between two worlds (whether moral, ideological, or geographical). As the narrators look back on the roads taken in their lives, they question whether or not their lives have been a waste and this questioning invariably brings them to a crisis-point. (Burton, 2007. p 42)

The erosion of traditional Japanese values is intricately linked with the pervasive Americanization process, a cultural metamorphosis that permeates every aspect of society. Economic, topographical, and physical structures shift as monetary pursuits gradually replace the once-revered ideals of honor and respect. Simultaneously, the institution of the family undergoes a profound transformation. In the midst of these seismic societal changes, a conflicted artist emerges, seeking to strike a delicate balance between his familial obligations and the evolving demands of society. The American influence, pervasive and transformative, induces feelings of estrangement and displacement, not only within Ono’s psyche but in the collective consciousness of the Japanese people. Ono himself reflects on this profound societal transformation, remarking that “...something has changed in the character of the younger generation in a way I do not fully understand, and certain aspects of this change are undeniably disturbing." (Ishiguro, 1986, p.59) The radical shift, most pronounced in the younger generation, rattles Ono's sense of belonging and understanding of his own culture. As Zuzana Fonioková astutely observes, Ono's character is marked by his evolving perception of past events, a transformation that reverberates not only in his memories but also in his present behavior. He grapples with the changing values of the younger generation, who have forsaken traditional Japanese culture in favor of American ideals. This stark generational contrast prompts a thought-provoking comparison between pre-war and post-war Japan.

The novel commences with a poignant portrayal of the importance of respect and honor, exemplified through Ono's quest to purchase a house. This house, once owned by Akira Sugimura, is the object of Ono's desire. Sugimura's daughters, responsible for its sale in their father's absence, meticulously assess potential buyers and ultimately choose Ono, despite his modest wealth. Their decision hinges on the emotional connection to the house, constructed by their father's hands. However, even in this poignant moment, the daughters' preference veers toward financial gain as they candidly admit that the house, while important, is now “strictly secondary.”In this intricately woven narrative, Kazuo Ishiguro invites readers to traverse the multifaceted landscapes of memory, culture clash, and personal evolution, creating a symphony of emotions and societal transformations that resonate long after the final page is turned.

Ono’s ability to secure the house rested upon his revered status as an artist, a mantle of honor that granted him this privilege. However, as the winds of change reshaped the economic landscape, a materialistic ethos began to ascend, redefining society's perspective on wealth, endowing it with newfound value and prestige. This transformation becomes strikingly evident towards the novel's conclusion during a poignant exchange between Ono and his son-in-law, Taro. Their conversation revolves around the whirlwind changes that have swept through Japan's business realm in an astonishingly brief span. The emerging Japanese
have ushered in a new era, bringing in fresh recruits while ushering out the old guard. In this
raises a profound question to Taro, one that probes the compatibility of the altered legal ap

Principal
Dyal Singh College
KARNAL

practices instituted by the new management with the ethos of his own firm. The discussion encapsulates the seismic shifts unfurling in post-war Japan's economic fabric, where tradition and modernity clash, and where the concept of honor and value undergoes a profound metamorphosis. Taro has prepared his response: “We needed new leaders with a new approach appropriate to the world of today” (Ishiguro, 1986, p.185). In the quest for economic supremacy, the call arises for visionary leaders, adorned in the garments of fresh ideologies and inventive approaches. Within this panorama, Ono's grandson emerges as an emblematic figure, epitomizing the ethos of the burgeoning generation, one singularly driven by the siren call of wealth. Despite his relatively tender years and limited experience, when probed about his aspirations, he boldly proclaims, “President of Nippon Electrics!”(Ishiguro, 1986, p.186). This declaration reverberates as a harbinger of the shifting tides and evolving ambitions within the up-and-coming cohort. Ono, as an individual, cherishes traditional societal values, yet he grapples with the perplexing ideologies held by both his son-in-law and grandson. The aftermath of World War II ushered in a novel world order, one that openly championed and propelled the tenets of capitalism, ushering in the era of globalization. Japan, too, found itself swept up in this transformative wave, catalyzing a sea change in the younger generation's perception of wealth. Kathryn Woodward astutely notes that the process of globalization bears a profound impact on the crisis of identity. She articulates, “Globalization constitutes an intricate interplay between economic and cultural factors, where shifts in production and consumption patterns give rise to novel collective identities” (Woodward, 1997, p.16). However, these transformations yield multifaceted outcomes for individual identity, a phenomenon exemplified in Ono's personal journey. Furthermore, Woodward elucidates that “the cultural uniformity propagated by global marketing has the potential to sever identity from its traditional moorings of community and locale” (Woodward, 1997, p.16). In this intricate dance of shifting identities and global influences, the essence of one's self can become detached from the familiar anchors of community and place.

In the looming shadow of materialism, the cherished traditional values that once anchored Japanese society found themselves adrift, their significance slowly eroding. Notions of patriotism and heroism, once the bedrock of national unity, have gradually faded into obscurity. These conceptual elements, integral to the fabric of nationalism, have undergone a substantial diminution in significance. Within the pages of Antony Smith's illuminating work, "Nationalism: Theory, Ideology, History," nationalism is defined as a visionary pursuit. It is a quest to establish and safeguard self-governance, social cohesion, and a distinct cultural identity for a group of individuals, a collective deemed by some among them to constitute a present or potential nation.

Yet, the novel at hand paints a vivid tableau of intergenerational conflict, where the wisdom of age clashes with the ideals of youth. The chasm widens as Ono and the younger generation grapple with differing perspectives on pivotal issues like patriotism, heroism, and nationalism.

The younger voices within the narrative cast a critical eye back on their forebears, unflinchingly questioning the decisions of the previous generation, particularly their involvement in the cataclysmic Second World War. To them, the Japanese politicians' choice to attack Pearl Harbor appears reckless and devoid of value. A stark example of this ideological divide emerges in the conversations between Ono and Miyake, the latter being Ono's “prospective son-in-law.”

For Miyake, those who participated in the war are not heroes but rather akin to criminals. In contrast, Ono, who lost his beloved son Kenji during the conflict, harbors no bitterness towards the war effort. To him, those who fought with unwavering loyalty and dedication for their country during those trying times deserve honor and respect. On this subject, their perspectives diverge sharply. For Ono, wartime service is a testament to immense dedication and an honorable endeavor; however, for Miyake, it is utterly futile.

The widening gulf in their viewpoints becomes evident when Miyake shares the news of the President's suicide, a man who took his own life as an act of apology for the company's wartime activities. To Ono's astonishment, Miyake applauds the President's decision, viewing it as a just course of action. In Miyake's eyes, the President bore the greatest responsibility for instigating the war and was, in essence, one of its chief architects. Another illustration of this generational divide unfolds through the character of Hirayama's son, a young man considered foolish. During the war's peak, he had been hailed and rewarded for serenading patriotic songs to the crowds on Kayabashi Bridge. However, the post-war landscape, less favorable to Japan, witnessed a stark turn of events. He was met with violence when he attempted to sing those same songs, his once-celebrated patriotism now met with hostility. In these intricate clashes of ideology and generational perspectives, the novel navigates the turbulent waters of a society grappling with the profound changes brought on by the passage of time and the shifting tides of history. An Artist of the Floating World has been described in a review in the following way:

“An Artist of the Floating World” is a sensitive examination of the turmoil in postwar Japan, a time when certainties were overturned, gender politics shifted, the hierarchy of the generations seemed to topple and even the geography of cities changed. All this is made more poignant when seen through the eyes of a man who is rejected by the future and who chooses to reject his own past. (Maloney, 2015)

The seismic transformation within society has cast its profound shadow upon the hallowed realm of traditional Japanese art, and within this evolution, Ono's creative odyssey bore witness to rem

In the nascent stages of his artistic journey, Ono wielded his brushes in the time-honored Jap conjuring compositions that often depicted the breathtaking vistas of nature, resplendent wom

Principal
Dyal Singh College
KARNAL

nestled serenely amid the wilderness (Ishiguro, 1986, p.69).Yet, the crucible of war altered the very essence of Ono's artistic expression, propelling it into the realm of patriotism and heroism. His canvases became potent tools of propaganda, igniting fervor and nationalism in the hearts of his compatriots. In a twist of fate, Ono's once-venerated painting technique came under scrutiny, as his Marxist comrade, Matsudo, questioned the very essence of his artistry. Matsudo, a harbinger of change, led Ono to a locale now relegated to the status of a "shanty area," a stark consequence of the relentless march of industrialization (Ishiguro, 1986, p.166). With a heavy heart, Matsudo pronounced, "...Only two or three years ago, this was not such a dire place. But now, it is burgeoning into a shanty district, with an ever-growing population ensnared in poverty" (Ishiguro, 1986, p.166).

Kazuo Ishiguro skillfully reveals a crucial moment in Ono's transformation in "An Artist of the Floating World." This change occurs when Matsudo, aiming to show Ono the harsh realities of poverty resulting from industrialization, leads him through the slums. Matsudo criticizes politicians and businesses for neglecting these conditions and emphasizes artists' unique responsibility to engage with society. Matsudo's passionate plea urges Ono to act, asserting that passivity contributes to the persistence of poverty. This Marxist ideal calls on artists to use their craft for the greater good. This encounter profoundly changes Ono, instilling in him a sense of empathy for the slum dwellers. Inspired, Ono shifts from pursuing aesthetic ideals to creating political art. His artwork transforms destitute slum children into nationalist warriors against post-colonial influences. While Ono's mentor had emphasized aesthetic pursuits, the post-colonial context reshapes Ono into a compassionate advocate. His contemporary works focus on the post-colonial world, moving away from traditional art references. This transformation reflects Ishiguro's exploration of how societal changes impact individuals, particularly artists, and how their perspectives evolve in response to new realities. Ishiguro masterfully captures the evolution of Ono's self-concept, a transformation that resonates with the shifting sands of the post-war era. In his book, Imagining Japan: The Japanese Tradition and its Modern Interpretation, Robert Bellah delves into the influence of Marxism in Japan during the tumultuous decades of the 1920s, 1930s, and the early years of World War II. Bellah astutely observes, "Amid the tensions and anxieties of Japan's uneven development, Marxism emerged as a comprehensive, theoretically sophisticated explanation, offering a clear alternative to the prevailing emperor-system nationalism"(Bellah, 2003, p.47).

Historically, when Japan surrendered in WWII, allied troopers controlled the country, bringing about big change. It took years for the Japanese to recover from air strikes and bombings. After 1945, Japanese history is rewritten. Ishiguro mentions it as:

Actually, until I was about twenty, I did a lot of reading about Japan and whenever there was a Japanese movie, I would go see it. Looking back now, it had a lot to do with my wanting to write at all. Japan was a very strong place for me because I always believed I would eventually return there, but as it turned out, I never went back. This very important place called Japan which was a mixture of memory, speculation, and imagination was fading with every year that went by. I think there was a very urgent need for me to get it down on paper before it disappeared altogether. (LI, 2021, p 9)

The Meiji administration prompted westernization in that time that clearly indicates it was happened to take advantage of. Hundreds of personnel from Western countries have been appointed by using the Meji administration in sectors like as education, banking, law, army affairs, and transportation. They have been westernized in their culture and art. Music and videos are also made with blended Western and Japanese elements. Under the supervision of the US Army and the American Constitution, they lost political and economic power. The persistent presence of the American occupation exerted a continual influence, gradually eroding the foundations of Japan's national identity, affecting both its physical and spiritual aspects. Within the context of this story, Ono's grandson, the lively Ichiro, stands out as a tangible representation of the profound cultural changes. A youthful spirit, he is enamored by the charm of cinema and fascinated by the mystique surrounding the American cowboy. In one poignant moment, Ono observes Ichiro immersing himself in a game, adopting the role of a hero, a stark departure from his Japanese cultural roots. Ono, inquisitive and somewhat bemused, ventures to ask his grandson a profound question: "Who do you wish to become, my young warrior? Lord Yoshitsune, the storied samurai, or perhaps a stealthy ninja?" To this query, Ichiro offers a response that embodies the pervasive influence of American culture - "The Lone Ranger," the iconic American cowboy. Of particular significance is Ichiro's linguistic foray, a symbolic gesture that underscores the omnipresence of American culture. Ono notes with a mixture of admiration and concern, "He attempts to communicate in English"(Ishiguro, 1986, p.35). Through language, heroes, and the very fabric of entertainment, American culture casts its formidable shadow upon Japanese society, rendering visible the gaping chasm of generational divide wrought by its profound impact.

Within this narrative, we find Ono, a man haunted by the ghosts of his past, his son's sacrifice in the war echoing through the corridors of his memories. In the embrace of his modest abode, he shares his days with his daughter, granddaughter, and the lingering specters of yesteryears. In the grand theater of this post-war landscape, our main characters take center stage—Ono, Kuroda, Noriko, Matsuda—and a host of supporting players who contribute their nuances to this unfolding drama. The heart of the narrative beats in sync with Ono's quest, a relentless exploration of his family's place in this brave new world. This is the epitome of post-war cultural metamorphosis, where the entire societal canvas undergoes a breathtaking transformation. Ono grapples not only with the shifting sands of post-war society and culture but also with the intı his relationships, particularly those with his daughters, Setsuko and Noriko. Through Ono's ey

Principal
Dyal Singh College
KARNAL

the intricate web of the past weaving itself into the present, a delicate thread that will ultimately shape the contours of their shared future. One stark reality confronts him—a past affiliation with the government that now casts a long shadow over his daughter Noriko's life. The fissures in Ono's marriage, a fracture that emerged when the plaintiff's family relocated, are laid bare. Once an ardent supporter of the war, Ono now stands branded as a traitor by former colleagues, his allegiance now a mark of shame. Setsuko, Noriko's sister, and her husband are convinced that this tarnished reputation played a pivotal role in Noriko's failed marriage, a marriage now lost to the annals of history. In this intricate dance of past and present, loyalty and betrayal, the narrative unfolds, revealing the profound impact of individual choices against the backdrop of a society in metamorphosis. It is a poignant exploration of the shifting sands of identity and allegiance in the wake of a world forever altered by the tempestuous tides of war and peace.

Within the intimate confines of their home, a tempest brews, as Setsuko points an accusatory finger squarely at Ono, laying the blame for the shattered negotiations at his feet. In this charged moment, Noriko steps into the role of a guardian, perched before the ancestral altar, offering her father sagely advice. It's a scene painted with intricate strokes, a snapshot of a familial dynamic in flux, captured within the pages of Ishiguro's 1986 opus (Ishiguro, 1986, p.50). In the vast portrayal of Japanese culture, where reverence for family ties, filial piety, and the sanctity of marriage are revered as sacred ideals, Ono's daughters navigate these hallowed traditions with a dash of irreverence, a touch of humor, and a hint of playful jest. Their banter, at times gentle ribbing and at others a gleeful teasing, is a testament to the evolving landscape of Japanese society. Gone are the days of stifled voices; the winds of change have ushered in a new era where women, once bound by tradition, now revel in the freedom to express themselves. In this familial theater, where age-old norms and contemporary mores dance in a delicate waltz, the daughters gently prod their father's sensibilities, an endearing reminder that even amidst the shifting sands of cultural revolution, the bonds of love and family remain resilient and enduring. As Elisabeth Rehn and Ellen Johnson Sirleaf point out, “Violence against women during conflict has reached epidemic proportions. Civilians have become the primary targets of groups who use terror as a tactic of war. Men and boys as well as women and girls are the victims of this targeting, but women, much more than men, suffer gender-based violence.” (Rehn and Sirleaf. p. 10)

Conclusion:

An Artist of the Floating World offers a compelling meditation on the intricacies of memory and power, inviting readers to interrogate their own relationship to history and truth. Through the lens of New Historicism, this paper has examined how Ishiguro navigates the complexities of post-war Japan, weaving together personal narrative and historical context to construct a multi-layered portrait of a society in transition. By analyzing the interplay between individual subjectivity and collective memory, this study has shed light on the ways in which literature serves as a site of contestation and negotiation, where alternative narratives can challenge dominant discourses and offer new perspectives on the past. Ultimately, An Artist of the Floating World reminds us of the importance of confronting uncomfortable truths and interrogating the stories we tell ourselves about who we are and where we come from.

REFERENCES

Primary Sources

1. Bellah, Robert N. (2003). Imagining Japan: the Japanese Tradition and Its Modern Interpretation. London: University of California Press.
2. Burton, Rob. (2007) Artists of the Floating World: Contemporary Writers between Cultures. Lanham: University Press of America.
3. Chalise, Keshav Raj. (2021). Ranahar: Textuality of History, Culture and Politics. Journal of Balkumari College. Vol-10 .https://www.sciencegate.app/document/10.3126/jbkc.v10i1.42090
4. Eagleton, T. (1996). Literary theory: An Introduction (2nd ed.). Minneapolis: The University of Minnesota Press.
5. Fonioková. Zuzana. (2015). Kazuo Ishiguro and Max Frisch: Bending Facts in Unreliable and Unnatural Narration. Peter Lang Edition: Frankfurtam Main.
6. Ishiguro K. (1986). An Artist of the Floating World. London: Faber&Faber.
7. LI, XINYI. (2021). A study on trauma in the novels of Kazuo Ishiguro. Trabajo Fin de Máster. Universidad de Alcalá. https://ebuah.uah.es/dspace/handle/10017/50139
8. Lyu, Xiaotang. (2021). An Introduction to New Historicism. Advances in Social Science, Education and Humanities Research. Vol- 543. https://www.atlantis-press.com/article/125955026.pdf
9. Maloney, Iain. (2015). An Artist of the Floating World. https://www.japantimes.co.jp/culture/2015/03/07/books/book-reviews/artist-floating-world/
10. Mason, Gregory. (1989). An Interview with Kazuo Ishiguro. Contemporary Literature. Vol. 30.No. 3. 334-347 ,http://www.jstor.org/stable/1208408
11. Rehn, Elisabeth and Ellen Johnson Sirleaf. (2002). Women, War and Peace: The Indepen Assessment on the Impact of Armed Conflict on Women and Women’s Role in Peace-bui

Principal
Dyal Singh College
KARNAL

Nations Development Fund for Women, https://www.unfpa.org/sites/default/files/pub-pdf/3F71081FF391653DC1256C69003170E9-unicef-WomenWarPeace.pdf
12. Shunya, Yoshimi. (2008). What Does "American" Mean in Postwar Japan? Nanzan Review of American Studies. Vol. 30.https://core.ac.uk/download/pdf/236154389.pdf
13. Woodward, Kathryn. (1997). Identity and Difference. London: Sage Publications Ltd.

Secondary Sources

1. Baş Korkmaz, Z. (2023). Culture as Industry in Kazuo Ishiguro's An Artist of the Floating World (1986). https://dergipark.org.tr/tr/pub/itbhssj/issue/81862/1357950
2. Choudhury, S.R. (2022), "Globalization with controlled income inequalities: a cross-country study", in Globalization, Income Distribution and Sustainable Development, Emerald Publishing, Bingley. doi: 10.1108/978-1-80117-870-920221010.
3. Close, N. (2018), "Tradition vs pop culture: attracting tourists with the cool Japan campaign", Mutual Images, Vol. 5.doi: 10.32926/2018.5.clo.tradi.
4. Craig, T. (2020), "The 'cool Japan' strategy: industrial policy for cultural industries", in Craig, T. (Ed.), Cool Japan: Inside Japan's Cultural and Creative Industries, Bluesky Publishing, Ashiya.
5. Das, Shruti. (2018). Political Representation in Ishiguro's an Artist of the Floating World and the Remains of the Day. Asian Resonance. https://www.socialresearchfoundation.com/upoadreserchpapers/1/212/1806280729041st%20%20shurti%20das.pdf
6. Eckel, Jan . (2023). Pivot Years. World War II in 20th-Century History. Journal of Modern European History. https://journals.sagepub.com/doi/10.1177/16118944231163225
7. Ishiguro, Kazuo. (2017). Kazuo Ishiguro – Interview. NobelPrize.org. https://www.nobelprize.org/prizes/literature/2017/ishiguro/interview/
8. Jr.,William A. Darity, Editor In Chief. (2008). International Encyclopedia of the Social Sciences. 2nd ed. Macmillan Reference USA. http://philosociology.com/UPLOADS/_PHILOSOCIOLOGY.ir_INTERNATIONAL%20ENCYCLOPEDIA%20OF%20THE%20SOCIAL%20SCIENCES_Second%20Edition_%20Darity_5760%20pgs.pdf
9. Katzenstein, Peter. (2014). "The fog of peace.". Post- Conflict Studies: An Interdisciplinary Approach. 1st Ed. London: Routledge, Taylor & Francis Group. https://www.book2look.com/embed/9781317801733
10. Lang, JM. (2000).Public memory, private history: Kazuo Ishiguro's The Remains of the Day. Clio. https://go.gale.com/ps/i.do?p=AONE&u=googlescholar&id=GALE|A62981231&v=2.1&it=r&sid=AONE&asid=04ecfb0b
11. Laato, S. and Rauti, S. (2021), "Central themes of the Pokémon franchise and why they appeal to Humans", paper presented at the Hawaii International Conference on System Sciences 2021 (HICSS54). doi: 10.24251/HICSS.2021.344.
12. Mansbach, Richard W. (2000). The Global Puzzle: Issues and Actors in World Politics. USA: Iowa State University.
13. Matthews, Sean, and Sebastian Groes, editors. (2010). Kazuo Ishiguro: Contemporary critical perspectives. Continuum International Pub. Group
14. Nakajima, Ayaka. (2015). "That Little World Has Passed Away" "Japanized" Japan as a Metaphorical Place in Kazuo Ishiguro's An Artist of the Floating World Author(s). https://hdl.handle.net/11094/61352
15. Raphael, Linda Schermer. (2002). Narrative Skepticism: Moral Agency and Representations of Consciousness in Fiction. University Press Copublishing Division / Fairleigh Dickinson University Press
16. Said, Edward. (1979). Orientalism. Vintage Books: New York
17. Severino, F.S. and Silva, F. (2023), "The trend of Japanese pop culture and its differentiating approach through event tourism", International Journal of Event and Festival Management, Vol. 14 No. 4. https://journals.sagepub.com/doi/10.1177/16118944231163225
18. Shaffer, B.W. (2001). Contemporary Literature: An Interview with Kazuo Ishiguro. University of Wisconsin Press. Spring. http://www.jstor.org/stable/1209082
19. Smith, A. D. (2013). Nationalism: Theory, Ideology, History. Polity Press: UK.
20. Tellini, Silvia.(2018). Identity and Nation in Kazuo Ishiguro's An Artist of the Floating World. Transnational Literature Vol. 10 no. 2, May. http://fhrc.flinders.edu.au/transnational/home.html
21. Walkowitz, R.L. (2001). Ishiguro's Floating Worlds. The Johns Hopkins University Press. Winter. http://www.jstor.org/stable/30032004

Principal
Dyal Singh College
KARNAL

35

THE DIGITAL INDIA: AN OVERVIEW

Dr. Sarika Choudhary

Abstract

Digital India campaign is a technology driven concept which transforms the economy into a knowledge based economy. The vision behind this campaign is transformation of Indian economy through technological advancement. To develop digitally empowered society, this campaign has become a transformative force. For the ease of living of society, digital infrastructure will lead the wave of digital transformation. Therefore, the Digital India initiative has been instrumental in achieving this goal, and it has been extended with a total budget of Rs, 14,903 Cr from 2021-22 to 2025-26. Government has developed various Public Digital Platforms such as Digilocker, UMANG, Rapid Assessment System, OpenForge, API Setu, Poshan Tracker, National AI Portal, MyScheme, India Stack Global and many others. For this National E-governance Division has been framed to support Minstry of Electronics and information technology. The present paper is basically tries to analyse the need of the digitalization of Indian economy and what are the benefits and challenges in this wave of digitalization. This paper throws light on key vision areas, focus areas and loopholes of this process as well as issues emerging after launching this project as most of population of India lives in rural areas.

KEYWORDS: DIGITALISATION, INFORMATION TECHNOLOGY, TECHNOLOGICAL ADVANCEMENT, NEGD, PUBLIC DIGITAL PLATFORMS.

INTRODUCTION:-

Today is the era of digitalization. Everything from pin to plane is today digitalizing. Everything can be done on internet. Internet is becoming very important in our day to day life. It is necessary for everyone to become "digital literate". But in country more than half of the total population is living in rural areas, where internet is not available as easily in urban areas. So the concept of "digital India" becomes the need of the hour. Digital India, a much ambitious programme, was launched on 1st of July (Wednesday) in 2015 at the Indira Gandhi Indoor Stadium, Delhi. It was launched in the presence of various top industrialists (Tata Group chairman Cyrus Mistry, RIL Chairman and Managing Director Mukesh Ambani, Wipro Chairman AzimPremii, etc). In the meeting, they shared their ideas of bringing digital revolution to mass people of India from cities to villages. Various events have been held in the presence of Information Technology companies to cover 600 districts in the country. Digital India programme is a big step taken by the government of India to make this country a digitally empowered country. The aim of launching this campaign is to provide Indian citizens electronic government services by reducing the paperwork. It is very effective and efficient technique which will save time and man power to a great extent.

WHY DIGITAL INDIA?

Many people in rural areas have no Internet connection, and also the content in regional languages is not sufficient to keep the readers engaged. Only 15% of the households can access the Internet, and few people can access mobile broadband. There are vast differences in urban centres such as metropolitan cities and remote rural areas. There is unwanted delay in govt. works, so people have to suffer a lot for smart cities and better metro cities.

According to a report, nearly 33% of Indian population is functionally illiterate (rank: 95), one-third of youth do not attend secondary education. So it is "need of hour"

MAIN FOCUS AREAS

This plan will really ensure the growth and development in India especially in the rural areas by connecting rural regions and remote villages with high-speed internet services. The overall project monitoring will be under the Prime Minister himself. Citizens of digital India may improve their knowledge and skill level after getting covered under the umbrella of internet. It is an ambitious project will benefit everyone especially villagers who travel long distance and waste time and money in doing paper works for various reasons. The main focus areas or also called nine pillars of digital India are as follows:

Principal
Dyal Singh College
KARNAL

1. Broadband highways.
2. Public internet access programmes.
3. Mobile connectivity everywhere.
4. E-kranti
5. E-governance.
6. Information for all
7. **Electronics Manufacturing,**
8. **IT Training for Jobs,**
9. **Early Harvest Programmes**.

In rural areas , people are not much aware with internet facility. They don't even heard about internet but after the scheme launched by Prime Minister NarenderModi, they are bocoming "digitally literate". We can see everyone today using whatsapp, facebook and many social websites.

THREE MAIN KEY VISION AREAS:

1. Digital infrastructure all through the country is like a utility to the Indian people as it will make available high speed internet delivering all the government services with ease and fast. It will provide lifelong, unique, online and authenticable digital identity to the citizens. It will make easy access to any online services like handling bank account, financial management, safe and secure cyber-space, education, distance learning, etc.
2. High demand of good governance and online services will make available all the services in real time through digitalization. Digitally transformed services will also promote people for doing online business by making financial transactions easy, electronic and cashless.
3. Digital empowerment of Indian people will really make possible of digital literacy through universally accessible digital resources. It will enable people to submit required documents or certificates online and not physically in the schools, colleges, offices or any organization.

EXECUTION OF THE PROGRAMME

The government is leveraging technologies in mobile, analytics, Internet of Things and cloud technology to implement the Digital India program, which is in turn associated with program such as Smart Cities and Make in India. The World Economic Forum (WEF) shows though India today has a better political and regulatory environment, its performance ranked 91. One of the reasons for India's low ranking is that its performance has remained static while that of other countries is improving fast to cope up the new emerging technologies. WEF has further attributed such poor performance to poor infrastructure and poor technology skills (individual level). The poor skills have become an impediment to widespread acceptance of information and communication technology. **BENEFITS OF DIGITAL INDIA**

1. It will boost up the "digital literacy" of India, especially in rural areas, where people are not much familiar wi-fi internet facilities.
2. It may ease the important health care services through e-Hospital system such as online registration, taking doctor appointments, fee payment, online diagnostic tests, blood check-up, etc.
3. It may ease the important health care services through e-Hospital system such as online registration, taking doctor appointments, fee payment, online diagnostic tests, blood check-up, etc.
4. Open access of broadband highways in all the cities, towns and villages will make possible the availability of world-class services.
5. For better management of online services on mobile such as voice, data, multimedia, etc, BSNL's Next Generation Network will replace 30-year old telephone exchange.
6. It provides benefits to the beneficiaries through National Scholarship Portal by allowing submission of application, verification process, sanction and then disbursal.
7. It will increase the "work efficiency".
8. It ensures the achievement of various online goals set by the government.
9. There is a plan of outsourcing policy also to help in the digital India initiative.
10. It will remove the unnecessary delay or "red tapism".
11. It is an effective online platform which may engage

Principal
Dyal Singh College
KARNAL

people in governance through various approaches like "Discuss, Do and Disseminate".

12. Its main motto is "power to empower".
13. People will become self-dependent with the ease of doing services.

PERFORMANCE OF PROJECT

Rs 1.3 trillion the Digital India program seeks to launch a large number of e-governance services across different sectors. These include education, healthcare and banking. Of course, the objective of all this is to bring transparency in the administration of services provided by the government to its citizens. Further, it would reduce corruption and lead to inclusive growth.

SPECIAL ACHIEVEMNTS OF INDIA

India has made a few achievements in e-governance projects such as Digital Locker, etc., the linking of Aadhaar to bank accounts to disburse subsidies.

Bharat Net the country's digital infrastructure has created a common service centre for each panchayat, for which all post offices and CSCs are to be upgraded.

As for broadband technology, India is better placed. According to a report, India's average broadband speed is 23.5 Mbps and maximum speed is 25.5 Mbps.

LOOPHOLES IN THE PROJECT

As a coin has two sides, same is the case with "digital India". The programme has many loopholes like some people don't feel comfortable while giving their personal details on Internet. They don't want to share their bank details etc. for payment purposes. Some major loopholes are as follows:

1. We may have to give our personal details like Aadhar no. , mobile no. etc. and there may be chances of "hacking" etc.
2. Some network programmes are big issues.
3. Everybody doesn't have knowledge regarding internet.

CHALLENGES AHEAD:-

The digital campaign is still facing the following challenges:

1. As most of people are living in rural area, therefore 25% of total population is still digitally illiterate. To literate people is a big challenge.
2. Low internet speed is also a big hindrance in the digital India initiative.
3. India is lacked behind in digital infrastructure.
4. Private sector participation in this campaign is most urgent as only public sector can't reach efficiently to the masses.
5. The access of internet in far off villages or backward regions is still a big challenge.

CONCLUSION:-

To conclude, it can be said that digital India is a great initiative by Govt. of India. Despite of so many advantages and disadvantages, it will prove a boon for India. So many new projects are being undertaken by govt. of India for its successful implementation. There are big challenges to implement fully this campaign, but it is possible only if there are some improvements like digital literacy awareness programmes, cyber risk security, proper installation of digital infrastructure will be done at national level.

References

- Rani Suman(2016) .Digital India: Unleashing Prosperity . Indian Journal of Applied Research, volume-6, Issue 4, pp187-189.

"Government aims to give 'Digital India' benefits to farmers: PM Modi"

- , The Times of India, 18 February 2016.
- Seema Dua(2017). "Digital India: Opportunities & Challenges". IJSTM,volume-6, Issue 3, pp61-67
- https://en.wikipedia.org/wiki/Digital_India

https://www.digitalindia.gov.in/

· https://digitalindia.gov.in/vision-vision-areas/

· https://negd.gov.in/about-national-e-governance-division/

· https://www.investindia.gov.in/team-india-blogs/digital-india-revolutionising-tech-landscape

· https://www.tice.news/tice-trending/assessing-impact-digital-india-initiative-startups

·https://www.researchgate.net/publication/369602917_Digital_India_An_analysis_of_its_impact_on_Economic_Social_and_Environmental_sectors

· https://euroasiapub.org/wp-content/uploads/2017/06/6IMMay-4879.pdf

Kindly send Hard copy of the Journal on the following Address

Sender's address :- Dr. Sarika Choudhary, House No. 11, Dewan Colony, Behind Ashoka Cinema, Karnal-132001, Haryana. Mobile No. 9991777779

Principal
Dyal Singh College
KARNAL

Indian Journal of Social Concerns

A RESEARCH JOURNAL OF HUMANITIES AND SOCIAL SCIENCES
(An International Peer-Reviewed & Refereed Journal)
(कला–मानविकी–समाजविज्ञान–जनसंचार–विधि–वाणिज्य–विज्ञान, वैचारिकी की अंतरराष्ट्रीय द्विमासिक शोध पत्रिका)

RNI - UPBIL / 2011 / 38102 ISSN - 2231 - 5837 www.ijscjournal.com Journal Impact Factor No. : 7.841
Volume - 13 : Issue - 59 May - June 2024

Certificate ID : IJSC/036

CERTIFICATE OF PUBLICATION

This is to certify that the paper entitled

35. The Digital India: An Overview

Authored by

Dr. Sarika Choudhary

Page No.
111–113

Research Journal is indexed in the International Innovative Journal Impact Factor (IIJIF) database

Hari Sharan Verma
Dr. Hari Sharan Verma
D.Litt
Editor in Chief

Principal
Dyal Singh College
KARNAL

Has been published in

Volume - 13 : Issue - 59 May- June 2024

RABINDRA BHARATI PATRIKA
ISSN : 0937-0037

BAL GANGADHAR TILAK AND THE HOME RULE MOVEMENT

Jyoti
Assistant Professor History, Dyal singh college Karnal

Abstract:

This paper explores the pivotal role of Bal Gangadhar Tilak in the Home Rule Movement in India, highlighting his significant contributions to the Indian independence struggle. It examines the socio-political context of early 20th-century India, the inception and objectives of the Home Rule Movement, and the strategies employed by Tilak to mobilize public support. By analysing Tilak's leadership, propaganda efforts, and alliances, the paper delves into the movement's profound impact on the broader Indian nationalist movement and its enduring legacy in India's fight for freedom. Through this exploration, the paper underscores Tilak's enduring influence on the trajectory of India's quest for self-governance.

Keywords: ***Bal Gangadhar Tilak, Home Rule Movement, Indian Independence Struggle, Swaraj, British Colonial Rule, Indian Nationalism***

Introduction:

Often referred to as the "Father of Indian Unrest," Bal Gangadhar Tilak played a crucial role in the Indian independence struggle. His fervent support of Swaraj, or self-rule, and his pivotal participation in the Home Rule Movement signalled turning points in the resistance movement against British colonial control. Tilak, who was born in Ratnagiri, Maharashtra, in 1856, became well-known as a fiery nationalist who supported mass mobilisation and direct action as means of achieving political objectives. Many were inspired by his forceful attitude and captivating leadership, which won him a respected position in Indian history.

The early 20th century was a period of burgeoning nationalist sentiment in India, with increasing dissatisfaction over British policies that led to economic exploitation, cultural suppression, and social inequities. In response to these oppressive conditions, Indian leaders began to organize and demand greater autonomy. Among them, Tilak stood out for his unyielding demand for complete self-governance and his ability to galvanize diverse sections of Indian society.

Tilak and Annie Besant started the Home Rule Movement in 1916 with the goal of achieving self-governance inside the British Empire. They did this by calling for constitutional changes and informing the Indian population of their rights. This movement was pivotal in transforming Indian nationalism from a moderate to a more assertive force, laying the groundwork for future mass movements.

This paper aims to provide a comprehensive analysis of Bal Gangadhar Tilak's leadership and the Home Rule Movement's contributions to India's quest for independence. It will explore the socio-political context of the time, the strategic initiatives undertaken by Tilak, and the movement's impact on the broader Indian nationalist movement. Through this examination, the paper seeks to underscore the enduring legacy of Tilak and the Home Rule Movement in the broader tapestry of India's struggle for freedom.

Objective of Research:

1) To understand the socio-political environment of early 20th-century India that led to the rise of the Home Rule Movement.

Principal
Dyal Singh College
KARNAL

2) To investigate the leadership style, strategies, and actions of Bal Gangadhar Tilak within the movement.
3) To explore the methods and tools used by Tilak to mobilize public support and raise political consciousness among Indians.
4) To evaluate the immediate and long-term impacts of the Home Rule Movement on the Indian nationalist movement.
5) To trace the legacy of Tilak and the Home Rule Movement, highlighting their influence on subsequent phases of the Indian independence struggle.

Literature Review:

a. **Stanley Wolpert (1962).** "Tilak and Gokhale: Revolution and Reform in the Making of Modern India". In Wolpert's ground-breaking book, the divergent approaches to India's freedom struggle are highlighted through a comparative analysis of Bal Gangadhar Tilak and Gopal Krishna Gokhale. Wolpert emphasizes Tilak's radical methods and his role in mobilizing the masses, contrasting it with Gokhale's moderate stance. This book provides valuable context for understanding Tilak's revolutionary tactics during the Home Rule Movement.
b. **Sumit Sarkar (1983).** "Modern India: 1885-1947". Sarkar's comprehensive history of modern India includes a detailed examination of the Home Rule Movement. Sarkar situates the movement within the broader nationalist activities of the time, discussing Tilak's strategies and their effectiveness in galvanizing public support. The book is instrumental in understanding the movement's place within the larger independence struggle.
c. **Judith M. Brown (1972).** "Gandhi's Rise to Power: Indian Politics 1915-1922". Brown's book offers significant insights into the political climate of India during the Home Rule Movement, despite its primary concentration on Mahatma Gandhi. She offers a nuanced perspective on how Tilak's activism set the stage for later mass movements as she explores the relationship between Tilak's activity and Gandhi's growing influence.
d. **Peter Heehs (1994).** "Indian Nationalism and the Early Congress". The Indian National Congress's involvement and the evolution of Indian nationalism are both covered in Heehs' book. His examination of the Home Rule Movement centres on Tilak's contribution and the movement's influence on Congress. Heehs highlights the shift from moderate to more radical approaches within the nationalist movement, influenced significantly by Tilak's leadership.
e. **Sawarkar (2005).** "Tilak: A Revolutionary Leader". Sawarkar's biography of Tilak offers an in-depth look at his life, ideology, and political activities. This work provides detailed accounts of Tilak's involvement in the Home Rule Movement, his methods of mobilization, and his enduring impact on Indian nationalism. Sawarkar's portrayal of Tilak as a revolutionary leader adds a personal dimension to the historical narrative.

The reviewed literature collectively underscores the importance of Bal Gangadhar Tilak and the Home Rule Movement in India's independence struggle. Each work contributes to a multifaceted understanding of Tilak's leadership, the movement's strategies, and its lasting impact on Indian nationalism. This foundation of scholarship provides a robust basis for further exploration and analysis in this research paper.

Research Methodology:

The secondary data analysis method used in this study makes use of information from a variety of sources, including books, journals, governmental organisations, academic studies, and rese

Principal
Dyal Singh College
KARNAL

Bal Gangadhar Tilak and The Home Rule Movement:

"Lokmanya" Tilak, also known as Bal Gangadhar Tilak, played a crucial role in the Indian independence struggle. Born in Ratnagiri, Maharashtra, on July 23, 1856, he was a gifted student who rose to prominence in the Indian National Congress (INC) in 1890. He represented the extremist faction, which demanded swaraj (self-rule) and believed in more assertive forms of protest.

The Irish Home Rule Movement, which aimed to provide Ireland autonomy inside the United Kingdom, served as an inspiration for the Home Rule Movement in India. Tilak and Annie Besant worked to ensure Indians throughout the British Empire had self-governance because they saw the model's promise for India. In 1914, Tilak returned to India after serving a six-year prison sentence in Mandalay, Burma, for sedition. The outbreak of World War I further exacerbated India's economic hardships and political discontent, providing a ripe context for the Home Rule Movement.

Annie Besant established her Home Rule League in Madras (now Chennai), while Tilak established the Indian Home Rule League in Pune, Maharashtra, in 1916. While operating separately, the two leagues shared the objective of achieving self-rule. "Kesari," Tilak's periodical, was crucial in spreading the movement's ideals and inspiring others to join it. The catchphrases of the campaign, "Home Rule for India" and "Swaraj is my birthright, and I shall have it," struck a deep chord with the people of India.

Tilak's approach to the Home Rule Movement was multifaceted, advocating for constitutional means, mass mobilization, and political education. He believed that a well-informed and united populace was essential for the success of the movement. Under Tilak's leadership, the Home Rule League organized numerous rallies, public meetings, and processions, raising political awareness and fostering a sense of national unity. The movement also sought to bridge communal divides, promoting Hindu-Muslim unity in the fight against colonial rule.

The Home Rule Movement faced significant challenges, both from within and outside the Indian political landscape. The British authorities viewed the movement as a threat to their dominance and responded with repression. Leaders and activists were arrested, and newspapers were censored or shut down. In 1917, Annie Besant was arrested, sparking widespread protests and further galvanizing support for the movement. Internal divisions within the Indian National Congress also posed challenges, with moderate leaders like Gopal Krishna Gokhale favoring a more conciliatory approach towards the British.

An important turning point in the Indian independence movement was the participation of Bal Gangadhar Tilak in the Home Rule Movement. His leadership, strategic acumen, and unwavering commitment to the cause of self-rule galvanized a nation and set the stage for the larger freedom struggle that followed. The Home Rule Movement not only challenged British colonial authority but also united Indians across regions and communities in the fight for their rights.

Historical Context: Early 20th Century India:

During the early 20th century, India was under British rule, leading to growing discontent due to oppressive policies, economic exploitation, and racial discrimination. The British administration's practices severely impacted Indian agriculture and industry, causing poverty and famine. Racial discrimination also fostered resentment among Indians, who were treated as second-class citizens. The partition of Bengal in 1905 was a pivotal moment in the rise of Indian nationalism. The Viceroy, Lord Curzon, divided Bengal into two provinces for administrative efficiency, but the real motive was to weaken the nationalist movement by creating religious and regional divisions. This led to a significant upsurge in nationalist sentiments across India and the beginning of more radical and mass-based approaches in the Indian freedom struggle.

Principal
Dyal Singh College
KARNAL

The early nationalist movement in India was dominated by moderate leaders who sought self-governance through constitutional reforms and gradual negotiations with British authorities. They focused on lobbying for more Indians in government jobs, greater fiscal responsibility, and increased legislative representation. However, their efforts were limited, leading to widespread frustration and disillusionment within the nationalist ranks. More assertive leaders emerged, believing in stronger measures to achieve self-rule.

Bal Gangadhar Tilak and the Shift towards Assertive Nationalism:

Bal Gangadhar Tilak, also known as "Lokmanya," was a charismatic leader who believed in the birthright of every Indian and that passive methods were not sufficient. His political philosophy was rooted in a blend of traditional Indian values and modern understanding of political struggle, and he was a staunch advocate of using cultural symbols and festivals to mobilize the masses.

Tilak's confrontational stance led to his imprisonment on several occasions, with his most notable imprisonment being in 1908 for sedition due to his fiery writings in his newspapers, Kesari and Maratha. During his incarceration in Mandalay, Burma, Tilak wrote his seminal work, Gita Rahasya, which emphasized the importance of action and duty, reinforcing his belief in active resistance against injustice.

Tilak and Annie Besant started the Indian Home Rule Movement in 1916, taking inspiration from the Irish Home Rule Movement. They intended to attain self-governance for India under the British Empire, operating as a forerunner to eventual independence. The movement's strategies included mass mobilization, political education, and legislative action. Tilak's ability to connect with the masses was unparalleled, emphasizing the importance of cultural unity and the revival of Indian heritage as a means to foster national solidarity.

The Indian National Congress's internal strife and the British government posed serious obstacles to the Home Rule Movement. Severe repression was the British government's response to the movement, which they saw as an open danger to their authority. Public gatherings were outlawed, leaders and activists were detained, and media were controlled. The movement was further energised by the huge protests that followed Annie Besant's 1917 arrest. Challenges were also created by internal divides within the Indian National Congress, which was divided between moderates and radicals.

The Home Rule Movement had a lasting impact on the Indian independence struggle, marking a significant shift from moderate to more assertive forms of political activism and setting the stage for future mass movements. It succeeded in spreading the demand for self-rule across India, involving a broader section of society in the nationalist cause. One of the key achievements of the Home Rule Movement was the transformation of Indian political consciousness, making self-rule a tangible and achievable goal for millions of Indians.

Bal Gangadhar Tilak's role in the Home Rule Movement cemented his legacy as a stalwart of Indian nationalism. His insistence on swaraj and his ability to mobilize the masses inspired future generations of freedom fighters. Although Tilak passed away in 1920, his vision and ideals continued to influence the Indian independence movement, particularly in the subsequent Non-Cooperation and Civil Disobedience movements led by Mahatma Gandhi.

The Home Rule Movement: Inception and Objectives

In 1916, Annie Besant and Bal Gangadhar Tilak started the Home Rule Movement, which proved to be crucial in India's fight for freedom. Drawing inspiration from the Irish Home Rule League, the movement aimed to achieve self-governance within the British Empire. It sought to educate the Indian populace about their political rights and the necessity of self-rule through extensive pr

Principal
Dyal Singh College
KARNAL

public engagement.

Tilak's dynamic leadership was the driving force behind the Home Rule Movement, emphasizing the need to reach out to all sections of society, including peasants, workers, and students. He understood that the movement needed to be broad-based and inclusive, transcending regional, linguistic, and class barriers. His strategic use of vernacular languages made the movement accessible to the common people, ensuring that the message of self-rule resonated deeply with them.

Tilak was adept at forming strategic alliances to strengthen the movement, such as the Lucknow Pact of 1916, which aimed to present a united front to the British authorities. This agreement addressed communal representation and bridging communal divides, expanding the reach and influence of the Home Rule Movement, making it a truly national movement.

The Indian independence movement was significantly and permanently impacted by the Home Rule Movement, which signalled a shift from peaceful, petition-based strategies to more forceful, mass-based activity. It dramatically increased Indians' political consciousness and made the desire for self-rule a popular and achievable objective. A significant legacy of the Home Rule Movement in India was the mobilisation of a diverse range of Indian society, including women, students, workers, and peasants.

Tilak's legacy as a fearless advocate for swaraj endures, reminding future generations of the power of determined and principled leadership. The Home Rule Movement set the stage for the larger freedom struggle that ultimately led to India's independence in 1947, highlighting the crucial role of mass mobilization and national unity in achieving political liberation.

Impact of the Home Rule Movement:

The Home Rule Movement was a significant event in Indian history, awakening political consciousness among the nation through the spread of self-rule messages through newspapers, public meetings, and rallies. This movement instilled a sense of national pride and unity among Indians, recognizing their stake in their country's governance and the achievable goal of self-rule. This newfound political awareness laid the foundation for future mass movements and shaped the course of the Indian independence struggle.

The movement's widespread agitation and public support led to significant pressure on British authorities, forcing them to acknowledge the legitimacy of Indian aspirations for greater autonomy. This pressure ultimately led to the Montagu-Chelmsford Reforms of 1919, which introduced limited self-governance in India for the first time. Although not fully achieving self-rule, the reforms marked a concession by the British and a step towards greater Indian participation in governance.

The Home Rule Movement left a lasting legacy throughout the Indian independence struggle, influencing future leaders like Mahatma Gandhi to adopt more radical forms of protest. The organizational structures and mobilization tactics developed during the movement served as a blueprint for subsequent mass movements, emphasizing grassroots activism, cultural revivalism, and unity across communal lines.

The Home Rule Movement played a pivotal role in shaping Indian history, awakening political consciousness, exerting pressure on British authorities, and laying the groundwork for future mass movements.

Conclusion:

Bal Gangadhar Tilak's leadership in the Home Rule Movement stands as a testament to his unwavering commitment to India's freedom struggle. Tilak's vision, strategies, and ability to mobilize the masses were instrumental in challenging British authority and laying the groundwork

Principal
Dyal Singh College
KARNAL

The Home Rule Movement marked a pivotal moment in India's fight for independence, inspiring millions to join the cause and instilling a sense of national pride and unity. While the movement did not achieve immediate self-rule, its impact endured, shaping the trajectory of the Indian nationalist movement. Tilak's legacy as a fearless advocate for swaraj continues to inspire future generations, reminding us of the power of determined and principled leadership in the pursuit of justice and freedom. The Home Rule Movement remains a defining chapter in India's history, serving as a testament to the resilience and determination of those who dared to dream of a free and independent India.

References:

- *Brown, Judith M. Gandhi's Rise to Power: Indian Politics 1915-1922. Cambridge University Press, 1972.*
- *Heehs, Peter. Indian Nationalism and the Early Congress. Oxford University Press, 1994.*
- *Kulke, Hermann, and Dietmar Rothermund. A History of India. Routledge, 2004.*
- *Sarkar, Sumit. Modern India: 1885-1947. Macmillan, 1983.*
- *Wolpert, Stanley. Tilak and Gokhale: Revolution and Reform in the Making of Modern India. University of California Press, 1962.*
- *Bipan Chandra. India's Struggle for Independence. New Delhi: Penguin Random House India, 2016.*
- *Amaresh Misra. Tilak and Gokhale: Revolution and Reform in the Making of Modern India. Rupa Publications, 2005.*
- *Guha, Ramachandra. "Bal Gangadhar Tilak and the Rise of Militant Nationalism." The Economic and Political Weekly 39, no. 33 (2004): 3737-742.*
- *Kumar, Ravindra. "Home Rule Movement in India: A Study." The Indian Historical Review 35, no. 1 (2008): 87-101.*
- *Patel, Prakash. "Bal Gangadhar Tilak: A Study of His Role in the Indian National Movement." PhD diss., University of Mumbai, 1998.*
- *Sharma, Shyam Sundar. "The Home Rule Movement in India: A Historical Analysis." MPhil thesis, Jawaharlal Nehru University, 2010.*
- *"Bal Gangadhar Tilak." Indian National Congress. Accessed January 20, 2024. https://www.inc.in/en/leadership/past-party-president/bal-gangadhar-tilak*
- *"The Home Rule Movement." National Portal of India. Accessed January 20, 2024. https://www.india.gov.in/my-government/indian-political-system/home-rule-movement*
- *Bakshi, S. R. (1984). Home Rule Movement. http://books.google.ie/books?id=oFkeAAAAMAAJ&q=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=1&source=gbs_api*
- *Bakshi, S. R. (1989). Documents of Home Rule Movement. http://books.google.ie/books?id=PEpuAAAAMAAJ&q=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=2&source=gbs_api*
- *R, B. S., & Bakshi, S. R. (1990). Bal Gangadhar Tilak. Anmol Publications Pvt Ltd. http://books.google.ie/books?id=LOjhv5g629UC&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=4&source=gbs_api*

Principal
Dyal Singh College
KARNAL

- *Inamdar, N. R. (1983). Political Thought and Leadership of Lokmanya Tilak. Concept Publishing Company. http://books.google.ie/books?id=NPLBbZSYXXEC&printsec=frontcover&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=5&source=gbs_api*
- *Team, Y. E. (n.d.). Modern India & Indian National Movement. YOUTH COMPETITION TIMES. http://books.google.ie/books?id=DkEgEAAAQBAJ&pg=PA130&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=7&source=gbs_api*
- *Tilak, B. G. (1992). Selected Documents of Lokamanya Bal Gangadhar Tilak, 1880-1920. http://books.google.ie/books?id=DSBuAAAAMAAJ&q=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&dq=BAL+GANGADHAR+TILAK+AND+THE+HOME+RULE+MOVEMENT&hl=&cd=8&source=gbs_api*
- *Pinney, C. (2011). The Tiger's Nature, but Not the Tiger: Bal Gangadhar Tilak as Mohandas Karamchand Gandhi's Counter-Guru. Public Culture, 23(2), 395–416. https://doi.org/10.1215/08992363-1161967*
- *Brown, D. M. (1958). The Philosophy of Bal Gangadhar Tilak: Karma vs. Jñāna in the Gītā Rahasya. The Journal of Asian Studies, 17(2), 197–206. https://doi.org/10.2307/2941466*
- *Kamra, S. (2016). Law and Radical Rhetoric in British India: The 1897 Trial of Bal Gangadhar Tilak. South Asia: Journal of South Asian Studies, 39(3), 546–559. https://doi.org/10.1080/00856401.2016.1196529*
- *KIRANŞAN, I. (2019a). Hindistan İstiklal Mücadelesinin Kahramanlarından Bal Gangadhar Tilak'ın Hayatı ve İcraatları. JOURNAL OF HISTORY AND FUTURE, 6(4), 1595–1607. https://doi.org/10.21551/jhf.843346*
- *Seth, S. (2006). The critique of renunciation: Bal Gangadhar Tilak's Hindu nationalism. Postcolonial Studies, 9(2), 137–150. https://doi.org/10.1080/13688790600657819*
- *KIRANŞAN, I. (2019b). Hindistan İstiklal Mücadelesinin Kahramanlarından Bal Gangadhar Tilak'ın Hayatı ve İcraatları. JOURNAL OF HISTORY AND FUTURE, 6(4), 1595–1607. https://doi.org/10.21551/jhf.843346*
- *Wickberg, E., & Kerr, G. H. (1975). Formosa. Licensed Revolution and the Home Rule Movement, 1895-1945. Pacific Affairs, 48(4), 611. https://doi.org/10.2307/2756468*

Principal
Dyal Singh College
KARNAL

RABINDRA BHARATI PATRIKA

রবীন্দ্র ভারতী পত্রিকা

BAL GANGADHAR TILAK AND THE HOME RULE MOVEMENT

Authored By

Jyoti

Assistant Professor History, Dyal singh college Karnal

Principal
Dyal Singh College
KARNAL

Published in

Rabindra Bharati Patrika: Rabindra Bharati University

ISSN No: 0937-0037

Impact Factor: 6.4

Vol.: XXVII, No. : 1, January 2024

UGC CARE, Peer Reviewed and Refereed Journal

ज्ञान-विज्ञान विमुक्तये

Rabindra Bharati Patrika ISSN No: 0937-0037

Editor
Rabindra Bharati Patrika