

"Ending plastic pollution"

The Journal of
AGRICULTURE AND ENVIRONMENT

Volume: 26

July 2025



Government of Nepal
Ministry of Agriculture and Livestock Development
Singhadurbar, Kathmandu
July, 2025

The Journal of

AGRICULTURE AND ENVIRONMENT

Volume: 26

July 2025



Government of Nepal
Ministry of Agriculture and Livestock Development
Singhadurbar, Kathmandu
July 2025

Published by:

Government of Nepal
Ministry of Agriculture and Livestock Development
Food Security and Food Technology Division
Singhadurbar, Kathmandu, Nepal

Telephone: +977-1-4211940
Web: www.moald.gov.np
Email: info@moald.gov.np,
agrijournal@moald.gov.np (manuscript submission)
ISSN: 2091 - 0991

Disclaimer: The views and opinions expressed in these articles are those of the authors and do not necessarily reflect the views of the publisher.

PATRONS

Govinda Prasad Sharma, Ph.D., Secretary (Agriculture Development)

Deepak Kumar Kharal, Ph.D., Secretary (Livestock Development)

Ministry of Agriculture and Livestock Development

Singhadurbar, Kathmandu

The Journal of

AGRICULTURE AND ENVIRONMENT

Volume-26

EDITORIAL BOARD

Editor-in-Chief

Januka Pandit, Ph.D.

Joint Secretary, Ministry of Agriculture and Livestock Development

EDITORS

Prof. Resham Bahadur Thapa, Ph.D., Agriculture and Forestry University

Pramod Koirala, M.Sc. (Nutrition), Ministry of Agriculture and Livestock Development

Bishnu Hari Devkota, M.Sc. (Int. Horticulture), Ministry of Agriculture and Livestock Development

Prakash Raj Bista, Ph.D., Agriculture Information and Training Center

Shyam Sundar Yadav, M.A.(Eco. of Agri. Dev.), Ministry of Agriculture and Livestock Development

Sujit Poudel, M.Sc. (Agriculture), Ministry of Agriculture and Livestock Development

Prateek Joshi, M.S. (Food Science), Ministry of Agriculture and Livestock Development

DESIGN AND LAYOUT

Ministry of Agriculture and Livestock Development

Singhadurbar, Kathmandu

EDITORIAL

The Journal of Agriculture and Environment (26th Volume) is a publication legacy of the high-quality journal which has been published annually by the Ministry of Agriculture and Livestock Development, Government of Nepal. This volume is a collection of research articles, review and analytical papers. This journal tries to cover wide areas of agriculture, like food and nutrition security; climate change; agricultural biodiversity; insect, pest and disease management; sustainable agricultural practices; crop and soil management; livestock and fisheries production; and agricultural policy frameworks.

Agriculture practices are changing globally due to climate change, technological innovations, Internet of Things (IoT), youth migration, the perishable nature of agricultural commodities, which demands tools and methods that support sustainable agricultural development. The innovative ideas, tools and methodologies included in the articles of this journal will pave the way for policy formulation towards sustainable agricultural development.

There are 23 articles in this volume, and we would like to extend our sincere thanks to the authors and reviewers for their expertise and contribution to enhance the quality and standard of the articles of this journal. Our editorial board has been committed to maintain the quality of the journal through a peer review process, evaluated by at least two independent reviewers to ensure quality and credibility.

We would like to request our valuable readers to delve into these findings and apply them in the real world. Let us work together to achieve sustainable, equitable and resilient agricultural development of Nepal.

Thank you for the continuous support.

Dr. Januka Pandit

Editor-in-Chief

Guidelines to authors: Manuscript preparation and submission

The Journal of *Agriculture and Environment* is devoted to the cause of advancing understanding on the various aspects of Agriculture through literature review, theoretical analysis, research and practical experiences. Besides research and review papers, the journal may arrange spaces for case study, methodological approach, book review, report on seminar and meeting, short communication and letter to editor. Authors are requested to follow the following guidelines on preparation and submission of manuscript.

1. The manuscript must be an original work written in English and not published elsewhere.
2. The title should be short and specific, but it should reflect the contents in the manuscript.
3. The abstract should be in **Times New Roman** font (italics) 11-point font size, not exceeding 200 words, should concisely state major objective, methodology, findings and conclusion. It should not include diagram, footnote, equation or any parenthetical reference.
4. Key-words in alphabetical order should not exceed five standard words.
5. Main text of the technical manuscripts should include introduction, materials and methods, results and discussions, conclusions and references.
6. The manuscript should not exceed 4500 words in total. It should be in MS-word with pages set on A4 size, the top and left margins at 3 cm and the right and bottom margins at 2.5cm. The text format should be on **Times New Roman** font of, 11-point size, single space and **double columns**. Authors are encouraged to use the following **Microsoft Word-template** to prepare the manuscript;
 - a. The title of the manuscript set as HEADING 1 (paragraph style) should be all capitalized in bold 12-point font size.
 - b. Name of the author(s) should follow the title in new paragraph in normal 10-point font size, bold.
 - c. The first level headings should be all capitalized and bold 11-point font size. The second level headings should be bold, italic and first letter capitalized and in bold 11-point font size. The third level headings should be in sentence case, italicized and normal.
 - d. In tables, borders should be minimized, and text and numbers should be in 9-point font size.
 - e. Bibliographic entries in the reference should be in 9-point font size.
7. Number of footnotes should be minimized, and it should not come for citation.
8. Many/big tables and figures in the text should be avoided. Supplementary figures and tables may be placed in the annexure.
9. Whenever possible, SI Units (International System of Units) should be used.
10. Images/Diagrams should be of high-quality illustrations in any of the following formats: PNG/JPEG/TIFF. Written text in an image should be clear and easy to read and located only either at the top or bottom of the page.
11. APA referencing style should be used and must be individually listed in alphabetical order of at the end of the manuscript. Referencing style should be different for books, journals, dissertation, newspapers and other unpublished materials. Some examples are given as below:

For a journal article:

Joshi, P., Chauysrinule, C., Mahakarnchanakul, W., & Maneeboon, T. (2022). Multi-Mycotoxin Contamination, Mold Incidence and Risk Assessment of Aflatoxin in Maize Kernels Originating from Nepal. *Microbiology Research*, 13(2), 258-277.

For a book:

Manay Shakuntala, N., & Shadaksharaswami, M. (2001). *Food Facts and Principles*. New Age International (P) Limited, New Delhi, India.

For a chapter in a book:

Hinton, D.P., & Stevens-Gill, D. (2016). Psychometrics in organisational settings. In A. Attrill & C. Fullwood (Eds.), *Applied cyberpsychology: Practical applications of cyberpsychological research and theory* (pp. 236–255). London: Palgrave Macmillan.

For webpages:

British Psychological Society (BPS). (2018). Code of Ethics and Conduct (2018). Retrieved from <https://bps.org.uk/news-and-policy/bps-code-ethics-and-conduct>

For a thesis/dissertation:

JOSHI, P., & Mahakarnchanakul, W. (2022). *Assessment of Mycotoxins and Fungal Profile in Nepalese Maize* (Doctoral dissertation, Kasetsart University).

12. Following editorial scrutiny, the manuscripts are subject to rigorous peer review.
13. The Editor-in-Chief and the Editorial Board are not responsible for any damage or loss of submitted manuscript and return of unaccepted manuscripts to the authors whatever.
14. The Editor-in-Chief deserves final right to accept or reject a submission.
15. Previous issues of the journal are available at <http://www.moald.gov.np>.
16. Manuscripts that do not correspond to the above mentioned instructions can be returned without review.

TABLE OF CONTENTS

ARTICLE	NO.	PAGE
PATRONS		v
EDITORIAL BOARD		v
EDITORS.....		v
EDITORIAL		vii
GUIDELINES TO AUTHORS: MANUSCRIPT PREPARATION AND SUBMISSION.....		viii
EXPLOING FOOD INSECURITY AMONG INTERNALLY DISPLACED PEOPLE IN LAMKA, MANIPUR, NORTHEAST INDIA.....		1
	Mounching Zou, Glenn C Kharkongor and Melodynia Marpna	
TECHNICAL AND ECONOMIC FEASIBILITY OF NANOBUBBLE AERATION TECHNOLOGY FOR RAINBOW TROUT (<i>Oncorhynchus mykiss</i>) FARMING IN NEPAL.....		11
	Hareram Devkota, Dilip Kumar Jha, Tista Prasai Joshi, Shreemat Shrestha and Mahendra Prasad Bhandari	
ESTIMATE OF SUPPLY RESPONSE OF RICE USING TIME SERIES DATA IN NEPAL.....		21
	Durgesh Man Shrestha, Suraj Bharati, Bikesh Thapa and Usha Shrestha	
SCHOOL BASED ANEMIA PREVENTION PROGRAM IN NEPAL: GOVERNMENT INTERVENTIONS AND THE HEALTH BELIEF MODEL.....		32
	Pramod Koirala and Melodynia Marpna	
PRODUCTION ECONOMICS AND MARKETING OF POTATO (<i>Solanum tuberosum</i> L.) IN ROLPA, NEPAL.....		46
	Shuvechchha Dhakal, Jeevan RC, Nabin Bhandari, Naran Prasad Devkota, Mahesh Kumar Thapa and Aasish Bhandari	
EFFECT OF DIFFERENT MULCHING MATERIALS ON GROWTH AND YIELD OF CAULIFLOWER (<i>Brassica oleracea</i> var. <i>botrytis</i> L.) IN SALYAN, NEPAL.....		57
	Pratiksha Tumbapo, Deepika Timsina, Monika Thapa and Prajala Badal	
MONITORING AND MANAGEMENT OF FALL ARMYWORM, <i>Spodoptera frugiperda</i> (J.E. SMITH) (LEPIDOPTERA: NOCTUIDAE) ON MAIZE IN ROLPA, NEPAL.....		67
	Biroj Belbase, Kapil Kafle, Resham Bahadur Thapa and Dipak Khanal	
KNOWLEDGE AND ADOPTION OF RECOMMENDED TECHNOLOGY BY WHEAT FARMERS IN SUNWAL, NAWALPARASI WEST, NEPAL.....		77
	Pratikshya Pandey, Pankaj Raj Dhital, Puspa Raj Dulal and Naran Prasad Devkota	
MONITORING SCARAB BEETLES IN HORTICULTURAL FIELD OF PAKLIHAWA CAMPUS USING LIGHT TRAP.....		86
	Ganesh G.C. , Puja Roka and Dipak Khanal	
BIOLOGICAL MANAGEMENT OF CABBAGE BUTTERFLY (<i>Pieris brassicae nepalensis</i>) IN BAJURA, NEPAL.....		96
	Mahesh Rokaya, Ritambar Ghimire and Kailash Bhatta	

INSECT PESTS OF TOMATO AND THEIR MANAGEMENT PRACTICES ADOPTED BY FARMERS IN CHANDRAGIRI AND KIRTIPUR MUNICIPALITIES OF KATHMANDU DISTRICT.....	106
Janaki Pal, Rajanish Mishra, Ramesh Bahadur Karki, Lokmani Joshi and Naresh Joshi	
EFFECTS OF DIFFERENT METHOD OF SEED PRIMING ON SEED QUALITY PARAMETERS OF RAMPUR HYBRID-10 VARIETY OF MAIZE	119
Bipin Joshi, Deepika Timsina, Prarthana Joshi, Dhanendra Adhikari, and Sapana Shrestha	
DETERMINANTS OF INSURANCE FOR BANANA IN CHITWAN, NEPAL.....	126
Ashma Dhakal and Udit Prakash Sigdel	
FIELD EVALUATION OF BIOPESTICIDES AGAINST SPOTTED POD BORER ON YARDLONG BEAN AT JHUMKA, SUNSARI.....	141
Madhu Kumari Ray, Pratik Poudel, Kiran Acharya, Jharana Shrestha and Saraswati Shrestha	
SOIL FERTILITY STATUS OF NEPAL: ANALYSIS FROM 2011-2025.....	147
Santosh Shrestha, Saroj Koirala, Sudip Poudel, Deekshya Adhikari, Nirmal Mani Dahal and Janma Jaya Gairhe	
ECOFRIENDLY MANAGEMENT OF STRIPED FLEA BEETLE (<i>Phyllotreta striolata</i>) BY USING DIFFERENT BIOPESTICIDES ON RADISH AT JHUMKA, SUNSARI.....	159
Jharana Shrestha, Kiran Acharya, Madhu Kumari Ray and Saraswati Shrestha	
MONITORING OF FRUIT FLY POPULATION USING DIFFERENT LURES AND ATTRACTANTS ON CUCUMBER AT JHUMKA, SUNSARI, NEPAL.....	169
Kiran Acharya, Jharana Shrestha, Madhu Kumari Ray, Deepu Kumar Tiwari and Saraswati Shrestha	
EFFECT OF MULCHING MATERIALS AND VARIETIES ON GROWTH AND YIELD OF OKRA (<i>Abelmoschus esculentus</i> (L.) Moench) IN NUWAKOT, NEPAL.....	178
Aarati Rashaily , Tej Narayan Bhusal , Pabitra Bhujel and Amrit Adhikari	
DIETARY INTAKE AND NUTRIENT ADEQUACY AMONG VEGETARIANS AND NON-VEGETARIANS.....	190
Rubina Karki and Prateek Joshi	
ASSESSMENT OF FARMERS' KNOWLEDGE OF COFFEE WHITE STEM BORER (<i>Xylotrechus quadripes</i>) AND IT'S MANAGEMENT STRATEGIES IN GULMI, NEPAL.....	201
Prarthana Joshi, Bipin Joshi, Sabita Poudel and Amrita Basnet	
CARBON SEQUESTRATION BY DIFFERENT CITRUS SPECIES IN NEPAL: AN EMPIRICAL STUDY.....	209
UK Acharya, A Katuwal and AK Acharya	
DEGREE DAY MODEL OF GRAPEVINE PHENOLOGY IN THE MID-HILL CONDITIONS OF NEPAL.....	219
Anil Kumar Acharya, Durga Mani Gautam, Bhim Bahadur Khatri, Puspa Raj Poudel and Kishor Chandra Dahal	
EVALUATION OF SINGLE-CROSS MAIZE HYBRIDS IN WINTER AT RAMPUR, CHITWAN, NEPAL.....	227
Priyanka Bhandari, Bijay Mahato, Ghanashyam Bhandari, Aayam Poudel and Mahendra prasad Tripathi	

EXPLORING FOOD INSECURITY AMONG INTERNALLY DISPLACED PEOPLE IN LAMKA, MANIPUR, NORTHEAST INDIA

Mounching Zou^{1*}, Glenn C Kharkongor¹ and Melodynia Marpna¹

¹ Martin Luther Christian University, India

ARTICLE INFO	ABSTRACT
Keywords: Aid, conflict, food (in)security, internally displaced persons, uncertainty *Correspondence: Zmuanching11@gmail.com Tel: +918732844237	Food insecurity remains a critical challenge among internally displaced people (IDPs), particularly those affected by conflicts. This qualitative study explores food security challenges faced by IDPs in relief camps across Lamka, Manipur, northeast India following the ethnic clashes in May 2023 using in-depth interviews. Using thematic analysis supported by Latent Dirichlet Allocation (LDA), key themes related to economic challenges, dependency on aid, nutritional concerns, displacement impacts, and community resilience were identified. Findings highlight the IDPs' reliance on aid, difficulties in securing livelihoods, and concerns about long-term food security and self-sufficiency. The study emphasizes the urgent need for sustainable interventions addressing both immediate and structural food (in)security issues for displaced populations.

1. INTRODUCTION

Internally displaced persons (IDPs) are persons who have involuntarily fled from their homes to avoid the effects of armed conflict, situations or in general violence, violation of their human rights who have not crossed an internationally recognized state border (Guiding Principles of Internal Displacement, 1998).

Food insecurity is a major public health (Morales & Berkowitz, 2016), social (Odoms-Young, 2018), and human rights concern (De Schutter, 2012). Conflict has been reported to be among the leading causes of hunger (World Food Programme, n.d). Conflict is a primary driver of food insecurity (Muriuki, Hudson & Fuad, 2023); creating short to medium-term impacts on food security (Verme & Schuettler, 2021; Sova & Zembilci, 2023). Food security is when there is food sufficiency with no hunger or fear of starvation (Kah, 2017). According to Dubagat (2013), food security is multi-dimensional encompassing four key aspects: availability, access, adequate utilization and stability of food supply at all times. Food insecurity can also exist even when people have access to food that is

insufficient in quantity or quality (Kah, 2017).

1.1 The Manipur Crisis: A Case Study in Systemic Failure

About 67,000 people were displaced in Manipur, India, on May 3, 2023, due to ethnic violence between the Meitei and Kuki communities (Rights & Risk Analysis Group, 2023). Over 70,000 people were still displaced as of 2024 (Internal Displacement Monitoring Centre [IDMC], 2024; Rural Women Upliftment Society, 2023), accounting for 97% of South Asia's displacements in 2023 (The Hindu, 2024). IDPs are primarily housed in overcrowded camps in Lamka (12,838 people in 77 camps), Kangpokpi (10,305 in 47 camps), and nearby states like Mizoram (6,933 in 7 camps). These camps frequently lack basic amenities like food, security, and sanitary facilities (Guhathakurta, 2023). The UN Guiding Principles on Internal Displacement (United Nations, 1998), which require protection and assistance for internally displaced people, are being violated, as evidenced by reports of stopped food supplies (Imphal Free Press, 2024).

Despite the protracted nature of the crisis, there remains a critical gap in research assessing food insecurity among IDPs in Manipur. The study aims to address this gap by investigating the challenges of food access, availability and utilization in displacement setting.

2. MATERIALS AND METHODS

2.1 Study Area

A community-based qualitative study was conducted among 6 relief camps from November 2023 to January 2024 in Manipur, a state in the Northeastern region of India with 16 districts: 10 hilly and 6 valley districts. The study was conducted in Lamka*, also known as Churachandpur, a town in the Churachandpur district of Manipur, India. Inhabited primarily by the Kuki-Zo tribes, it has become a key center of refuge for the IDPs affected by the recent ethnic conflict in the region.

2.2 Methods

Camp Selection:

Purposive sampling was used to select relief camps exclusively inhabited by the Zou ethnic group, ensuring cultural and contextual consistency. Within these camps, participants were recruited with assistance from the camp leaders based on the following criteria:

- 18 years of age and above
- Displaced due to conflict
- Residing in the camp, and
- Willing to provide informed consent

The study utilizes primary data collected through in-depth interviews to explore the issue of food insecurity among IDPs. A structured questionnaire guided the interviews, ensuring a systematic approach to gathering detailed insights.

To ensure comprehensive data collection, interviews were conducted until data saturation was achieved—when no new themes or significant information emerged. Unusable content was discarded, and interviews continued until sufficient quality data was obtained. A total of 29 interviews were conducted by the researcher and two assistants, and 14 were deemed suitable for analysis, providing a robust dataset for understanding the nuanced experiences and

challenges IDPs face concerning food insecurity.

Ethics approval was obtained from Martin Luther Christian University before the commencement of data collection. Written consents were obtained before the interviews, and the participants were assured that anonymity would be maintained. Also, permissions were obtained to record the interviews.

2.3 Data and Preprocessing

The data consisted of 14 interview transcripts from IDPs in relief camps. These were processed and analysed using Latent Dirichlet Allocation (LDA) topic modelling in R Studio, following these preprocessing steps:

Text cleaning: Punctuation, numbers, and common stopwords were removed, and the text was converted to lowercase. Ordinal numbers and custom interview-related words (e.g., "interviewer," "respondent") were also eliminated to enhance clarity and relevance.

Tokenisation: The cleaned text was tokenised into bigrams (two-word sequences) to capture meaningful phrases, such as "food_security" and "earn_living."

Document-Term Matrix (DTM): A DTM was created to display the frequency of terms in the documents, forming the foundation for LDA topic modelling and identifying recurring themes.

3. RESULTS AND DISCUSSION

This section presents the result of the analysis of the 14 interviews. It explores key themes related to food access, economic hardships, and social support systems in the camps. Topic modelling was used to identify common concerns about food insecurity and challenges IDPs face to secure adequate nutrition and sustain their livelihoods.

3.1 Perplexity and Log-likelihood

The LDA model with 2 topics was evaluated using perplexity and log-likelihood. The model's perplexity was 465.77, indicating a good fit. Log-likelihood values improved from -2802.83 to -2481.92 by iteration 7, with minor fluctuations thereafter and stabilisation between -2491.30 and -2549.36, indicating model convergence and effective performance in capturing the underlying data patterns.

Table 1. Top 10 bigrams for 12 topics

Topic	Top 10 Terms Bigrams
<i>Topic 1: Economic Challenges and Livelihood</i>	'food_security', 'can't_work', 'earn_living', 'nothing_certain', 'day_many', 'ever_since', 'camp_think', 'household's_food', 'future_considering', 'ahead_future'
<i>Topic 2: Endurance Amidst Economic Hardships</i>	'believe_continue', 'food_security', 'even_though', 'can_earn', 'uncertainties_related', 'dc_office', 'money_left', 'earn_living', 'even_return', 'food_secure'
<i>Topic 3: Relocation and Food Scarcity</i>	'food_security', 'we're_relocated', 'can't_even', 'meals_day', 'house_burnt', 'relief_camp', 'think_food', 'food_secure', 'can_say', 'future_think'
<i>Topic 4: Aid Dependency and Future Uncertainties</i>	'we're_receiving', 'food_security', 'household's_food', 'future_uncertainties', 'want_focus', 'source_income', 'receiving_food', 'think_future', 'security_think', 'ideas_suggestions'
<i>Topic 5: Camp Conditions and the Role of Aid Organisations</i>	'future_uncertainties', 'think_future', 'situation_camp', 'passed_away', 'food_situation', 'source_income', 'future_food', 'aid_organisations', 'within_outside', 'household's_food'
<i>Topic 6: Employment Hopes and Aid Insecurity</i>	'earn_living', 'food_security', 'you're_receiving', 'even_though', 'leave_camp', 'employment_opportunities', 'firmly_believe', 'anything_say', 'there's_employment', 'wanted_know'
<i>Topic 7: Household Resilience and Community Reliance</i>	'household's_future', 'think_food', 'since_arrived', 'right_yes', 'we're_receiving', 'source_income', 'food_security', 'even_though', 'leave_camp', 'primary_source'
<i>Topic 8: Access to Nutritious Food and Future Concerns</i>	'food_security', 'source_income', 'sometimes_think', 'leafy_vegetables', 'earn_living', 'we're_receiving', 'future_well', 'leave_camp', 'outside_camp', 'future_think'
<i>Topic 9: Economic Resilience and Uncertainty</i>	'earn_money', 'ask_help', 'might_continue', 'earn_living', 'food_situation', 'household's_future', 'household's_food', 'don't_think', 'still_hope', 'uncertainties_related'
<i>Topic 10: Dependence on Aid and Employment Hopes</i>	'food_security', 'household's_food', 'related_household's', 'relief_camp', 'employment_opportunity', 'future_food', 'security_well', 'though_we're', 'within_outside', 'future_think'
<i>Topic 11: Health Concerns and Long-Term Food Security</i>	'future_food', 'food_secure', 'go_back', 'two_meals', 'earn_money', 'due_injury', 'think_food', 'since_we're', 'future_well', 'work_earn'
<i>Topic 12: Immediate Food Security and Circumstantial Adaptation</i>	'food_secure', 'food_security', 'leave_camp', 'right_now', 'camp_i've', 'considering_circumstances', 'secure_now', 'don't_know', 'future_food', 'thinking_future'



Figure 1. World cloud depicting top terms from each topic

3.2 Document-Term Matrix Density

The density of the DTM is a measure of the proportion of the non-zero values relative to the total possible values. In this analysis, the DTM density was calculated to be 0.0833, indicating that the matrix has a sufficient number of meaningful interactions between terms and documents, making the topic model effective.

3.3 Thematic Analysis Based on the Top Terms in Each Topics

6 main themes were identified from the 12 topics derived as depicted in Table 1, and each topic was placed as a sub-theme.

Theme 1- Economic Challenges and Livelihood

Security and economic uncertainty

Conflict-related disruption has made it challenging for many internally displaced people to maintain their livelihood, which has resulted in food insecurity and fiscal instability (Tellez & Balcells, 2024). One participant noted, *“We can’t work as we used to before. Ever since the conflict started, earning a living has become uncertain”* (F, 65 y/o), aligning with IDMC (2022), reporting approximately 78% IDP experience livelihood disruption.

As another respondent shared, *“As daily wage workers, if we get work, we eat; otherwise we go hungry”* (M, 62 y/o), depicting vulnerabilities faced daily wage workers which is at par with the World Food Programme’s (2023) report that found that 63% of displaced daily laborers experience food insecurity.

There is a ubiquitous sense of uncertainty about the future. The quote, *“Everything about our future is uncertain. How will we feed our families when there is no consistent work?”* (F, 57 y/o), reflects the anxiety and fears that many IDPs face, as their inability to generate a stable income threatens their capacity to meet even basic needs. This topic emphasizes the urgent need for interventions that address immediate food insecurity and the long-term economic resilience of displaced populations.

Employment hopes and aid insecurity

Although aid is essential in meeting current needs, its limitations become apparent, especially in ensuring long-term sustainability. One participant expressed this concern: *“There’s no stable employment in the camp, and aid isn’t enough to sustain us in the long term”* (F, 23 y/o). This demonstrates the insufficiency of humanitarian assistance as a lone solution, emphasizing the importance of long-term livelihood strategies.

Employment is viewed as a means of not just achieving financial independence, but also of restoring dignity and autonomy. As one respondent remarked, *“I firmly believe that having a job would help us regain our independence”* (F, 66 y/o). This reflects the strong desire among IDPs to move beyond aid dependency and regain control over their lives, contrasting Sithole & Coetzee’s (2018) finding that IDPs became reliant on aid.

The challenges of aid insecurity and the need for stable employment echoed in all the interviews, which highlights the importance of long-term economic empowerment strategies, which should focus on integrating sustainable livelihoods.

Economic resilience and uncertainty

Economic resilience for IDPs refers to their ability to manage change and adapt to the effects of forced displacement on their living standards and overall well-being (Ekezia, 2022).

IDPs frequently face the combined challenges of surviving in unpredictable situations while attempting to reclaim control of their lives. While aid is critical in fulfilling urgent needs, many IDPs seek self-

sufficiency and long-term solutions. This drive for economic independence is illustrated by the ambitions and resilience of people who, despite countless obstacles, are determined to restore their lives.

M, 63 y/o exemplifies resilience, saying, *“I would go and earn money and return as soon as I saved enough for us to start a new life in our village.”* His proactive approach underscores a common hope among IDPs to rebuild their lives despite uncertainty.

F, 42 y/o shared similar aspirations, revealing her intention to start a business: *“I’ve been thinking about a small shop for quite some time now... I hope to start a business to support my family.”* This reflects a deep desire to regain control over their economic future.

However, the dependency on aid remains a pressing concern. F, 35 y/o reflects on the limitations of aid: *“Right now, we rely on the aid we receive for food and basic items, but I wish there were employment opportunities so we wouldn’t have to depend on it.”* This emotion echoes a common yearning for self-sufficiency, as many individuals are frustrated by the absence of sustainable opportunities except for charity.

The yearning for self-sufficiency and economic freedom is obvious, but the impediments are significant. Many IDPs want to start enterprises or find work, but they confront structural barriers such as inadequate resources, a lack of access to credit, and displacement instability.

Theme 2- Food Security and Dependency on Aid

The second theme revolves around the reliance on aid for food, the anxieties surrounding future food security, and the role of external organizations in sustaining IDPs. It highlights both short-term food security and long-term concerns about self-sufficiency.

Aid dependency and future uncertainties

Aid dependency and future uncertainties pose significant challenges for many IDPs (ODI Global, 2024), one stated, *“We rely completely on aid. Without it, I don’t know how we’d survive”* (F, 27 y/o), reflecting total reliance on aid aligning with Sithole

and Coetzee’s (2018) finding in. The lack of reliable income and food sources has left many IDPs vulnerable, depending on aid organizations to meet daily needs. While aid alleviates immediate food insecurity, the uncertainty of the future remains a significant concern.

One participant shared, *“Our household’s food supply depends on the aid we’re receiving. It’s not enough, but it keeps us going for now”* (F, 35 y/o), emphasizing the insufficiency of aid. Another respondent expressed concern, *“Future food security is a big concern for us. Once aid stops, how will we manage?”* (F, 50 y/o). These statements highlight the need for long-term solutions that reduce aid dependency and promote sustainable livelihoods.

Camp conditions and the role of aid organizations

Life in the camps remains difficult despite the assistance provided by aid organizations. As one respondent stated, *“Life in the camp is hard. The food situation is precarious even with aid organizations helping us”* (M, 62 y/o). This quote highlights the harsh realities of camp life, where food security is fragile even with external support. Although aid organizations play a critical role, their assistance is not a permanent solution to food security, as it remains uncertain and insufficient in the long term (Seligman & Berkowitz, 2018).

Moreover, the total reliance on aid fosters a lack of autonomy and independence (Andriessen et al., 2025). *“Living in camps has made us completely dependent on external aid”* (F, 42 y/o) reflects the vulnerability of IDPs who, due to their circumstances, are left without control over their survival and are dependent on aid. This dependency, combined with inadequate living conditions in camps, exacerbates the sense of instability and insecurity faced by IDPs.

Dependence on aid and employment hopes

The theme of dependence on aid traverses with IDPs' aspirations for employment opportunities. While grateful for the assistance they receive, there is a strong desire for self-sufficiency through

employment as reported (Crawford & Holloway, 2024). One participant noted, *“Right now, we rely on the aid we receive for food and basic items, but I wish there were employment opportunities so we wouldn’t have to depend on it”* (F, 35 y/o), highlighting the tension between immediate relief and the long-term goal of economic independence.

Employment is crucial to restoring dignity and self-reliance. One respondent shared, *“I hope to find work soon. Depending on aid makes me feel helpless, and I want to support my family myself”* (F, 53 y/o), reflecting the emotional toll of aid dependency. Another participant added, *“We cannot be dependent on aid forever. What we need is employment or land to work on”* (F, 23 y/o), stressing the urgent need for sustainable solutions beyond temporary assistance.

Immediate food security and circumstantial adaptation

This topic examines the short-term focus on food security and the ongoing adaptation to displacement. Many IDPs voiced concerns about their immediate food supply, yet anxiety about the future remained. As one respondent noted, *“The food we have is just enough for now. We can only think about today, not the future”* (F, 42 y/o). This demonstrates the constrained extent of food security, where current requirements have been fulfilled but there is no certainty of future food access.

The statement emphasizes this sense of uncertainty: *“Considering our circumstances, we are surviving, but we’re unsure how long this food will last”* (M, 62 y/o), reflecting the precarious nature of food availability in camps. Many participants noted their anxiety about the future, with some emphasizing the loss of autonomy over food production. *“I’ve adapted to this situation in the camp, but I miss the freedom of being able to grow my food”* (F, 66 y/o) highlights the emotional and practical consequences of displacement, where IDPs long for the self-sufficiency they had before the conflict.

Finally, as one participant shared, *“For now, we feel secure about food, but only because aid is still being provided”* (F, 42 y/o),

reinforcing the idea that their food security is temporary and entirely contingent on ongoing external support. The necessity for long-term solutions that would enable IDPs to reclaim control over their food security and livelihoods is highlighted by the fear of the future.

Theme 3- Health, Nutrition and Food Quality

This theme emphasizes the quality of food available in camps, as well as the health risks linked with inadequate food security. IDPs are concerned not only with food quality but also with its nutritional value.

Access to nutritious food and future concerns

Access to nutritious food remains a significant challenge for internally displaced persons (IDPs). Many participants reported a lack of essential nutrients in their daily meals, especially green leafy vegetables. As one woman (35) stated, *“We eat to survive, we miss nutritious food like green leafy vegetables,”* highlighting how camp rations fail to meet nutritional needs. This reliance on basic, non-nutritious food shifts priorities from health to mere survival, posing long-term risks to well-being. A systematic review conducted by Khuri et al., (2022) reported that there’s an insufficient supply of nutrient-rich foods, which poses risk for nutritional deficiencies.

The issue is particularly concerning for families with children. One respondent (50) explained, *“Our children need healthy meals, but we can’t afford anything beyond basic rations,”* emphasising the economic barriers to accessing a balanced diet. Children in refugee camps face a heightened risk of malnutrition due to insufficient quality and quantity of nutrients, with underweight prevalence reported between 12% and 41% (Panchal et al., 2025).

Participants also reflected on their pre-displacement diets, drawing stark contrasts with their current circumstances. A woman (53) shared, *“Sometimes I think about the food we had before the conflict and how much healthier it was,”* reflecting the loss of dietary diversity and quality brought on by displacement.

Health concerns and long-term food security
The connection between food insecurity and health problems is evident in the narratives surrounding long-term food security. Health concerns, including limited access to nutritious food and the physical toll of stress, compound the struggles of IDPs. One participant shared, *“Due to my injury, I can’t work, which makes it harder to provide for my family”* (F, 65 y/o). Health issues, including injuries, illnesses, and stress, further reduce their capacity to work, thus intensifying the struggle to secure adequate food and income.

Moreover, the scarcity of food in the camps contributes directly to poor health outcomes. A respondent remarked, *“We only have two meals a day in the camp, which isn’t enough”* (F, 53 y/o). This low food intake, combined with the diet’s repetitious nature, depletes crucial nutrients, leading to nutritional deficiencies like anaemia, reported to be as high as 59.3% in Lebanese refugee camps (Khuri et al., 2022).

The effects of poor nutrition and stress were also highlighted by a respondent who stated, *“My health has deteriorated since we arrived at the camp. Lack of proper food and stress are to blame”* (F, 57 y/o). This highlights the broader consequence of displacement, where poor food quality and stress contribute to deteriorating physical and mental health, further obstructing economic resilience and the ability to rebuild lives.

Theme 4- Displacement, Relocation and Long-term Impact

The themes address the impact of displacement, including the immediate effects on food security and the long-term consequences, such as the uncertainty of returning to normal life or rebuilding.

Relocation and food scarcity

Conflict-induced relocation disrupts the lives of IDPs and significantly impacts their food security. As one participant shared, *“After our house was burnt, we had no choice but to move to the camp where food is scarce”* (M, 63 y/o), reflecting the hardships faced by IDPs who are forced to abandon their homes and livelihoods, entering camps where food scarcity and poor living conditions

exacerbate their suffering. Moreover, insufficient and nutritionally inadequate meals within these camps further compound the difficulties faced by IDPs, highlighting the unpredictable nature of food security in these settings.

Another participant remarked, *“Relocation has made everything more difficult. We don’t even have proper meals now”* (F, 50 y/o). This statement emphasizes the loss of normal food systems and the absence of stable food access after relocation. The immediate effects of displacement on food security are stark, with many IDPs struggling to secure adequate meals and facing uncertainty regarding the future availability of food.

The relocation process also underscores the loss of self-sufficiency that many IDPs previously enjoyed. As one respondent reflected, *“Before the conflict, we could grow our own food. Now, we’re completely dependent on others”* (F, 23 y/o). This contrasts their prior autonomy and ability to meet food needs through farming with their current reliance on external aid. The loss of self-sufficiency adds an emotional and psychological toll, as IDPs not only face food insecurity but also experience a deep sense of dependence and vulnerability.

Theme 5- Future Uncertainties and Long-Term Planning

This theme delves into the continuous concerns that IDPs have concerning their ability to restore their lives in the long run. It highlights the importance of home resilience and community reliance in assisting IDPs in navigating the obstacles of displacement and planning for a volatile future. Individual and family efforts determine IDPs' resilience, but so does the quality of their community support systems, which give critical resources and emotional solidarity during times of disaster.

Household resilience and community reliance

The narratives of IDPs highlight the critical role of household resilience in overcoming the difficulties of displacement (Ezekie, 2022). Many respondents expressed the uncertainty of their future but found strength in mutual reliance within their families. One

of the participants shared, *“Our household’s future is uncertain, but we rely on each other to get through this”* (F, 35 y/o). This demonstrates how, despite a lack of stability, families find ways to adapt and thrive by relying on each other’s strengths. Familial support becomes a lifeline, allowing IDPs to endure hardships and stay hopeful in the face of an uncertain future.

Community dependence is essential for delivering comfort, in addition to family resilience (Tassang et al., 2023). The value of community resources during difficult times is shown by one respondent’s statement, *“We’ve been able to manage so far thanks to the support of our community”* (F, 42 y/o). In addition to creating a sense of solidarity and shared responsibility, the support of friends, neighbours, and community leaders fills in the gaps left by limited resources and possibilities. This community-based resilience helps people cope with the obstacles they face by alleviating some of the stress associated with displacement.

Optimism among the respondents despite their current circumstances was a recurring theme, which is not usually observed, as studies have usually reported high psychological distress (Mamed et al., 2024) leading to the need for medical assistance (Maruta et al., 2020). One participant shared, *“Even though times are tough, our community will help us rebuild”* (F, 53 y/o), highlighting the collective hope and resilience that arise in response to displacement. This statement suggests that, while the future is uncertain, there is a strong belief in the power of community collaboration to restore stability and rebuild lives. Mutual support serves as the cornerstone of recovery, offering emotional and material resources to start anew in an uncertain environment.

Theme 6- Community, Social Support and Collective Well-Being

This theme emphasizes the role of community support systems, household resilience, and collective effort to cope with challenges due to displacement. It underlines the importance of family and community-based resilience to cope with hardships.

Endurance amidst economic hardships

The persistence of IDPs in navigating economic struggles is a testament to their inner resilience and determination. Despite limited resources, many IDPs hope for better days, relying on one another for emotional and practical support. One participant shared, *“Even though we have little, we believe we can continue with each other’s support”* (F, 57 y/o), which emphasizes the importance of mutual assistance within families and communities as a key source of resilience, similar to Ezekie’s (2022) finding among refugees in northern Nigeria. This support is vital in maintaining a sense of hope, as it strengthens IDPs’ ability to endure despite the hardships they face.

Another respondent reflected, *“Hardships will come and go, but our spirit keeps us going”* (F, 53 y/o), underscoring their resilience and optimism. The idea that they can conquer the obstacles ahead, even in their current situation, is the reason behind their perseverance. The use of the word spirit extends beyond tangible means but refers to the fortitude to continue pushing forward on an emotional, psychological, and religious level. Community support also plays a crucial role in helping IDPs cope with their circumstances. As one participant stated, *“Our community leaders have been instrumental in ensuring we survive these tough times”* (F, 42 y/o), highlighting the essential role of leadership in organizing collective resources and providing direction. Community leaders serve as both practical resources and symbols of solidarity, helping to guide displaced populations through periods of uncertainty. This sense of unity within the community provides a strong foundation for survival, as collective action ensures that no one is left behind.

4. CONCLUSION

The study highlights that the IDPs in Lamka experience extreme food insecurity as a result of their livelihood being upended, their reliance on insufficient aid, malnourishment, and also the psychological effects of displacement. Although humanitarian aid offers temporary respite, chronic food insecurity has resulted from its inadequacy, particularly for women, children, and the

elderly. Self-reliance has been undermined, and vulnerability has increased as a result of the breakdown of traditional food systems. Although these informal support networks are unsustainable in the absence of systemic intervention, displaced communities demonstrate resilience in spite of these obstacles. For Manipur's internally displaced people to break the cycle of dependency and guarantee food security and dignity, there is a need for both short-term and long-term solutions, including nutrition-sensitive aid,

access to healthcare, livelihood restoration, land access, and policy reforms.

CONFLICTS OF INTEREST AND ACKNOWLEDGEMENTS

The author declares no conflict of interest. The author acknowledges the financial support of the University Grants Commission (UGC) through the National Eligibility Test- Junior Research Fellowship (NET-JRF). I express sincere gratitude to all participants for their valuable contributions to this study.

REFERENCES

- Andriessen, T., van der Horst, H. & Morrow, O. Forms of autonomy and dependence in food aid: unravelling how they are related and perceived by recipients. *Agric Hum Values* (2025). <https://doi.org/10.1007/s10460-025-10715-2>
- Anonymous (16 May, 2024). Manipur violence accounted for 97% of displacements in South Asia in 2023: Report. *The Hindu*.
- Anonymous (3 July, 2023). Press release: About 70000 displaced, Manipur's riots destabilizing north east's regional peace and security. <https://www.rightsrisks.org/press-release/press-release-about-70000-displaced-manipurs-riots-destabilising-north-east-s-regional-peace-and-security/>
- Conflict and hunger. World Food Programme. (2024). Retrieved from <https://www.wfp.org/conflict-and-hunger>
- Dubagat, K.K. (2013). Special Report: Food Security Challenges in West Africa: A focus on agriculture. *West Africa Insight*.
- Ekezie W. (2022). Resilience actions of Internally Displaced Persons (IDPs) living in camp-like settings: a Northern Nigeria case study. *Journal of migration and health*, 6, 100115. <https://doi.org/10.1016/j.jmh.2022.100115>
- Guhathakurta, S. (Oct 22, 2023). The Manipur Conflict: Rights of the Internally Displaced Get Compromised. *Berkeley Journal of International Law*. Retrieved on 10/08/2024 <https://www.berkeleyjournalofinternationallaw.com/post/the-manipur-conflict-rights-of-the-internally-displaced-get-compromised>
- <https://www.thehindu.com/news/national/manipur/manipur-violence-accounted-for-97-of-displacements-in-south-asia-in-2023-report/article68177995.ece>
- Internal Displacement Monitoring Centre. (2022). *Global report on internal displacement 2022*. <https://www.internal-displacement.org/global-report/grid2022/>
- Internal Displacement Monitoring Centre. (2024). *Global report on internal displacement 2024*. Internal Displacement Monitoring Centre. Retrieved from <https://www.internal-displacement.org/global-report/grid2024/>
- Kah, H.K. (2017). 'Boko Haram is Losing, But so is Food Production': Conflict and Food Insecurity in Nigeria and Cameroon. *Africa Development*. XLII (3). Pp 177-196.
- Khuri, J., Wang, Y., Holden, K., Fly, A. D., Mbogori, T., Mueller, S., Kandiah, J., & Zhang, M. (2022). Dietary Intake and Nutritional Status among Refugees in Host Countries: A Systematic Review. *Advances in nutrition (Bethesda, Md.)*, 13(5), 1846–1865. <https://doi.org/10.1093/advances/nmac051>
- Mamed, G.E., Tefera, G., Bitew, M., & Yu, M. (2024). The overlooked war in Northern Ethiopia: Examining psychological capital, mental distress, and post-traumatic stress disorder among internally displaced people in Amhara region. *International Journal of Social Psychiatry*, 71, 705 - 714. <https://www.semanticscholar.org/paper/61fd81a280044afd4bb1eb24a8a0fdcfa07e8785>
- Maruta, N., Kalenska, G., & Panko, T. (2020). Integrative program of psychocorrection of mental disorders in internally displaced persons.
- Morales, M. E & Berkowitz, S. A. (2016). The relationship between Food Insecurity, Dietary Patterns, and Obesity. *Curr Nutr Rep*. 25:5(1). Pp 54-60.
- Muriuki, J., Hudson, D. & Fuad, S. (2023). The impact of conflict on food security: evidence from household data in Ethiopia and Malawi. *Agriculture & Food Security*. 12 (41).
- Panchahal, P., Usman, m., Longkumer, T., babu, R., Khatib, M., Razak, S., & Menon, K. (2025). The hidden crisis: double burden of malnutrition among refugee children in South Asia- a systematic review and meta-analysis from observational studies. *Nutritional Epidemiology*. 11. <https://doi.org/10.3389/fnut.2024.1480319>
- Rural Women Upliftment Society (RWUS). Retrieved from <https://rwus.org/donate-to-manipur/>
- Seligman, H. K., & Berkowitz, S. A. (2019). Aligning Programs and Policies to Support Food Security and Public Health Goals in the United States. *Annual review of public health*, 40, 319–337. <https://doi.org/10.1146/annurev-publhealth-040218-044132>
- Sithole, W.W., & Coetzee, J.K. (2018). Food aid for internally displaced persons in Manicaland, Zimbabwe. *Africanus: Journal of Development Studies*.
- Tellez, J.F., & Balcells, L. (2024). Social Cohesion, Economic Security, and Forced Displacement in the Long Run: Evidence From Rural Columbia. *Journal of Conflict Resolution*. <https://doi.org/10.1177/00220027241253532>
- Tessaang, A., guoqing, S., Akintunde, T., isangha, S., Adeddeji, A., & Musa, T. (2023). Social integration, solidarity, and psychological health of internally displaced persons in Cameroon: exploring the role of community satisfaction. *Heliyon*. 9(10). E20361.
- The Guiding Principles on Internal Displacement. (1998). <https://www.internal-displacement.org/sites/default/files/publications/documents/199808-training-OCHA-guiding-principles-Eng2.pdf>
- United States Institute of Peace (2023). Understanding India's Manipur Conflict and Its Geopolitical Implications (2023). Retrieved from <https://www.usip.org/publications/2023/06/understanding-indias-manipur-conflict-and-its-geopolitical-implications>
- Verme, P & Schuettler, K. (2021). The impact of forced displacements on host communities: A review of the empirical literature in economics. *Journal of Developmental Economics*. 150. 1026
- World Food programme. Conflict and hunger. <https://www.wfp.org/conflict-and-hunger>
- Zova, C. & Zembilci, E. (21 April, 2023). Dangerously Hungry: The Link between Food Insecurity and Conflict. *Centre for Strategic & International Studies(CSIS)*. Retrieved from <https://www.csis.org/analysis/dangerously-hungry-link-between-food-insecurity-and-conflict>

TECHNICAL AND ECONOMIC FEASIBILITY OF NANOBUBBLE AERATION TECHNOLOGY FOR RAINBOW TROUT (*Oncorhynchus mykiss*) FARMING IN NEPAL

Hareram Devkota ^{1*}, Dilip Kumar Jha¹, Tista Prasai Joshi², Shreemat Shrestha³ and Mahendra Prasad Bhandari³

¹ Department of Aquaculture, Agriculture and Forestry University (AFU), Rampur, Chitwan, Nepal

² Environmental Research Laboratory, Nepal Academy of Science and Technology (NAST), Lalitpur, Nepal

³ Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Dissolved oxygen, nanobubble aeration technology, productivity, rainbow trout *Correspondence: hdevkota6@gmail.com Tel: +9779856033580	<i>This 180-day study, conducted from October 17, 2022, to April 16, 2023, at the Rainbow Trout Fishery Research Center in Dhunche, Rasuwa, Nepal, evaluated the technical and economic effects of nanobubble aeration technology on rainbow trout farming. The experiment compared three treatments: control (gravitational water flow), nanobubble aeration and a combination of both. Nanobubble aeration significantly improved dissolved oxygen levels (up to 11.93 ± 0.33 mg/L), resulting in enhanced fish growth and farm productivity. Trout in the nanobubble group showed superior performance with a final average weight of 204.88 ± 12.23 g and a productivity rate of 25.37 ± 0.23 kg/m² both statistically higher than in other groups (p < 0.05). The feed conversion ratio (FCR) decreased to 2.1 ± 0.0, while the benefit-cost (BC) ratio rose to 1.60 ± 0.04, indicating better economic returns. The nanobubble system also improved daily weight gain (0.69 ± 0.70 g) and lowered mortality rates (1.5 ± 0.52%). These findings clearly support that nanobubble technology enhances water quality, promotes faster fish growth, and improves profitability in trout farming. The study recommends its adoption in Nepalese aquaculture for improved productivity and economic growth, positioning nanobubbles as a forward-looking solution for sustainable fish farming.</i>

1. INTRODUCTION

The rainbow trout (*Oncorhynchus mykiss*) is a cold-water species which inhabits the upper parts of rivers and streams where the oxygen level is greater than 8 mg/L (Peter & L, 2007). These fishes are also known to live in a range of places from freshwater lakes to the ocean. Anglers appreciate them for their strength and beautiful colors. In the late 1960s, it was introduced from the UK, Japan, and India to Nepal, and began their farming. Initially, the primary objective of the strategy was to utilize the abundant cold-water resources in the country, despite challenges arising from a lack of technical expertise and practical experience (Gurung, & Basnet, 2003). The reintroduction program initiated in 1988 was supported by the Nepal Agricultural Research Council (NARC),

Numerous trout farms in Nepal utilize elongated concrete raceways with a 5:1 slope, typically covering around 20 m², as these designs support effective farm management through continuous water circulation. However, the structural incline and limited surface area can hinder the efficient removal of fecal matter, leading to water quality deterioration and increased vulnerability to disease outbreaks. The integration of nanobubble technology in such aquaculture systems has been shown to significantly improve the removal of suspended solids and organic waste through enhanced flotation processes (Shen et al., 2022). Nanobubbles possess a high oxidative potential and generate localized microcirculation, which promotes the decomposition and mobilization of fecal

materials, thereby improving water quality and promoting better fish health (Beijnen & Yan, 2021). The report of Rainbow Trout Fishery Research Center RTFRC, (2023) says that trout farming has grown to 42 districts in Nepal and is now a profitable business for private companies as well. The combination of trout with the food and hospitality industries has created a unique niche in Nepal's agricultural field. Trout farming's emphasis on quality and sustainability attracts tourists seeking a genuine farm-to-table experience. This helps the local economy and promotes ecotourism in rural parts of the country. Rainbow trout farms have done very well due to this, making Nepal a center for sustainable aquaculture (Gurung et al., 2014). To enhance oxidation in raceway ponds, we employed several different aeration methods. Trout farming in Nepal has long struggled with issues such as water quality deterioration, accumulation of fecal matter, low dissolved oxygen levels, and slow oxidation at the bottom of raceways. In contrast, other countries have adopted more sustainable and advanced aquaculture practices to address these challenges. As a result of adopting similar innovations, Nepal's fishing industry is beginning to improve, gaining greater visibility in the global market and creating new opportunities for export (Gurung et al., 2014). A decrease in dissolved oxygen levels can result in increased mortality rates, reduced productivity, and increased production expenses (Gurung, & Basnet, 2003). Therefore, maintaining an excellent water condition is essential for the farming of rainbow trout in Nepal. We have tried several different ways to add air to raceway ponds to solve the problem of insufficient oxidation. Nanobubble aeration technology improves water quality and oxygen levels by oxidizing water to solve these problems. The aeration technology of nanobubbles also improves water quality in the aquaculture system (Agarwal et al., 2011). This innovative technology offers significant advantages for aquaculture producers by boosting productivity and supporting economic development. Nanobubbles are especially effective because their high surface-to-volume ratio improves gas

transfer and enhances essential oxidation processes in water. They are stable over time, dissolve gases easily, and transfer oxygen more efficiently (Beijnen & Yan, 2021; Zhou et al., 2022). Nanobubbles raise the amount of dissolved oxygen in water in raceway ponds. This technology provides a long-lasting and effective way to improve oxidation in raceway ponds, which in turn improves the overall performance of the pond. According to Huang et al., (2023); Ng et al., (2023) nanobubble technology is better at moving oxygen than traditional oxygenation systems. This technology has shown promise in a number of areas, including agriculture, aquaculture, and wastewater treatment. Nanobubbles might also be able to make the whole system work better and use less energy during oxygenation processes. Nanobubble technology enhances the physical condition of farmed trout by delivering oxygen to the water more efficiently. This leads to higher productivity and lower production costs. The study by Mahasri et al., (2018) showed that using nanobubbles in aquaculture increased fish growth and the overall health of the fish. This suggests that the industry could benefit from this technology. Nanobubbles' ability to stay stable in water for long periods of time also allows for continuous oxygenation, which is perfect for fish growth and development. This demonstrates the potential of nanobubble technology to enhance the performance of aquaculture systems and improve oxygen transfer efficiency. This new method meets the need for oxygen by creating many gas bubbles smaller than 100 nm in water (Agarwal et al., 2011). Using this technology could revolutionize trout farming in Nepal and foster sustainable aquaculture growth. This study provided with intriguing new insights into how nanobubble technology can transform aquaculture, providing a promising solution to enhance production efficiency and contribute to the global protein supply to meet the growing demand for fish. The aim of this study was to determine how nanobubble aeration technology affects the quality of water and the amount of dissolved oxygen in Nepalese trout farms.

2. MATERIALS AND METHODS

2.1 Study site

This research was carried out in Dhunche, Rasuwa district, approximately 200 km north of Kathmandu, near the border with China, at the Rainbow Trout Fishery Research Center, using glacier water from Ghatte Khola which is located at an elevation of about 1900m Mean Sea Level (MSL), which is shown in Figure 1 with yellow colour highlight. This study was conducted from October 2022 to April 2023.



Figure 1. Study site: Rainbow Trout Fishery Research Center Dhunche Rasuwa (shown in yellow colour)

2.2 Performance test of nanobubble generator

The two microbubble generator units had a flow rate of 6 L/min. Before using for trout farming, the instrument was tested at the Nepal Academy of Sciences and Technology (NAST) in Lalitpur, Nepal, using a zeta sizer. The generator utilized air to produce nanobubbles, and the resulting milky water product was continuously monitored for water quality parameters for a duration of 30 min. This process aims to ensure consistency in the size, density, and dissolved oxygen levels of the water generated by nanobubble generators.

2.3 Experimental design and trial setup

In this experiment, there were three groups, and each one used a different culture system. Experiment was carried out in CRD layout (3×3). The first treatment (T1) for the control system was plain water. The second treatment (T2) was for the nanobubble flow system which only used nanobubble water. A polyethylene pipe carried nanobubble water

from the EDON nanobubble generator chamber to all three tanks. In step T3, we used a polyethylene pipe to send a mix of nanobubble water and regular water to three copies. Each treatment had six copies, and each copy had six tagged fish. This study used 54 fish with Radio Frequency Identification (RFID) tags, with 18 fish in each group. The test fishes were collected from the Rainbow Trout Fishery Research Center in Dhunche, Rasuwa. The stocking size of fish was about 21.8 ± 1.4 cm long and 80.56 ± 3.03 g weight. We regularly tracked their growth and their RFID tags were used for identification. Six tagged fish were kept in each replication at a stock density of 12 kg/m^2 where fish without tags also incorporated to maintain the recommended stocking density. The RFID scanner scanned and collected the trout once a month to measure their growth where clove oil was put in the water for fish to sedate and gauged their length and weight in specific ways during record keeping. Fish which weighed more than 12 kg/m^2 were removed from the water and marked them as "harvested."

2.4 Statistical analysis

XLSTAT Statistics 19 was used for data analysis and statistical calculations, Microsoft Office Excel 2021 for data organization and Origin 22 for figure creation. One-way variance analysis (ANOVA) was used to understand the effectiveness of different aeration methods. Following the ANOVA, applied Duncan's multiple range test to identify any significant differences between the treatments. Spearman rank correlation in the data tab software to identify the links between production and water quality parameters.

2.5 Water Quality Parameters

Water quality parameters, such as DO, temperature, pH, ammonia, nitrite, hydrogen peroxide, alkalinity, calcium hardness, total hardness, conductivity, and phosphate, were measured monthly by Pasco Scientific Sensors and the e-xact water quality strips and its idip colorimeter.

2.6 Feed and Growth Performance Measures

$$\begin{aligned} \text{Survival Rate} &= \frac{T.\text{no of fish stocked} - T.\text{no of fish harvested}}{\text{Total number of fish stocked}} \times 100 && \text{Equation 1} \\ \text{Feed Conversion Ratio(FCR)} &= \frac{\text{Weight gain of fish (kg)}}{\text{Total feed given (kg)}} && \text{Equation 2} \\ \text{Feed Conversion Ratio(FCR)} &= \frac{\text{Total feed given (kg)}}{\text{Weight gain of fish (kg)}} \times 100 && \text{Equation 3} \\ \text{Productivity} \left(\frac{\text{kg}}{\text{m}^2} \right) &= \frac{\text{Total Harvest biomass (kg)}}{\text{Initial stock} \times \text{time}} \times 100 && \text{Equation 4} \end{aligned}$$

Where,

Total Harvested Biomass = Total weight of fish harvested (kg)

Initial Stock = Number of fishes initially stocked

Time = Duration of the production cycle

2.7 Condition Factor

It illustrates the relationship between a fish's length and weight. Stress, sex, season, feed availability, and water quality parameters are some of the variables that can alter the condition factor. A condition factor of 1 indicates that the fish is "normal" and in good health. Values higher than 0.8 mean the fish is thinner, while numbers higher than 1.2 or 1.5 mean the fish is fatter. Condition factor was used to estimate a fish's weight based on its length and condition. The described experiment also included feeding the animals once a day. The condition factor tells us a lot about the health and growth patterns of fish. It is essential to understand these performance measures and condition factors in order to improve aquaculture

practices and make sure that fish farming methods are sustainable. Many types of fish, including trout and other aquatic animals important to business, can benefit from these measurements. Researchers and aquaculture professionals can figure out how healthy and productive fish populations are by looking at these performance measures and the condition factor. This helps them make smart choices about feeding plans, water quality management, and other aspects of fish farming. The benefit-cost ratio formula helps businesses and organizations figure out how likely it is that a project will succeed and whether an investment is a beneficial idea by comparing the expected profits to the costs. We found the benefit-cost ratio (B/C ratio) by dividing the gross return by the gross cost.

$$\text{Benefit – Cost Ratio} = \frac{\text{Gross Return (kg)}}{\text{Total variable cost}} \times 100 \quad \text{Equation 5}$$

$$\text{Condition Factors(K)} = \frac{\text{Weight(w)}}{\text{Length(L}^3\text{)}} \times 100 \quad (\text{Ragheb, 2023}) \quad \text{Equation 6}$$

3. RESULTS AND DISCUSSION

This study evaluates the impact of nanobubble technology on aquaculture productivity, water quality, and its cost effectiveness for the farmers. By synthesizing

empirical results with established literature, this section explores the mechanisms underpinning nanobubble efficacy, and highlights innovations in sustainable aquaculture practices.

Table 1. Information required for the calculation of economic and production parameters

Parameters	Culture System (Treatments)			Remarks
	Nanobubble	Combined	Control	
Price of Fish (NPR/tail)	30	30	30	2022 AD
Electric cost (NPR /Unit)	10	10	10	2022 AD
Used Electricity (Unit)	208	208	1	NB Generator
Culture Period (Days)	180	180	180	Cold & warm seasons
Selling Rate (NPR/ Kg)	1200	1200	1200	2022 AD
Total Feed used (Kg)	26	25	24	Abilitum
Total Cost of Feed (NPR)	5200	5000	4800	2022 AD
Cost of Electricity (NPR)	2080	2080	10	2022 AD
Total Cost of Fish (NPR)	2250	2250	2250	2022 AD
Total Expenditure (NPR)	9530	9330	7060	Calculation
Total Production (Kg)	12.69	9.81	8.82	
Total Income (NPR)	15224	11772	10578	Calculation

3.1 Economic Viability and Production Efficiency

Table 2. Comparison of Production, growth and economic parameters (mean± SD) of the water supply system observed during the research period at the Rainbow Trout Fishery Research Center, Dhunche, Rasuwa, Nepal

Production / growth and economic parameters	Culture System			p-Value
	Nanobubble	Combine	Control	
Initial Weight (g)	80.36 ± 2.83	79.73 ± 2.88	80.56 ± 2.78	0.231
Final Weight (g)	204.89 ± 11.49 ^c	191.93 ± 2.79 ^b	171.41 ± 8.18 ^a	< 0.0001
Condition Factor	1.27 ± 0.06 ^a	1.23 ± 0.05 ^b	1.20 ± 0.05 ^b	0.007
Daily Weight Gain(g/day)	0.69 ± 0.05 ^c	0.62 ± 0.04 ^b	0.51 ± 0.06 ^a	< 0.0001
Feed Amount (kg)	26.08 ± 0.64 ^c	25.10 ± 0.97 ^b	24.33 ± 0.93 ^a	0.000
Feed Conversion Ratio	2.10 ± 0 ^a	2.60 ± 0 ^b	2.80 ± 0 ^c	< 0.0001
Feed Efficiency (%)	48.70 ± 0 ^c	39.00 ± 0 ^b	36.20 ± 0 ^a	< 0.0001
Mortality (%)	1.33 ± 0 ^a	16.00 ± 0 ^b	21.30 ± 0 ^c	< 0.0001
Productivity(g/m ²)	25375.25 ± 81.32 ^c	19615.56 ± 18.49 ^b	17624.16 ± 59.24 ^a	< 0.0001
Total Cost (NRS)	9543.87 ± 129.91 ^c	9349.02 ± 195.40 ^b	7128.47 ± 185.85 ^a	< 0.0001
Benefit Cost Ratio	1.60 ± 0.03 ^c	1.26 ± 0.04 ^b	1.48 ± 0.06 ^a	< 0.0001
Total income (NRS)	15225.20 ± 468.80 ^c	11769.33±107.01 ^b	10574.54 ± 353.54 ^a	< 0.0001

Note: Values are mean ± SD. Different superscript letters (a, b, c) within a row indicate significant differences between culture systems (Tukey's HSD, $p < 0.05$). NS = non-significant ($p \geq 0.05$)

The nanobubble system demonstrated superior economic performance despite higher operational costs. With a total expenditure of 7,450 NPR, it incurred significantly greater expenses than the Control system (Table 1). However, this investment translated into maximum production (12.69 kg) and highest income (NPR 15,224) outperforming both the Control and Combined systems. The system's elevated electricity consumption (208 units vs. 1 unit in Control) reflects the energy demands of nanobubble generation, a challenge noted by (Molear, 2024). Despite this, the 44% higher return compared to the Control system (Table 3) underscores its long-term cost-effectiveness. This aligns with Ulatowski & Sobieszuk, (2020) assertion

that nanobubbles enhance resource efficiency in aquaculture by optimizing feed utilization and reducing waste. The Benefit-Cost (BC) ratio of 1.60 (vs. 1.48 for Control and 1.26 for Combined) highlights the system's profitability. These findings mirror Mauladani et al., (2020) who reported a 32% increase in productivity in nanobubble-integrated systems due to improved feed conversion efficiency. The 25% reduction in FCR (Feed Conversion Ratio) (Table 3) further supports this, as lower FCR indicates enhanced nutrient absorption and biomass conversion, a phenomenon attributed by (Ebina et al., 2013) to nanobubbles' ability to break down complex organic compounds into bioavailable nutrients. Collectively, these results suggest that while nanobubble

systems require higher upfront investments, their ability to maximize yields and minimize

waste justifies their adoption in commercial aquaculture.

3.2 Water Quality

Table 3. Comparison of Water quality parameters (mean $\pm$ SD) of the water supply system observed during the research period at the Rainbow Trout Fishery Research Center, Dhunche Rasuwa, Nepal

Water quality parameters	Culture System			P-value
	Nanobubble	Combine	Control	
DO (mg/L)	11.82 $\pm$ 0.72 ^a	9.59 $\pm$ 0.15 ^b	9.33 $\pm$ 0.33 ^b	< 0.0001
Temperature (°C)	11.56 $\pm$ 2.89	10.29 $\pm$ 2.15	9.43 $\pm$ 2	0.092
PH	6.87 $\pm$ 0.22 ^c	7.13 $\pm$ 0.14 ^b	7.27 $\pm$ 0.14 ^a	< 0.0001
Total hardness (mg/L)	74.5 $\pm$ 4.93 ^c	90 $\pm$ 2.82 ^b	105 $\pm$ 6.95 ^a	< 0.0001
Alkalinity (mg/L)	16.48 $\pm$ 1.48 ^c	51.64 $\pm$ 1.18 ^b	87 $\pm$ 2.12 ^a	< 0.0001
Conductivity (S/m)	218.45 $\pm$ 4.79 ^a	185.57 $\pm$ 4.06 ^b	153.43 $\pm$ 9.35 ^c	< 0.0001
Oxygen gas saturation (%)	21.35 $\pm$ 0.36 ^a	20.57 $\pm$ 0.19 ^b	19.73 $\pm$ 0.31 ^c	< 0.0001
Turbidity (NTU)	17.76 $\pm$ 2.11 ^a	9.21 $\pm$ 0.83 ^b	1 $\pm$ 0 ^c	< 0.0001
Calcium (mg/L)	12.01 $\pm$ 1.03 ^c	13.5 $\pm$ 0.77 ^b	15.22 $\pm$ 0.83 ^a	< 0.0001
NO ₃ (mg/L)	7.6 $\pm$ 0.71 ^c	4.79 $\pm$ 0.5 ^b	3.29 $\pm$ 0.46 ^c	< 0.0001
NH ₃ (mg/L)	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001	0.815
Hydrogen peroxide (mg/L)	0.001 $\pm$ 0.002	0.001 $\pm$ 0.004	0 $\pm$ 0	0.73
NO ₂ (mg/L)	0 $\pm$ 0	0.003 $\pm$ 0.008	0.001 $\pm$ 0.004	0.879
PO ₄ (mg/L)	0.004 $\pm$ 0.005	0.002 $\pm$ 0.004	0.003 $\pm$ 0.004	0.167

Note: Values are mean $\pm$ SD. Different superscript letters (a, b, c) within a row indicate significant differences between culture systems (Tukey's HSD, $p < 0.05$). NS = non-significant ($p \geq 0.05$).

Nanobubble treatment induced significant improvements in water quality, with critical implications for fish health. Dissolved oxygen (DO) levels in the nanobubble system were 28% higher (11.93 mg/L) than in the Control (9.32 mg/L) (Table 2). This aligns with Kikuchi et al., (2009), who demonstrated that oxygen nanobubbles water elevate DO levels. According to Rahmawati et al., (2020) found that nanobubbles treatment is more effective than traditional aeration methods. The prolonged suspension of nanobubbles (<100 nm) in water ensures continuous oxygen diffusion, which is critical for aerobic metabolic processes in fish (Huang et al., 2023). Total gas saturation in the nanobubble system reached 113.95%, 15.6% higher than the Control (98.58%). This hyperoxygenation likely reduced physiological stress and enhanced metabolic rates, as noted by (Chirwa et al., 2024). However, the system also exhibited elevated turbidity and conductivity, likely due to nanobubble-induced particle suspension (Galang et al., 2019). While temporary turbidity poses no long-term harm, it underscores the need for filtration adaptations in systems housing light-sensitive species. Notably, phosphate (PO₄) levels decreased

by 50% in the nanobubble system. This reduction may stem from oxidative processes triggered by nanobubbles, which break down organic phosphorus compounds into inert forms (Linh et al., 2023). Lower phosphate levels mitigate eutrophication risks, aligning with Xue et al., (2022) who emphasized emphasis on nanobubbles role in sustainable aquaculture. Conversely, nitrate (NO₃) levels increased, likely due to enhanced nitrification in oxygen-rich environments. The strong positive correlation between NO₃ and productivity ($r = 0.89$) (Table 4) suggests that controlled nitrate accumulation supports growth without compromising water quality. While (Galang et al., 2019) deemed turbidity transient, its impact on light-sensitive species warrants exploration. Dissolved Oxygen (DO) Stability: The nanobubble system maintained DO levels above 10 mg/L throughout the culture period, peaking at 10.5 mg/L (Figure 4), while the Control system declined to 8.2 mg/L. This stability is critical for aerobic respiration and protein synthesis in fish, as low DO levels impair growth and immune function (Chirwa et al., 2024). The correlation between DO and productivity ($r = 0.82$) (Table 4) reinforces the centrality of oxygen management in aquaculture success.

3.3 Growth Performance and Mortality

The nanobubble system achieved 19.5% higher final fish weight compared to the Control and 11.9% higher than the Combined system (Table 3). Growth divergence began in January (Figure 2), with nanobubble-treated fish reaching 205 g by April, surpassing the Control (172 g) and Combined (195 g) systems. This acceleration correlates with daily weight gain peaking at 1.05 g/day (Figure 3), nearly double than the Control's rate (0.65 g/day). These trends align with Beijnen & Yan, (2021) findings on nanobubbles' ability to remove parasites and reduce stress, which collectively enhance growth rates. The system also recorded a 93.2% reduction in mortality compared to the Control (Table 3). This dramatic improvement can be attributed to three interrelated factors: Nanobubbles' oxidative properties reduce bacterial loads (Linh et al., 2023), minimizing disease outbreaks. Dissolved nanobubble water exhibits antioxidant activity Kato et al., (2007) and mitigating oxidative stress in fish (Mahasri et al., 2018). Sustained oxygen saturation (Figure 4) prevents hypoxia, a common cause of mortality in densely stocked fish farming systems (Saputra et al., 2020). The negative correlation between FCR and productivity ($r=-0.87$) (Table 4) further underscores the system's efficiency. Lower FCR indicates that fish converted feed into biomass more effectively, reducing waste and operational costs, a key advantage highlighted by (Molear, 2024).

3.4 Temperature Moderation

The nanobubble system operated at slightly higher temperatures (Figure 5), likely due to the exothermic nature of nanobubble generation. Warmer water accelerates metabolic rates, explaining faster growth in the early stages (Galang et al., 2019). However, excessive heat risks thermal stress, necessitating temperature monitoring in tropical climates. Oxygen Transfer Mechanisms: Prolonged nanobubble suspension Ng et al., (2023) ensures continuous oxygen availability, explaining the system's high DO levels (Figure 4) and growth rates (Figure 2). The 25% lower FCR aligns with Ebina et al., (2013), who

attributed improved feed conversion to nanobubbles' ability to enhance nutrient bioavailability. Reduced phosphate levels and lower mortality support Ulatowski & Sobieszuk, (2020) argument that nanobubbles promote eco-friendly aquaculture which make aquaculture sustainable. Identifying novel correlations, such as the FCR-mortality linkage ($r=0.89$), which suggests feed inefficiency exacerbates disease susceptibility.

Demonstrating temporal growth patterns (Figures 2–3), providing a roadmap for optimizing feeding schedules.

Table 4. Observation of correlation among growth and water quality parameters of different treatments

water quality parameters	DO	NO ₃	NH ₃	FCR	Mortality	Productivity	BC Ratio
DO (mg/l)	1	0.80***	0.08	-0.81***	-0.84***	0.82***	0.50***
NO ₃ (mg/l)		1	-0.02	-0.89***	-0.87***	0.89***	0.43***
NH ₃ (mg/l)			1	-0.02	-0.05	-0.02	0.04
FCR				1	0.89***	-0.87***	-0.38**
Mortality (%)					1	-0.90***	-0.42***
Productivity (g/m ³)						1	0.45***
BC Ratio							1

Note: denote statistical significance levels (e.g., $p < 0.05$, $*p < 0.01$, $**p < 0.001$ ***).

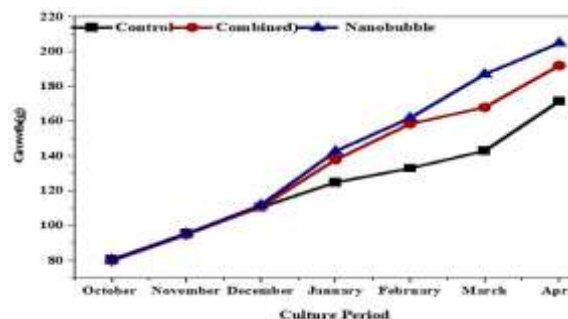


Figure 2. Rainbow trout growth trends during 2022 October to 2023 April

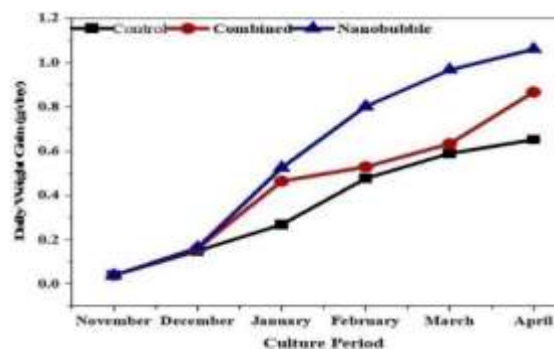


Figure 3. Daily weight gain of rainbow trout fish during 2022 October to 2023 April

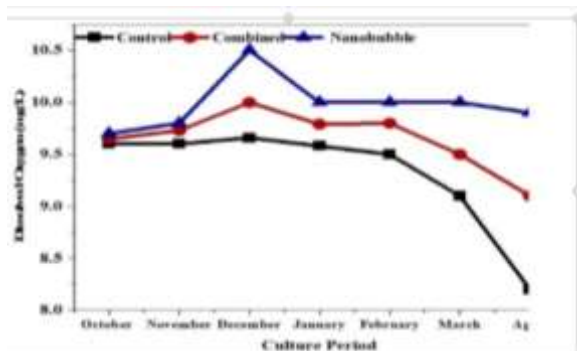


Figure 4. Dissolved oxygen amount in water at the Rainbow Trout Fishery Research Center at Dhunche Rasuwa from 2022 October to 2023 April

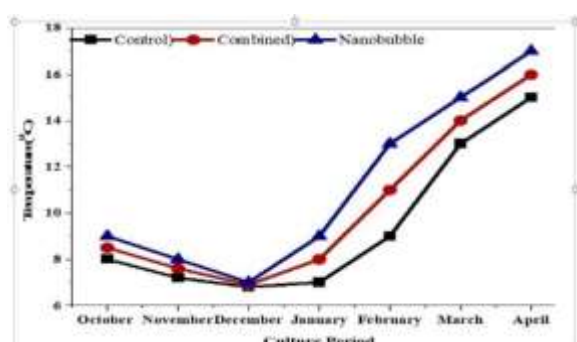


Figure 5. The water temperature of different water supply systems at the Rainbow Trout Fishery Research Center at Dhunche Rasuwa from 2022 October to 2023 April

4. CONCLUSION

Nanobubble aeration technology significantly enhances aquaculture productivity achieving 19.5% higher fish weight 93.2% lower mortality and 44% more return. Improved water quality including a 28% rise in DO and 50% phosphate reduction which supports fish health and mitigates eutrophication risks. While challenges like temporary turbidity

and energy demands exist, the system's superior Benefit-Cost ratio (1.60) underscores long-term viability. Future efforts should optimize energy efficiency, test diverse species, and adapt systems for scalability in energy-constrained regions. This innovation offers a sustainable blueprint for balancing economic gains with ecological stewardship in aquaculture, though infrastructure and species-specific adaptations require further exploration.

ACKNOWLEDGMENTS

We express our sincere appreciation to the following institutions for their significant support and contributions to our research. The EBA program of NAST has offered substantial funding and resources. The authors express their heartfelt gratitude to the NARC and AFU for their provision of essential research facilities and technical assistance. We express our gratitude to the Rainbow Trout Fishery Research Center for collaboration and the resources.

AUTHOR CONTRIBUTIONS

HR Devkota designed and conducted the research, collected and analyzed data, and drafted the initial manuscript. DK Jha, S. Shrestha, TP Joshi reviewed the manuscript other member of the team Mahendra Bhandari had a role of logistic support during research. All authors reviewed and approved the final version for publication.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

REFERENCES

- Agarwal, A., Ng, W. J., & Liu, Y. (2011). Principle and applications of microbubble and nanobubble technology for water treatment. *Chemosphere*, 84(9), 1175–1180. <https://doi.org/10.1016/j.chemosphere.2011.05.054>
- Beijnen, J. V., & Yan, G. (2021). A breath of fresh air: How nanobubbles can make aquaculture more sustainable. *News*. <https://ln.run/gDAM>
- Chirwa, W., Li, P., Zhan, H., Zhang, Y., & Liu, Y. (2024). Application of fine bubble technology toward sustainable agriculture and fisheries. *Journal of Cleaner Production*, 449, 141629. <https://doi.org/10.1016/j.jclepro.2024.141629>
- Ebina, K., Shi, K., Hirao, M., Hashimoto, J., Kawato, Y., Kaneshiro, S., Morimoto, T., Koizumi, K., & Yoshikawa, H. (2013). Oxygen and air nanobubble water solution promote the growth of plants, fishes, and mice. *PLoS ONE*, 8(6), e65339. <https://doi.org/10.1371/journal.pone.0065339>
- Galang, D. P., Ashari, A. K., Sulmawati, L., Mahasri, G., Prayogo, & Sari, L. (2019). The oxygen content and dissolved oxygen consumption level of white shrimp *Litopenaeus vannamei* in the nanobubble cultivation system. *IOP Conference Series: Earth and Environmental Science*, 236(1), 012014. <https://doi.org/10.1088/1755-1315/236/1/012014>
- Gurung, T., & Basnet, S. (2003). Introduction of rainbow trout *Onchorynchus mykiss* in Nepal: Constraints and prospects. *Aquaculture Asia*. <http://surl.li/dgtsfk>
- Gurung, T., Wagle, S. K., Nepal, A. P., & Lamsal, G. P. (2014). Emerging trends of rainbow trout (*Oncorhynchus mykiss*) aquaculture in Nepal Himalaya. *Nepalese Journal of Biosciences*, 4(1), 7–15. <https://doi.org/10.3126/njbs.v4i1.41677>
- Huang, Q., Ng, P. H., Marques, A. R. P., Cheng, T. H., Man, K. Y., Lim, K. Z., MacKinnon, B., Huang, L., Zhang, J., Jahangiri, L., Furtado, W., Hasib, F. M. Y., Zhong, L., Kam, H. Y., Lam, C. T., Liu, H., Yang, Y., Cai, W., Brettell, D., & St-Hilaire, S. (2023). Effect of ozone nanobubbles on the microbial ecology of pond water and safety for jade perch (*Scortum barcoo*). *Aquaculture*, 576, 739866. <https://doi.org/10.1016/j.aquaculture.2023.739866>
- Kato, T., Kubota, M., Kobayashi, N., & Suzuoki, Y. (2007). Effective utilization of by-product oxygen from electrolysis hydrogen production. *Energy*. <https://doi.org/10.1016/j.energy.2004.07.004>
- Kikuchi, K., Ioka, A., Oku, T., Tanaka, Y., Saihara, Y., & Ogumi, Z. (2009). Concentration determination of oxygen nanobubbles in electrolyzed water. *Journal of Colloid and Interface Science*, 329(2), 306–309. <https://doi.org/10.1016/j.jcis.2008.10.009>
- Linh, N. V., Khongcharoen, N., Nguyen, D.-H., Dien, L. T., Rungrueng, N., Jhunkeaw, C., Sangpo, P., Senapin, S., Uttaratotai, T., Panphut, W., St-Hilaire, S., Doan, H. V., & Dong, H. T. (2023). Effects of hyperoxia during oxygen nanobubble treatment on innate immunity, growth performance, gill histology, and gut microbiome in Nile tilapia, *Oreochromis niloticus*. *Fish & Shellfish Immunology*, 143, 109191. <https://doi.org/10.1016/j.fsi.2023.109191>
- Mahasri, G., Saskia, A., Apandi, P. S., Dewi, N. N., Rozi, & Usuman, N. M. (2018). Development of an aquaculture system using nanobubble technology for the optimization of dissolved oxygen in culture media for Nile tilapia (*Oreochromis niloticus*). *IOP Conference Series: Earth and Environmental Science*, 137, 012046. <https://doi.org/10.1088/1755-1315/137/1/012046>
- Mauladani, S., Rahmawati, A. I., Absirin, M. F., Saputra, R. N., Pratama, A. F., Hidayatullah, A., Dwiarto, A., Syarif, A., Junaedi, H., Cahyadi, D., Saputra, H. K. H., Prabowo, W. T., Kartamiharja, U. K. A., Noviyanto, A., & Rochman, N. T. (2020). Economic feasibility study of *Litopenaeus vannamei* shrimp farming: Nanobubble investment in increasing harvest productivity. *Jurnal Akuakultur Indonesia*, 19, 30–38. <https://doi.org/10.19027/jai.19.1.30-38>
- Molear. (2024). Nanobubbles support environmental stewardship while maintaining productivity for aquaculture. *Molear*. <https://www.moleaer.com/industries/aquaculture>
- Ng, P. H., Huang, Q., Huang, L., Cheng, T. H., Man, K. Y., Cheng, K. P., Rita, P. M. A., Zhang, J., & St-Hilaire, S. (2023). Assessment of ozone nanobubble technology to reduce freshwater algae. *Aquaculture Research*, 2023, 1–8. <https://doi.org/10.1155/2023/9539102>
- Peter, D., & L, S. D. (2007). *Dissolved oxygen requirements of freshwater fishes* (FAO Fisheries Technical Paper No. 86).
- Ragheb, E. (2023). Length-weight relationship and well-being factors of 33 fish species caught by gillnets from the Egyptian Mediterranean waters off Alexandria. *Egyptian Journal of Aquatic Research*, 49(3), 361–367. <https://doi.org/10.1016/j.ejar.2023.01.001>
- Rahmawati, A. I., Saputra, R. N., Hidayatullah, A., Dwiarto, A., Junaedi, H., Cahyadi, D., Saputra, H. K. H., Prabowo, W. T., Kartamiharja, U. K. A., Shafira, H., Noviyanto, A., & Rochman, N. T. (2020). Enhancement of *Penaes vannamei* shrimp growth using nanobubble in indoor raceway pond. *Aquaculture and Fisheries*. <https://doi.org/10.1016/j.aaf.2020.03.005>
- Saputra, R. N., Rahmawati, A. I., Absirin, M. F., Junaedi, H., Cahyadi, D., Noviyanto, A., Nugroho, D. W., Suryandaru, Ikono, R., & Rochman, N. T. (2020). Effect of nitrogen nanobubble preservation on the quality, microbial population, and storage life of fresh yellowfin tuna (*Thunnus albacares*). *IOP Conference Series: Earth and Environmental Science*, 472, 012021. <https://doi.org/10.1088/1755-1315/472/1/012021>

- Shen, W., Mukherjee, D., Koirala, N., Hu, G., Lee, K., Zhao, M., & Li, J. (2022). Microbubble and nanobubble-based gas flotation for oily wastewater treatment: A review. *Environmental Reviews*, 30(3), 359–379. <https://doi.org/10.1139/er-2021-0127>
- Ulatowski, K., & Sobieszuk, P. (2020). Gas nanobubble dispersions as the important agent in environmental processes – Generation methods review. *Water and Environment Journal*, 34(S1), 772–790. <https://doi.org/10.1111/wej.12577>
- Xue, S., Zhang, Y., Marhaba, T., & Zhang, W. (2022). Aeration and dissolution behavior of oxygen nanobubbles in water. *Journal of Colloid and Interface Science*, 609, 584–591. <https://doi.org/10.1016/j.jcis.2021.11.061>
- Zhou, S., Liu, M., Chen, B., Sun, L., & Lu, H. (2022). Microbubble- and nanobubble-aeration for upgrading conventional activated sludge process: A review. *Bioresource Technology*, 362, 127826. <https://doi.org/10.1016/j.biortech.2022.127826>

ESTIMATE OF SUPPLY RESPONSE OF RICE USING TIME SERIES DATA IN NEPAL

Durgesh Man Shrestha^{1*}, Suraj Bharati², Bikesh Thapa³ and Usha Shrestha¹

¹ University of the Philippines Los Banos (UPLB), Philippines.

² Ministry of Agriculture and Livestock Development, Nepal.

³ Institute of Agriculture and Animal Science, Tribhuvan University, Nepal.

ARTICLE INFO	ABSTRACT
Keywords: Nerlove model, rice, supply response, time-series analysis *Correspondence: dmshrestha1993@gmail.com	<i>This study examines the supply response of rice in Nepal using a time-series dataset from 1990 to 2023. The study employs the Nerlove partial adjustment model to estimate the responsiveness of rice production to price changes. A single-equation empirical model incorporating variables such as lagged production, producer prices of rice and maize, import quantity, and cultivated area is used. The study used augmented dickey fuller test for stationarity with zero lag, one lag and first differencing. The vector auto regression is used for the analysis taking log production as dependent variable and lag log production, lag log price of rice, lag log price of alternative crop maize, log import quantity and log area as independent variables. The area and import quantity are elastic in both short run and long run whereas other variables are inelastic. The findings indicate that while rice production has increased significantly, the cultivated area has remained relatively stable, suggesting that yield improvements have driven production growth. Additionally, rice imports surged after 2015, reflecting increased demand. The study analyzes farmers' responses to price and policy changes, supporting effective policy formulation and production planning. It highlights the need for sustainable productivity improvements and strategic interventions to reduce reliance on rice imports and strengthen national food security.</i>

1. INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereal crops in the world, feeding nearly half of the global population (Greenland, 1997; Maclean et al., 2002). In Nepal, rice is the major staple and crucial food crop, followed by maize and wheat. It's grown across a wide range of landscapes, from the lowlands of the Terai to the high hills, at elevations between 60 and 3,050 meters above sea level (Bhujel & Ghimire, 2006; Gadal et al., 2019; Pokhrel et al., 2020). Rice plays a huge role in Nepal's agriculture, supporting food security, employment, and income for farmers in addition to its contribution to the economy in Nepal (Gauchan et al., 2022). In 2023, Nepal produced 5,130,625 mt of rice, grown on 1,477,378 ha of land, with an average yield of 3.47 mt per ha (MoALD, 2023). It covers

over 42.3% of the total crop area and makes up 47.6% of the country's total food grain production (MoALD, 2023). Globally, Nepal ranks 17th in rice production but 64th in terms of productivity (Choudhary et al., 2022).

The average per capita consumption of rice was 138 kg every year, which makes up around 53% of their total grain intake and contributes 20% to the agricultural GDP (Yadav & Chaudhary, 2017; Tripathi et al., 2019; Kumar et al., 2020; Choudhary et al., 2022; Helgi Library, 2023). To support rice farming, Nepal has introduced 73 different rice varieties—62 for the main growing season and 11 for spring. More than 25% of these varieties are designed for mountainous areas, while over 60% are suited for the Terai and Inner Terai regions (NARC, 2018). Despite these efforts, only two hybrid rice varieties: Hardinath F1 Hybrid-1 and

Hardinath F1 Hybrid-3 have been developed so far (MOALD, 2023). In 2022, Nepal's National Seed Board approved seven new rice varieties for farmers to grow: Ghaiya-3, Hardinath-4, Hardinath-5, Hardinath-6, Ganga Sagar-1, Ganga Sagar-6, and Khumal Basmati-16 (IRRI, 2022). However, Nepal's rice productivity has seen a decline compared to other South Asian countries. Back in the 1960s, Nepal had the highest rice yields in the region, but today it has the lowest (Tripathi et al., 2019). With an average yield of 3.5 tons per hectare, Nepal trails behind Bangladesh (4.4 t/ha) and China (6.7 t/ha), though it's similar to India (3.7 t/ha) and Pakistan (3.5 t/ha). Between 1960 and 2017, Nepal's annual rice production growth rate was just 1.14%, much lower than India's 2.5%, Bangladesh's 3%, China's 4.2%, and the global average of 4.5% (FAOSTAT, 2019). Nepal's domestic rice production isn't enough to meet the country's needs, covering only 88.89% of demand (Hussain & Sinha, 2019). This gap has led to a growing reliance on rice imports, as people increasingly prefer rice over traditional grains like millets and maize (Pokhrel et al., 2021). Additionally, there's a rising demand for fine and fragrant rice varieties, which Nepal produces in limited quantities (Tripathi et al., 2019; Pokhrel et al., 2021). As a result, rice imports have gone up significantly, with Nepal spending USD 451 million on rice imports in 2021 alone, making up 2.85% of total import costs (Gairhe et al., 2021). This growing dependence on imports highlights the urgent need to improve productivity and find ways to meet the changing demands of Nepal's population. Farmers also face a significant yield gap of 50% (NRRP, 2019), which makes it even harder to meet demands of growing populations.

Rice production in Nepal faces numerous constraints that hinder its potential growth. Key challenges include limited arable land, significant yield gaps, inadequate technological adoption, particularly in rainfed areas and issues related to product quality, delayed input delivery, and restricted access to modern technologies (Tripathi et al., 2019). Additionally, inefficient technology transfer mechanisms and insufficient policy support further exacerbate these challenges.

Urbanization and industrialization have led to a reduction or stagnation in the area dedicated to rice cultivation, leaving increased cropping intensity and yield enhancement as the primary avenues for boosting production (Tripathi et al., 2019). Barriers to realizing this potential include shortages of high-quality seeds, fertilizers, and irrigation infrastructure, as well as inadequate transportation, storage facilities, organized marketing systems, and skilled labor resources (Bahadur et al., 2010; PMAMP, 2018; Tripathi et al., 2019; Joshi et al., 2020; Subedi et al., 2020; Paudel et al., 2021). The adoption of improved rice varieties has been shown to significantly enhance production and productivity, with potential yield increases of up to 25% (Gauchan & Pandey, 2011; Joshi et al., 2011; Pandit et al., 2020). Despite these challenges, the increased use of irrigation, fertilizers, and improved varieties has demonstrated positive impacts on productivity. The development and dissemination of high-yielding hybrid and stress-resistant rice cultivars, coupled with innovations in mechanization, offer promising pathways for enhancing rice production and productivity (Bhawan, 2011; Gairhe et al., 2021; Pandit et al., 2020; Pokhrel et al., 2021). Rice productivity and efficiency are influenced by internal and external factors. The internal factors include a) socio-economic profile of the farmers, b) farm resources, c) farming practices/technology adopted, and d) infrastructures for operations and internal factors also depend on external factors which are beyond the control of farmers. These include a) economics, b) environmental/climatic condition, and c) political/legal. In summary, while Nepal's rice sector faces significant constraints, there is considerable potential for increasing production through the adoption of improved technologies, enhanced seed systems, and targeted policy interventions. Addressing these challenges requires increased investment in research, infrastructure, and technology transfer mechanisms to bridge yield gaps and meet the growing demand for rice.

One of the most important issues in agricultural economic development is the supply response of crops. This is because the

responsiveness of farmers to economic incentives determines agriculture's contribution to the economy where the sector is the largest employer of labor. The supply response generally refers to the variation in agricultural output, primarily driven by changes in price. This concept encompasses both the shifting of supply curves and movements along the curves, reflecting how farmers adjust their production levels in response to price fluctuations. Essentially, supply response measures the output change resulting from a change in the price of a product, which may occur due to the reallocation or utilization of resources in response to price increases or decreases (Nerlove, 1958). Supply response is fundamental to understanding the price mechanism in agriculture. This response may be influenced by changes in farm size, as well as technological advancements and other production variables such as credit availability, price fluctuations, weather conditions, and market information. These factors can collectively drive supply response, which essentially involve elements that shift or move the supply curve (Askari & Cummings, 1977; Behrman, 1968; Mundlak, 2001). Furthermore, technological changes under the influence of production variables like credit, price, weather, market information, and so on may bring out supply response. Hence, supply response has to do with factors that move the supply curve (Mundlak, 2001). Price policy analysis has been found to be pivotal in agricultural production studies, with price being fundamental in determining farm output (Askari & Cummings, 1977). Hence the study utilizes time series data to study the supply response of rice in Nepal how farmers react to changes in rice prices and other economic factors. This helps policymakers design effective agricultural policies, improve food security, and ensure stable rice production to meet national consumption needs.

2. MATERIALS AND METHODS

This study was based on the time-series secondary data obtained from various sources spanning from 1990 -2023. Data was obtained from various sources which include online database maintained by Food and

Agriculture Organization (FAO), World Bank Data and Statistical Information on Nepalese Agriculture (MoALD).

2.1 Conceptual Model

Nerlove (1958) introduced the concept of partial adjustment, arguing that because it takes time for equilibrium to develop, partial adjustment occurs within a single time period. The delay in reaching the equilibrium could be due to various factors, including consumer preferences, which take time to change, and production that has already occurred and must be disposed of. Nerlove assumed that quantity supplied in the current time period (Q_t^s) is determined by the price expected in the current time period (P_t) then

$$Q_t^s = a + bP_t^* + e_t \quad (1)$$

Where, a and b are the parameters to be estimated and e_t is the error term and assumed to be distributed normally with zero mean and constant variance σ^2 .

The Nerlove's technique assumes that farmers each year revise the price they expect to prevail in the market in the coming year in proportion to the errors they make in predicting prices in the current time period. Mathematically,

$$P_t^* - P_{t-1}^* = r(P_{t-1} - P_{t-1}^*); 0 \leq r \leq 1 \quad (2)$$

Where, P_t^* and P_{t-1}^* are expected prices at time period t and $t - 1$; while r is a constant called coefficient of adjustment and ranges between 0 to 1. Furthermore, equation (2) can also be written as

$$P_t^* = \gamma P_{t-1} + (1 - \gamma)P_{t-1}^* \quad (3)$$

Indicating that the current expected price (P_{t-1}^*) is the weightage average of expected price in the previous year (P_{t-1}^*) and actual price in previous year P_{t-1} . However, expected prices (P_t^* & P_{t-1}^*) are unobservable and equation (2) can be written as

$$P_t^* = rP_{t-1} + r(1 - r)P_{t-2} + r(1 - r)^2P_{t-3} + \dots \quad (4)$$

Substituting equation (3) into Eq. (1) yields,

$$Q_t^s = a + b(\gamma P_{t-1} + \gamma(1-\gamma)P_{t-2} + \gamma(1-\gamma)^2 P_{t-3} + \dots + e_t) \quad (5)$$

Multiplying equation (5) by $(1-\gamma)$ and lagging it one time period (Koyck transformation)

$$(1-\gamma)Q_{t-1}^s = a(1-\gamma) + b[\gamma(1-\gamma)P_{t-2} + \gamma(1-\gamma)^2 P_{t-3} + \gamma(1-\gamma)^3 P_{t-4} + \dots + (1-\gamma)e_{t-1}] \quad (6)$$

Subtracting equation (6) from (5) yields

$$Q_t^s = a\gamma + b\gamma P_{t-1} + (1-\gamma)Q_{t-1}^s + \epsilon_t \quad (7)$$

Where $\epsilon_t = e_t - (1-\gamma)e_{t-1}$

$$Q_t^s = \pi_0 + \pi_1 P_{t-1} + \pi_2 Q_{t-1}^s + \epsilon_t \quad (8)$$

From Eq. (7) and (8), $\pi_2 = 1-\gamma$ hence $\gamma = 1-\pi_2$, and $\pi_1 = b\gamma$ and $b = \frac{\pi_1}{\gamma}$. The short run elasticity is given as

$$\epsilon_s = \frac{\partial Q_t^s}{\partial P_{t-1}} * \frac{P_{t-1}}{Q_t} = \pi_1 * \frac{P_{t-1}}{Q_t} \quad (9)$$

The long run supply elasticity can be derived as

$$\epsilon_L = \frac{\epsilon_s}{\gamma} \quad \text{where} \quad \gamma = 1-\pi_2 \quad (10)$$

Short-run supply elasticity refers to the supply responsiveness to a price adjustment during the initial phase of reaction. Short-term supply changes are projected to be most significant. Long-term elasticity refers to how supply responds to price changes over time.

2.2 Empirical model

Taking log of both sides in Eq (8) yields empirical model employed in study.

We use single model in order to estimate the total volume of domestic rice production which is expressed as

$$Q_t = f(Q_{t-1}^s, PR_{t-1}, PM_{t-1}, A_t, IQ_t, U_t) \quad (11)$$

Where,

Q_t
= volume of rice supplied in year t (tonnes)

Q_{t-1}^s =
volume of rice supplied in lagged one year (tonnes)

PR_{t-1}
= producer price of rice in lagged one year (USD per tonnes)

PM_{t-1}
= producer price of alternative crop maize in lagged one year (USD per tonnes)

IQ_t
= import quantity of rice (tonnes per year)

A_t = Area in ha in year t

U_t = error terms

Specific model specifications

$$\ln Q_t = \gamma_0 + \gamma_1 \ln Q_{t-1}^s + \gamma_2 \ln PR_{t-1} + \gamma_3 \ln PM_{t-1} + \gamma_4 \ln IQ_t + \gamma_5 \ln A_t + U_t \quad (12)$$

Autocorrelation between the error terms was anticipated to be an estimating problem because the study used time series data. Durbin-h statistic was employed in the study to identify autocorrelation issues. Prior to estimation, this equation was estimated using Stata software's vector autoregression. The Durbin h statistics was used to detect autocorrelation, and the enhanced Dickey Fuller test was used to check for stationarity.

3. RESULTS AND DISCUSSION

3.1 Area, Production and Import Quantity of Rice in Nepal (1990-2023)

Significant patterns in the supply and demand for rice are revealed by the graphic, which shows the trends in rice growing area, production, and import quantity from 1990 to 2023. Despite sporadic oscillations, rice output has largely increased, showing significant rise after 2010 and reaching over 5.72 million tons on 2023. The cultivated area, on the other hand, has stayed mostly constant over time, indicating that increased yields rather than agricultural expansion are the key drivers of output gains. Imports of rice were modest until about 2010, but after 2015, they increased significantly, reaching a peak in 2020 before slightly declining. This suggests a growing dependence on imports in spite of rising domestic production, which could be brought on by rising consumer demand or production shortages in some years. The stability of the cultivated area demonstrates how new agricultural techniques, such better seed varieties,

fertilizers, and irrigation, may increase output. The recent decline in imports beyond 2020 can be attributed to either legislative changes impacting the rice trade or attempts towards self-sufficiency. Overall, even though more rice is being produced, the

ongoing dependence on imports highlights the necessity of long-term productivity gains and calculated policy changes to balance domestic supply and demand (Tripathi et al., 2019; Joshi et al., 2020; Pokhrel et al., 2021; Timsina et al., 2023).

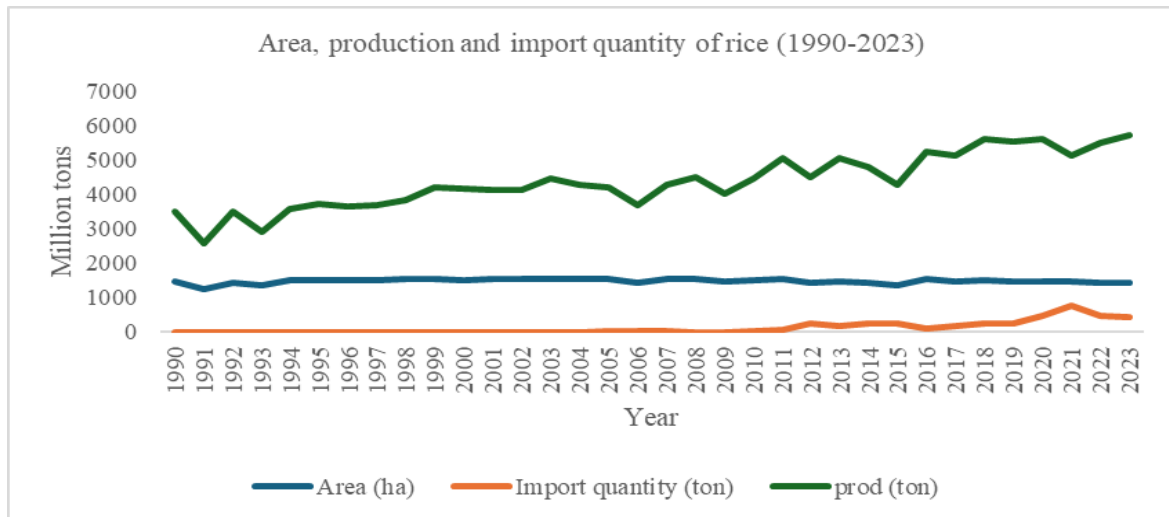


Figure 1. Area, production and import quantity of rice in Nepal (1990-2023) [Source: <https://www.fao.org/faostat/en/#data>]

3.2 Autocorrelation (Durbin h statistic)

The model employs lag dependent variables so for the detection of autocorrelation Durbin h statistic was used. Following Gujrati (2004) and; Dougherty (2006), Durbin h test for autoregressive model

$$h = (1 - \frac{1}{2}d) \sqrt{\frac{n}{1-n[\text{var}(\alpha)]}}$$

(13)

$\rho = 1 - \frac{1}{2}d$ where d = Durbin Watson; $\text{var}(\alpha)$ = variance of lag dependent variable
 $h \sim N(0,1)$ $\Pr(-1.96 \leq h \leq 1.96) = 95\%$

Decision rule if $|h| > 1.96$ there is autocorrelation in the autoregressive model
Hence, Durbin-Watson d-statistic (6, 33) = 1.88. Durbin h-statistic (h) = 0.421

Since $|h| = 0.421 < 1.96$ therefore there is no autocorrelation. The value of Durbin h statistic lies within the range showing that there is no autocorrelation problem in the data.

3.3 Stationary Augmented Dickey-Fuller (ADF) Test Results

The Augmented Dickey-Fuller (ADF) test was used to determine whether a time series is stationary or contains a unit root, meaning it follows a stochastic trend. If a time series is non-stationary, using it in regression can lead to spurious results, making it crucial to transform the data appropriately. Principle of the ADF Test: The null hypothesis (H_0) states that the series has a unit root (i.e., it is non-stationary). The alternative hypothesis (H_1) suggests that the series is stationary. Decision rule: A p-value greater than 0.05 means we fail to reject null hypothesis, indicating non-stationarity. If p-value less than 0.05 means we reject null hypothesis, indicating stationarity (Gujrati, 2004; Wooldridge, 2020). The ADF test (Table 1) shows that Production, Price of Rice, Price of Maize, and Import Quantity are non-stationary at level but become stationary after first difference. The Area variable is already stationary at level ($p < 0.05$), meaning it does not require differencing for further analysis.

Table 1. Stationary Augmented Dicky Fuller (ADF) test results

Variable Name	p-value (zero lag)	p-value (one lag)	p-value (1st difference)
Production	0.4947	0.5509	0.0000
Price of rice	0.9189	0.8766	0.0048
Price of Maize	0.8399	0.7818	0.0000
Import	0.7661	0.8413	0.0004
Area	0.0007	-	-

Source: Authors' estimation based on secondary data

3.4 Vector Autoregression (VAR)

Vector autoregression is used in this study because the dependent variable (production) is dependent on its endogenous variable (lag production). The results summarize the relationships between production, area, import quantity, and other variables over the sample period from 1990 to 2023, using 33 observations. The log likelihood is -501.07, and model selection criteria such as AIC (37.35), HQIC (38.53), and SBIC (40.96) suggest model fit. The model shows strong explanatory power for log-transformed variables Chi-square (χ^2) statistic are highly significant ($p < 0.05$) and high R-squared, with low RMSE indicating a good fit.

3.5 Regression Analysis

The regression analysis estimates supply response of rice in Nepal showed lagged rice production (Log Production (t-1) exhibits a statistically significant positive relationship with current rice production, as demonstrated by a p-value of 0.000, implying a strong persistence effect. The coefficient is small (9.44×10^{-8}), which in turn will have small changes. The previous years price of rice (t-1) also has a significant positive effect ($p = 0.035$), indicating that rice farmers respond positively to past rice prices. This price responsiveness is a critical factor for farmers' decision-making on the next planting.

Additionally, import quantity (t) have a statistically significant positive effect ($p = 0.033$), implying that rice production in Nepal is positively correlated with the volume of rice imports. Finally, the area under rice cultivation (t) has a highly significant positive effect ($p = 0.000$), as expected, illustrating the direct impact of agricultural land expansion on rice output. The coefficient for the previous year's price of maize (t-1) is not statistically significant ($p = 0.514$) impact on rice supply, maize is an alternative and substitute for rice.

Overall, the results reveal that the supply response of rice in Nepal is influenced by the price of rice, showing that a rise in rice price can cause an adjustment in supply in the production side. The value of R^2 is 0.9465 which shows that 94.65% of the dependent variable is explained by the independent variable. The value of $p > \chi^2$ (0.000) showing that the model is overall good fit.

$$\begin{aligned} \ln Q_t &= \gamma_0 + \gamma_1 \ln Q_{t-1}^s + \gamma_2 \ln PR_{t-1} \\ &\quad + \gamma_3 \ln PM_{t-1} + \gamma_4 \ln IQ_t \\ &\quad + \gamma_5 \ln A_t + U_t \\ \ln Q_t &= -16.20 + 9.44 \times 10^{-8} \ln Q_{t-1}^s \\ &\quad + 0.0014 \ln PR_{t-1} \\ &\quad + (-0.0004) \ln PM_{t-1} \\ &\quad + 0.0229 \ln IQ_t + 2.15 \ln A_t \\ &\quad + U_t \end{aligned}$$

Table 2. Regression results

Variable Name	Coefficient	Std. Err	p-value
Log Production(t-1)	$9.44 \times 10^{-8}***$	1.86×10^{-8}	0.000
Log Price of rice (t-1)	0.0014**	0.0006	0.035
Log Price of Maize (t-1)	-0.0004	0.0006	0.514
Log Import (t)	0.0229**	0.0101	0.033
Log Area (t)	2.15***	0.1987	0.000
Constant	-16.20***	2.839	0.000
Number of Obs.			33
Prob>F			0.0000

R-Squared	0.9465
Adj. R-squared	0.9366

Source: Authors' estimation based on secondary data

Note: *, **, *** denotes significance at 10 %, 5 % and 1% level, respectively.

Khan et al. (2019) found that rice production in Khyber Pakhtunkhwa, Pakistan, exhibited long-run elasticity with lagged production, advocating government price stabilization to aid farmers' land allocation decisions. Given Nepal's rising rice insecurity—evidenced by declining self-sufficiency (SSR) and growing import dependency (IDR) (Lamichhane et al., 2024)—this study identifies supply determinants and policy levers for a sustainable rice system. Prasada et al. (2018) demonstrated irrigated area's strong responsiveness to paddy supply in East Java, highlighting real price increases, irrigation expansion, and prior year harvested area as key drivers. Similarly, Niazi and Farooq (2019) linked Basmati rice supply in Pakistan to positive price and irrigation effects but negative fertilizer price impacts, reinforcing the need for price stabilization policies. Together, these studies underscore the role of price incentives, infrastructure, and lagged production in shaping rice supply, offering Nepal actionable insights to enhance resilience. As Joshi et al. (2021) show, while productivity gains offset declining cultivation area, labor scarcity critically impacts production - particularly in mid-hills where 60,500 ha lie fallow (National Statistics Office, 2023). Migration reduces family labor, raising costs and fallow likelihood by 50% (Karki et al., 2022; Khanal, 2018). Mechanization (Paudel et al., 2019) helps but

can't fully compensate for labor shortages driving land abandonment.

3.6 Calculations for γ

The coefficients of log model give short-run elasticities of the corresponding variables. The long-run elasticity can be derived using Eq. (10)

3.7 Elasticities

Table 3 shows that the variables area and import quantity are elastic in both the short run and long run whereas other variables are inelastic. Based on the results, the analysis reveals a significant correlation between rice production and several key factors. The long-run elasticity of rice price is 0.0014, indicating that a 1% increase in rice price leads to a 0.0014% increase in rice production. This suggests a weak, but positive, responsiveness of rice farmers to lagged prices. Imports are positively correlated with production; a 1% increase in imports leads to a 0.023% increase in rice production in the long-run. The coefficient of area is negative in the long run (-1.869) and positive in the short run (2.15), this indicates the presence of multicollinearity, which implies that the model contains highly correlated variables. Log Production(t-1) shows a minimal effect, both in the long run and short run.

Table 3. Short and long run elasticities

Variable Name	Long-run elasticity	Short-run elasticity
Log Production(t-1)	0.1×10^{-8}	9.44×10^{-8}
Log Price of rice (t-1)	0.0014	0.0014
Log Price of Maize (t-1)	-0.0003	-0.0004
Log Import (t)	0.0234	0.0229
Log Area (t)	-1.8695	2.15

Source: Authors' estimation based on secondary data

Our results align with Ho et al. (2024) and Ashrit (2021), demonstrating farmers' responsiveness to price signals, where a 10%

increase in paddy price boosts profits by 17.7%. However, this contrasts with global patterns observed by Iqbal and Babcock

(2018), who found rice cultivation area remained price-inelastic in both short and long runs due to government price stabilization measures. In Nepal, while Minimum Support Price (MSP) policies aim to stabilize markets, their effectiveness is limited by weak institutional presence, low farmer awareness, and wholesaler dominance in paddy markets (J. Joshi & Chaulagai, 2024), forcing farmers to rely on market prices when making production decisions. Even farmers participating in MSP programs adjust input use, cultivation area, and marketed surplus based on support price levels. Price volatility emerges as a critical factor, with Haile et al. (2016) showing that while rice shows weak short-run price responsiveness, volatility significantly reduces production area and input investments. Cross-crop effects are also evident, as Khan et al. (2019) found rising maize prices reduced rice cultivation in Pakistan, while reporting higher rice price elasticities than our Nepal-based study. Analysis reveals a positive correlation between imports and domestic rice production, where a 1% increase in imports leads to a 0.023% production increase in the long run, reflecting Nepal's 16% import dependency ratio (Pokhrel et al., 2021; Timsina et al., 2023). Approximately 90% of rice imports originate from India due to border proximity and favorable policies, with growing consumer preference for fine and basmati varieties exacerbating this dependency - evidenced by NPR 5.4 billion spent on basmati imports in FY 2080/81 ("Nepal's Shifting Rice Landscape; Self-sufficiency to Import Dependency," 2024). The area coefficient shows contrasting short-run (2.15) and long-run (-1.869) effects, aligning with Ho et al. (2024) who found 10% land expansion increases profits by 10.3%, while input costs reduce profitability. This suggests farmers adjust acreage short-term but require resilient seeds, mechanization, and irrigation for sustainable gains (Timsina et al., 2023). The model indicates multicollinearity among variables, with lagged production showing minimal impact. Cross-price elasticity reveals maize's substitution effect - a 1% maize price increase reduces rice supply by 0.00003% (long-run) and 0.0004% (short-run),

reflecting Nepal's dominant rice-maize-wheat cropping systems. These findings highlight the need for policies that address import dependency through aromatic rice promotion while stabilizing input markets to maintain production competitiveness.

4. POLICY RECOMMENDATIONS

Three important policy areas should be given top priority in order to increase rice self-sufficiency and lessen reliance on imports. First, increase price stability by lowering market volatility, encouraging farmers to cultivate consumer preference rice varieties, and enhancing the Minimum Support Price's (MSP) accessibility and implementation. Second, increase productivity by promoting mechanization to combat labor shortages brought on by migration, investing in high-yielding, climate-resilient rice varieties, and expanding infrastructure. To increase input efficiency, timely delivery of high-quality seeds, fertilizer, and extension services must also be guaranteed. Third, promote the production of fragrant and fine rice that meets domestic demand. Additionally, decentralized efforts should focus on region-specific strategies to utilize fallow land and increase cropping intensity, particularly in the mid-hills. These integrated measures, implemented through coordinated efforts among government bodies, local institutions, and private stakeholders, can sustainably transform Nepal's rice sector and strengthen national food and nutritional security.

5. CONCLUSION

The paper examines Nepal's rice production trends over the last three decades, highlighting major elements that influence supply dynamics. Despite fluctuations, rice output has been steadily increasing, driven primarily by higher yields rather than increased farming. The Nerlove's partial adjustment model adequately captures the supply response, suggesting that rice production has strong short and long-run price elasticity. The lag production of rice, lag market price of rice, import quantity and area were statistically significant and have also positive effect on the production. The competitive crop price (maize) has negative and statistically non-significant effect on the supply of rice. To increase rice production in

Nepal, the study suggests investing more in high-yield seed varieties, as well as improving irrigation and fertilizer use. Farmers will benefit from a more efficient supply network as their yields rise. This will help Nepal expand rice output, improve rice quality, and become self-sufficient.

Furthermore, efficient agricultural policy implementation requires a coordinated strategy involving government agencies, the corporate sector, and farmer cooperatives. This ensures long-term food security and self-sufficiency.

REFERENCES

- Ashrit, R. R. (2021). Input demand and output supply elasticities of coarse cereals in India: A translog profit and sure approach. *Asian Journal of Agricultural Extension, Economics & Sociology*, 39(11), 196–209.
- Askari, H., & Cummings, J. T. (1977). *Agricultural supply response: A survey of the econometric evidence*. Amsterdam: North-Holland Publishing Company.
- Behrman, J. R. (1968). *Supply response in underdeveloped agriculture: A case study of four major annual crops in Thailand, 1937-1963*. Amsterdam: North-Holland Publishing Company.
- Choudhary, D., Banskota, K., Khanal, N. P., McDonald, A. J., Krupnik, T. J., & Erenstein, O. (2022). Rice Subsector Development and Farmer Efficiency in Nepal: Implications for Further Transformation and Food Security. *Frontiers in Sustainable Food Systems*, 5. <https://doi.org/10.3389/fsufs.2021.740546>
- Dougherty, C. (2006). *Introduction to Econometrics*. Oxford University Press.
- Food and Agriculture Organization (FAO). (2019). FAOstat: Crop Production Data 2019. Rome: FAO. Retrieved from <https://www.fao.org/faostat/en/#data>
- Gadal, N., Shrestha, J., Poudel, M. N., & Pokharel, B. (2019). A review on production status and growing environments of rice in Nepal and in the world. *Archives of Agriculture and Environmental Science*, 4(1), 83–87. <https://doi.org/10.26832/24566632.2019.0401013>
- Gairhe, S., Gauchan, D., & Timsina, K. P. (2021). Temporal Dynamics of Rice Production and Import in Nepal. *Journal of Nepal Agricultural Research Council*, 7, 97–108. <https://doi.org/10.3126/jnarc.v7i1.36932>
- Gauchan D and S Pandey. 2011. Is investment in rice research in Nepal adequate and balanced across production environments? Some empirical evidence. *Q. J. Int. Agric.* 50(4): 305-324.
- Gauchan, D., Babu, D., Magar, T., & Gautam, S. (2016). Rice seed production and marketing practices in Nepal. In *The Journal of Agriculture and Environment* (Vol. 17).
- Greenland, D.J., 1997. The sustainability of rice farming. International Rice Research Institute (IRRI), 1099 Manila, Philippines.
- Gujrati, D. N. (2004). *Basic Econometrics* (4th ed.). McGraw-Hill.
- Haile, M. G., Kalkuhl, M., & Von Braun, J. (2016). Worldwide acreage and yield response to international price change and volatility: A dynamic panel data analysis for wheat, rice, corn, and soybeans. https://doi.org/10.1007/978-3-319-28201-5_7
- Helgi Library. (2023). *Rice consumption per capita in Nepal*. Retrieved November 16, 2023 from <https://www.helgilibrary.com/indicators/rice-consumption-per-capita/nepal/>
- Ho, P. T., Hung, P. X., & Nguyen, P. T. M. (2024). Estimating profit, input demand and output supply elasticities in rice production: Evidence from Vietnam. *African Journal of Agricultural and Resource Economics*, 19(4), 369–385. <https://doi.org/10.53936/afjare> 2024.19(4).22
- Hussain, A., & Sinha, R. (2019). The political economy of rice trade between Bangladesh, India and Nepal. *The Asia Foundation*
- Iqbal, M. Z., & Babcock, B. A. (2018). Global growing-area elasticities of key agricultural crops estimated using dynamic heterogeneous panel methods. *Agricultural Economics*, 49(6), 681–690. <https://doi.org/10.1111/agec.12452>
- IRRI (2022). “Nepal Release seven new and improved varieties to increase domestic rice production”. <https://www.irri.org/news-and-events/news/nepal-releases-seven-new-andimproved-rice-varieties-increase-domestic-rice>
- Joshi, J., & Chaulagai, T. R. (2024). Implication of minimum support price as a substantive ‘support’ to paddy farmers in Kanchanpur District, Nepal. **Food & Agribusiness Management (FABM)*, 5*(2), 73–78.
- Joshi, K. D., Upadhyay, S., Chaudhary, P., Shrestha, S., Bhattarai, K., & Tripathi, B. P. (2020). The Rice Processing Industry in Nepal: Constraints and Opportunities. *Agricultural Sciences*, 11(11), 1060–1080. <https://doi.org/10.4236/as.2020.1111069>
- Joshi, P., Gautam, P., & Wagle, P. (2021). Growth and instability analysis of major crops in Nepal. *Journal of Agriculture and Food Research*, 6, 100236. <https://doi.org/10.1016/j.jafr.2021.100236>
- Khan, S. U., Faisal, M. A., Haq, Z. U., Fahad, S., Ali, G., Khan, A. A., & Khan, I. (2019). Supply response of rice using time series data: Lessons from Khyber Pakhtunkhwa Province, Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, 18(4), 458–461.
- Khanal, U. (2018). Why are farmers keeping cultivatable lands fallow even though there is food scarcity in Nepal? **Food Security*, 10*(3), 603–614. <https://doi.org/10.1007/s12571-018-0805-4>

- Kumar A, Thapa G, Mishra AK, Joshi P.K (2020). Assessing food and nutrition security in Nepal: evidence from diet diversity and food expenditure patterns. *Food Secure* 12:327–354. <https://doi.org/10.1007/s12571-019-01004-y>
- Lamichhane, N., Dharmi, U., Dhakal, D., & Thapa, L. B. (2024). Rice cultivation area, demographic trends, and trade dynamics for food security in Nepal (2011–2021). *Plant- Environment Interactions*, 5(6), e70020.
- Maclean, J.L., Dawe, D.C., Hardy, B., Hettel, G.P., 2002. Rice Almanac, third ed., International Rice Research Institute (IRRI), Los Banos, Philippines, pp. 1–253.
- MoALD. 2023. Statistical Information on Nepalese Agriculture 2079-80. Ministry of Agriculture and Livestock Development, Government of Nepal.
- Mundlak, Y. (2001). Production and supply. In B. L. Gardner & G. C. Rausser (Eds.), *Handbook of agricultural economics* (Vol. 1, pp. 3-85). Amsterdam: Elsevier.
- National Statistics Office. (2023). National sample census of agriculture 2021/22. [https://agricensusnepal.gov.np/upload_file/files/post/1694250757_1312300734_National%20Sample%20Census%20of%20Agriculture%202021_22%20\(National%20Report\).indd.pdf](https://agricensusnepal.gov.np/upload_file/files/post/1694250757_1312300734_National%20Sample%20Census%20of%20Agriculture%202021_22%20(National%20Report).indd.pdf)
- Nepal's shifting rice landscape: Self-sufficiency to import dependency. (2024). National Policy Forum. <https://www.nationalpolicyforum.com/posts/nepals-shifting-rice-landscape-self-sufficiency-to-import-dependency/>
- Nerlove, M. (1958). The Dynamics of Supply: Estimations of Farmers' Response to Price. *Journal of Farm Economics*, 40(4), 719-755.
- Niazi, M. A., & Farooq, U. (2019). Supply response of Basmati rice in Pakistan. *Sarhad Journal of Agriculture*, 35(4), 1197.
- NRRP (2019). National Rice Research Program Nepal. Annual Report 2076/77. Agriculture Research Council, Kathmandu.
- Pandit, R., Devkota, D., Devkota, N. R., Bhattarai, P. C., & Shrestha, H. K. (2020A). Dynamics of rice sub-sector in Nepal: Research investment, production, and supply chain. *Agricultural Science and Technology*, 12(2), 178–188. <https://doi.org/10.15547/ast.2020.02.030>
- Paudel, G. P., Kc, D. B., Rahut, D. B., Justice, S. E., & McDonald, A. J. (2019). Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. *Land Use Policy*, 85, 104–113. <https://doi.org/10.1016/j.landusepol.2019.03.030>
- Pokhrel, P., Regmi, R. K., & Mainali, R. P. (2021). Rice trade trend and policy implication in Nepal. In *Agronomy Journal of Nepal (Agron JN)* (Issue 5). <http://datatopics.worldbank.org/world-development-indicators/>
- Poudel, U., Kattel, R. R., Gurung, B., Shrestha, S., Paudel, A., & Paudel, A. (2021). Economic analysis of rice (*Oryza sativa* L.) cultivation in Gorkha district of Nepal. *Archives of Agriculture and Environmental Science*, 6(4), 489–497. <https://doi.org/10.26832/24566632.2021.060>
- Prasada, I. Y., Dhamira, A., & Nugroho, A. D. (2018). Supply response of paddy in East Java: Policy implications to increase rice production. *AGRARIS: Journal of Agribusiness and Rural Development Research*, 4(2), 129–138.
- Shrestha, B., & Pokharel, D. (2016). Increased fallow land and food threats: A policy discourse. <https://csrcnepal.org/wp-content/uploads/2019/08/INCREASED-FALLOW-LAND-AND-FOOD-THREATS.pdf>
- Timsina KP, D Gauchan, S Gairhe, SR Subedi, BB Pokhrel, S Upadhyay, KD Joshi, S Pandey and J Shrestha. 2023. Rice demand and production projections for 2050: Opportunities for achieving self-sufficiency in Nepal. *Nepal Agriculture Research Journal* 15(1): 163-180. DOI: <https://doi.org/10.3126/narj.v15i1.51926>
- Tripathi, B. P., Bhandari, H. N., & Ladha, J. K. (2019). *Acta Scientific Agriculture* (ISSN: 2581-365X) Rice Strategy for Nepal.
- Wooldridge, J. M. (2020). *Introductory econometrics: A modern approach* (7th ed.). Cengage Learning.

SCHOOL-BASED ANEMIA PREVENTION PROGRAM IN NEPAL:
GOVERNMENT INTERVENTIONS AND THE HEALTH BELIEF MODEL

Pramod Koirala* and Melodynia Marpna

Martin Luther Christian University, Shillong, India

ARTICLE INFO	ABSTRACT
Key Words: <i>Adolescent anemia, Health Belief Model, Iron Deficiency Anemia, Social Behavior Change, Nepal</i> *Correspondence: pramodkoirala2016@gmail.com	<i>Iron Deficiency Anemia (IDA) is a life-threatening public health issue among adolescent girls in Nepal, severely impacting cognitive development, educational performance, physical stamina, and overall well-being. Despite a global decline in anemia prevalence, Nepal continues to experience high rates among adolescent girls, with a prevalence of 39.4%. In this review, adolescent anemia-related literature, relevant policies, and secondary data were analyzed. The Multi-Sector Nutrition Plan, National School Health and Nutrition Strategy, and Adolescent Health and Development Strategy are the primary policies aimed at addressing adolescent anemia in Nepal. The program, highlighted under the policy, includes iron-folic acid supplementation, deworming, dietary diversification, school-based nutrition education, and social behavior change (SBC). Research evidence from various countries indicates that the application of the Health Belief Model (HBM) is effective in reducing adolescent anemia. The use and promotion of this model may be appropriate for preventing adolescent anemia in Nepal. Research is needed to explore the possibility of HBM-based interventions for preventing adolescent anemia, which may be helpful in achieving the national target of reducing anemia in Nepal.</i>
1. INTRODUCTION Iron is a vital micronutrient critical for life processes such as oxygen transport, immunity, and cognitive development. Its deficiency, a foremost cause of anemia, unduly affects women and adolescent girls, increasing risks of maternal mortality, birth outcomes, and increase susceptibility to infections. (Haider et al., 2013) Iron is a crucial micronutrient for immune function, oxygen transport, and cellular growth (Jonker & Hensbrok, 2014). Its deficiency results in Iron Deficiency Anemia (IDA), specifically affecting cognitive development, physical stamina, and the immune system. Adolescents, particularly females, are very susceptible due to fast development spurts, menstruation, and inadequate dietary intake. IDA not only hinders educational performance and physical stamina but also negatively impacts overall well-being	(Chaparro & Suchdev, 2019; Ekasanti et al., 2020) Globally, anemia is a significant public health issue, mainly in developing nations (UNICEF, 2023). Globally, from 1990 to 2019, the prevalence of anemia reduced from 27.0% to 22.8%, yet the total number of cases increased from 1.42 billion to 1.74 billion. The maximum problem is in Western Sub-Saharan Africa, South Asia, and Central Sub-Saharan Africa, with anemia accounting for 58.6 million years lived with disability (YLDs). In Southeast Asia, more than half of adolescent girls are affected by anemia (Gardner & Kassebaum 2020; Khanal, 2023; Zaitun & Rivai 2024; Sethi et al., 2025,) In Nepal, many schoolchildren experience malnutrition and diseases that limit their potential. This malnutrition, combined with

related illnesses, leads to irregular school attendance and compromised learning abilities—unwell children are twice as likely to miss school. As a result, they struggle academically compared to their peers due to repeated infections that affect their retention, critical thinking, and attention.

Schools offer a structured and influential setting for cost-effective nutrition interventions. Programs not only enhance student health and academic outcomes, reducing dropout rates, but also benefit families, strengthen community nutrition, and improve the school's reputation. Implementing school-based nutrition programs enhances cognitive development and academic performance, supports lifelong health, reduces disease risk and childbirth-related complications, promotes intergenerational health literacy, prevents major diet-related conditions, boosts productivity, lowers healthcare costs, and contributes to national economic growth. (UNESCO, 2004, WHO 1997)

This review explores the application of the Health Belief Model (HBM) as a framework for guiding Social and Behavior Change (SBC) interventions aimed at preventing iron deficiency anemia (IDA) among adolescent girls in Nepal. The study examines the existing challenges in addressing adolescent IDA despite the presence of national policies and programs. By focusing on school-based settings, this review assesses how the HBM can enhance the design and delivery of SBC interventions to influence dietary practices, IFA compliance, and anemia awareness. The findings aim to contribute to the evidence base for integrating behavioral theories into national strategies for adolescent health promotion in low-resource contexts.

This study employed a multi-phase desk review integrating quantitative, qualitative, and policy analyses to assess adolescent anemia and its determinants in Nepal. Secondary data were analyzed to evaluate prevalence trends, sociodemographic correlates, and regional disparities among adolescent girls (10–19 years). National

policies, school health and nutrition programs, school curricula, and social and behavior change (SBC) strategies were thematically reviewed. A systematic search of peer-reviewed and gray literature identified school-based interventions leveraging the Health Belief Model (HBM) in low-resource settings, prioritizing studies with adolescent-focused outcomes. Publicly available data ensured ethical compliance, and findings were cross-verified with nutrition experts. A mixed-methods approach was followed, aiming to inform context-specific, theory-driven strategies for anemia reduction among adolescents.

2. IDA AMONG ADOLESCENTS' GIRLS IN NEPAL

Nepal has a high prevalence of anemia among adolescents, with rates ranging from 38% to 43%. (MoHP, 2001, 2006, 2011, 2016, 2022). According to the Nepal Demographic and Health Survey (NDHS) 2022, 39.4% of adolescent girls suffer from anemia.

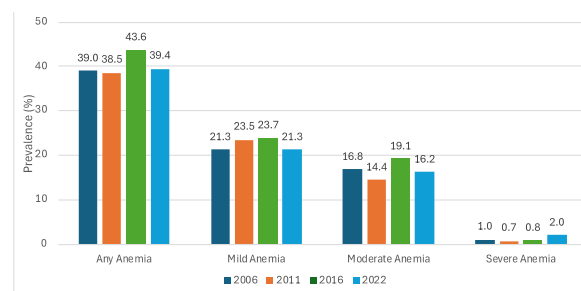


Figure 1. Trend in IDA among adolescent girls (15-19 years)

Overall, the prevalence of "any anemia" remained at 38.5% in 2011, peaking at 43.6% in 2016, followed by a modest decline to 39.4% in 2022. The prevalence of total anemia has not substantially improved over the past 16 years. Based on the existing trend, the linear forecast projects that the prevalence of any anemia will rise to 39.5% by 2030. Therefore, there is growing concern over the rise in anemia, emphasizing the need for intensified, targeted nutrition and public health interventions.

3. CAUSES OF HIGH PREVALENCE OF ANEMIA

Multiple interrelated factors influence adolescent anemia. Higher anemia prevalence is observed among marginalized ethnic groups, urban residents, those living in the terai region, married adolescents, and pregnant adolescents. Anemia among female adolescents was paradoxically higher in wealthier quintiles, richest (41.5%) and lowest among the poorest (25.5%). Urban adolescents have higher anemia rates than rural, a reversal of earlier years. Adolescents with no education are at the highest risk (61.4%). Disadvantaged caste/ethnicity groups (Dalits, Muslims) have higher anemia prevalence than Brahmin/Chhetri. (NDHS, 2022). Nutritional deficiencies, reflected in low dietary diversity, limited iron-rich food intake, poor BMI status, and low IFA supplementation, low education levels, inadequate sanitation, and lower socioeconomic status are also strongly associated with higher anemia rates. (Ghimire et al., 2024; Khanal, 2023).

4. GOVERNMENT POLICY AND PROGRAMS ON ADOLESCENT ANEMIA

The Government of Nepal has implemented several policies targeting adolescent anemia, emphasizing iron-folic acid supplementation, deworming, nutrition education, and dietary diversification. Key strategies, including the National School Health and Nutrition Strategy (2006), Adolescent Health and Development Strategy (2018), and the RMNCAH Strategy (2018–2030), focus on school- and community-based interventions. With the introduction of periodic plan by the Government of Nepal, such as the Sixteenth Development Plan (2023–2030) and the Multi-Sector Nutrition Plan (2022–2030), further strengthening multisectoral collaboration in the planning and implementation of nutrition programs is

anticipated. Central, provincial, and local governments collaborate to implement the nutrition program. In the area of policy formulation, coordination, strategic planning, and funding, the federal government has a significant role, whereas, provincial governments manage inter-district coordination and capacity building for the field staff. Local governments are for program implementation, community mobilization, and local-level monitoring.

In Nepal, anemia prevention among adolescent girls is guided by three World Health Organization (WHO) recommended interventions: weekly iron and folic acid (IFA) supplementation, regular deworming, and counselling focused on nutrition and healthy dietary practices.

Table 1. Government policy and major provisions of the reduction of adolescents’ anemia

Policies	Major provisions
National School Health and Nutrition Strategy, 2006	Focuses on improving the health and nutrition status of school children and adolescents. Includes programs such as deworming, iron and folic acid supplementation, and nutrition awareness.
National Anemia Control Strategy 2006	Enhance iron status through supplementation and dietary diversification, with a focus on vulnerable groups, including pregnant women, children, and adolescents. Underscore iron-folic Acid (IFA) supplementation and encourage the consumption of iron-rich foods. Support anemia prevention through public awareness, health worker training, and collaboration with stakeholders, and integrate anemia control into existing health and nutrition programs in schools and maternal health services.
Adolescent Health and Development Strategy, 2018	Highlight the need for improving the health and well-being of adolescents, including addressing anemia. Recommends interventions such as nutrition education, supplementation, and adolescent health services.
National Health Policy, 2019	Provides a framework for improving health outcomes, including reducing the prevalence of anemia. Emphasizes preventive and promotive health services for adolescents.
National Strategy for Reproductive, Maternal, Newborn, Child, and Adolescent Health (RMNCAH) (2018–2030)	Underline the importance of health consequences for adolescents, including addressing anemia. Recommends interventions such as iron and folic acid supplementation and nutrition counseling
Sixteenth Development Plan (2023-2030)	Strengthen adolescent nutrition through IFA supplementation, anemia screening, and health education, reinforced by the School Health and Nutrition Strategy. Endorse behavior change and iron-rich diets through community awareness, kitchen gardening, and food fortification
Multi-Sector Nutrition Plan (2022-2030)	All-inclusive plan to address malnutrition, including anemia, through multisectoral collaboration. Includes detailed adolescent interventions, such as school-based nutrition programs and awareness programs.

4.1 International commitments and target

In Nepal, Government has implemented policies to improve adolescent nutrition, leading to gradual progress in nutrition indicators. However, translating policies into effective action remains a challenge, especially for vulnerable groups, making it difficult to meet SDGs, N4G, and WHA goals for reducing anemia.

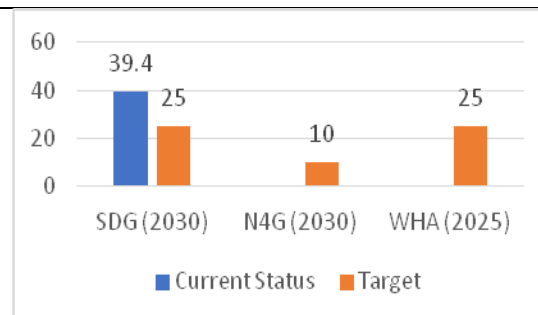


Figure 2. Target on adolescents’ anemia

4.2 Major nutrition program and minimum defined nutrition package

Nepal implements adolescent nutrition programs through multisectoral collaboration, led by the National Planning Commission. The Ministry of Health and Population focuses on IFA supplementation, deworming, and other micronutrients supplementation. Other ministries contribute through school meals, food fortification, WASH initiatives, and livelihood programs, coordinated by the National Planning Commission and the

Ministry of Federal Affairs. Nepal's minimum defined package for adolescent nutrition includes provision of health services, iron-rich school meals, IFA supplementation, WASH improvements, school-based nutrition activities, and integration of nutrition into local governance. The program is coordinated by provincial ministries at the provincial level in collaboration with the local governments of the respective areas.

Table 2. Major nutrition program and minimum defined nutrition package

Government agencies	Program	Minimum Defined Package
National Planning Commission	Coordination with Ministries/ External Development Partners	Multi-sector coordination
Ministry of Federal Affairs and General Administration	Integrated program approval, coordination Nutrition-friendly <i>palikas</i> declaration Assign budget code	Establish nutrition-friendly local governance Integration of nutrition into local policies, planning, and implementation
Ministry of Agriculture and Livestock Development	Production enhancement Food fortification Dietary diversity promotion	Establish fruit nurseries and orchards in the residential school
Ministry of Science, Technology and Education	School meals School health program	Ensure Iron-rich food in the school meal IFA and deworming tablet supplementation Provide nutrition education in schools Establish a nutrition corner in schools
Ministry of Water Supply	Safe drinking water Toilet facility Education awareness on WASH	Provide safe drinking water, toilets, and handwashing facilities.
Ministry of Women, Children	Sexual and Reproductive Health Livelihood	Nutrition promotion in gender training
Ministry of Health and Population	Adolescent health Prevention and control of Iron, Iodine and Vitamin A, Adolescent IFA supplementation Deworming Nutrition Specific Intervention training	Promote adolescents' friendly health and nutrition program

(Source: CNSI 2022)

4.3 External development partners in adolescents' nutrition program

Several development partners support adolescent nutrition program in Nepal. Key agencies include UNICEF and WHO, with program like the Partnership for Improved Nutrition. Other partners, such as WFP, FAO,

and the World Bank, address food security, agriculture, food fortification and nutrition. Organizations like UNFPA and Save the Children also promote nutrition-sensitive program, family planning and community-based health initiatives.

Table 3. External development partners in adolescents' nutrition program

Agencies	Core Area	Programme
United Nation Children's Fund (UNICEF)	Maternal, Adolescent, Infant and Young Child Nutrition (MAIYCN)	Partnership for Improved Nutrition in Nepal, Adolescent Nutrition, Emergency Nutrition
World Food Programme (WFP)	Food Security and Nutrition (Maternal and Child and Adolescents Nutrition)	Maternal and Child Nutrition - Mid-Day Meal Programme- NEKSAP
Food and Agriculture Organization (FAO)	Food Security and Agriculture Nutrition	Agriculture and Food Security Programme (Zero Hunger)
World Health Organization (WHO)	Maternal, Infant and Young Child Nutrition (MIYCN) with special focus to overweight/ obesity prevention and food safety	Non-communicable disease (NCD) prevention and control programme, Infectious disease prevention and control, WASH
United Nation Family Planning Association (UNFPA)	Reproductive Health and Nutrition	Nutrition Sensitive – Family Planning
European Union	Partnership for Improved Nutrition	Food Security and Nutrition
DFID/ UK	Nutrition during emergency	Emergency Nutrition
Norwegian Government	Adolescent Nutrition	Adolescent Nutrition component of MSNP
Government of India	Fortification	Universal Salt Iodization
World Bank	Maternal, Infant and Young Child Nutrition (MIYCN)	Golden 1000 days campaign
Asian Development Bank	Conditional Grant for children (Child Cash Grant linked with Infant and Young Child Feeding Promotion in Karnali Districts)	Child Cash Grant linked with Infant and Young Child Feeding Promotion in Karnali Districts.
Save The Children	Maternal and Child Nutrition linking with livelihood activities.	School Health and Nutrition, IYCF and Community Base Growth Monitoring

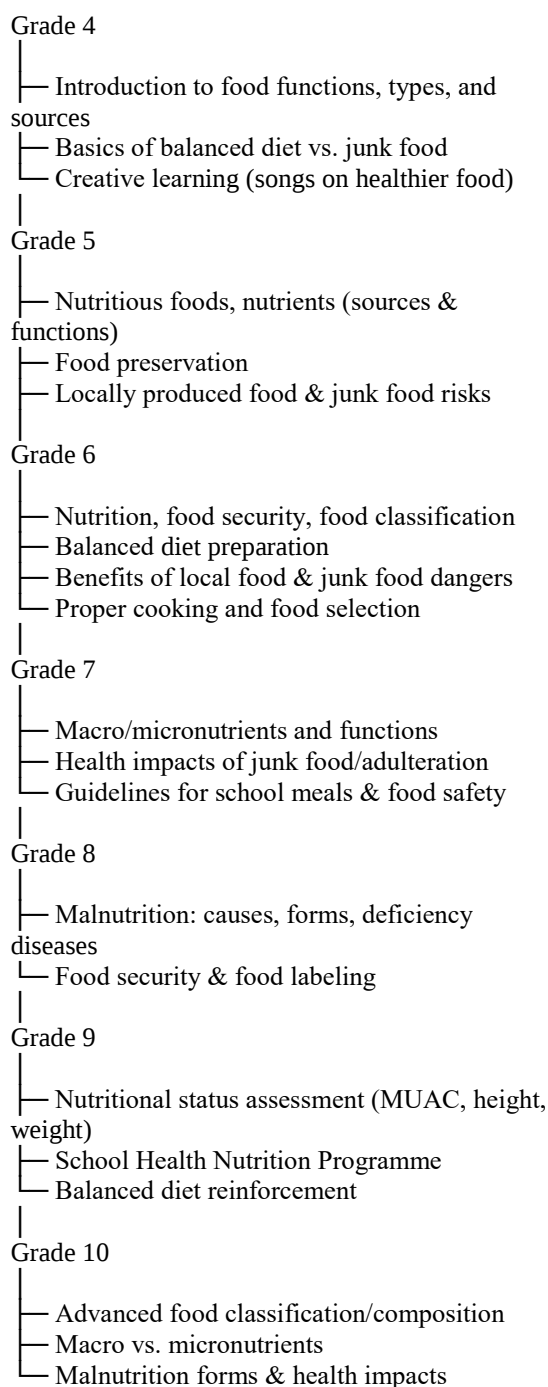
4.4 School health and nutrition: policy and program

Ministry of Health and Population (MoHP) and Ministry of Education (MOE) jointly formulated the policy ie School Health and Nutrition (SHN) policy 2006, and a Plan of Action 2008. As a SHN program, launched in 2009, to develop healthier physical and educational wellbeing in the schoolchildren. Major activities under the program include providing biannual deworming tablets, annual physical check-ups, a first-aid kit, and a school meal program.

4.4.1 Nutrition chapters in the school curriculum

Nutrition education in the school curriculum helps raise awareness among schoolchildren about the types of nutritional problems and ways to prevent them. School-based education built into the school curriculum helps to improve dietary behavior of schoolchildren as well as family as a whole.

One of the courses assigned to Government schools as a subject is Health, Physical, and Creative Arts, from grades from four to ten. The subject includes nutrition as chapters. Nutrition themes are introduced from grade four. The overall nutrition course emphasizes the importance of food-based nutrition, balanced diets, deficiency diseases, locally grown foods, and the impact of junk food. Anemia-related information is introduced from grade eight. Nutrition-related songs are part of the curriculum. A summary of nutrition content within the school curriculum framework is presented below.



(Source; CDC, 2021)

Figure 3. Nutrition content within the school curriculum

4.4.2 School meal program

Studies on the effectiveness of school meal programs show significant short—and long-term benefits for children. For every US\$1 invested, there is a return of \$5.20 to \$9 over a beneficiary's lifetime (MOEST, 2018; WFP, 2023).

In Nepal, the school meal program began in 1974 with WFP support, covering 100 schools across eight districts. It has since improved student attendance, reduced dropout rates, increased girls' enrollment, and enhanced health. In 1996, the program was scaled up with the Food for Education initiative, becoming a nationwide effort by 2019. Currently, it serves approximately 3.15 million children from Early Childhood Education to grade seven, with plans to extend to grade eight. (MOEST 2018; WFP 2019)

Local governments manage the program together with the School Management Committees (SMCs), which oversee meal preparation and distribution. A technical guideline has been developed by Ministry of Education Science and Technology, which provides the quantity and quality of food that should be provided for schoolchildren. The 2022 National Health and Nutrition Midday Meal Guidelines ensure school meals should meet 30% of children's daily nutritional needs and restrict ultra-processed food sales near schools (UNICEF, 2023). School meal program doesn't have legal back up, therefore, there is variation in the amount and quality of distributed food. Key challenges of the program include budgetary constraints, limited access to local food products, increased teacher workloads, and insufficient feeding facilities and kitchen supplies, all of which undermine its overall quality (World Bank, 2020; WFP, 2023)

5. IFA SUPPLEMENTATION PROGRAM

5.1 Background and early efforts (Pre-2003)

In the 1990s, maternal anemia was a critical public health issue in Nepal, affecting approximately 75% of pregnant women. Although government policy at the time recommended universal iron and folic acid (IFA) supplementation—60 mg of iron and 400 µg of folic acid daily from the second trimester to 45 days postpartum—coverage remained alarmingly low (Paudyal et al., 2022). Distribution relied heavily on health workers through health posts and outreach clinics. By 1997, only 10% of pregnant women had accessed any IFA, with merely

2% achieving the recommended 90-day intake. However, a 1999 operational research study revealed that integrating Female Community Health Volunteers (FCHVs) into the distribution system dramatically improved coverage, increasing IFA uptake from 8% to 76% in intervention districts. (Paudyal et al., 2022)

5.2 Iron intensification Programme (IIP) – 2003

To address persistently low iron and folic acid (IFA) coverage among pregnant women, the Government of Nepal launched the Iron Intensification Programme (IIP) in 2003. The program adopted a community-based approach, emphasizing the distribution of IFA through trained Female Community Health Volunteers (FCHVs). Key components included integration with antenatal care (ANC) promotion and anthelmintic treatment, monthly IFA distribution during mothers' group meetings, and targeted counseling by FCHVs on the benefits, potential side effects, and importance of adherence. Initially piloted in five districts, the IIP was progressively scaled up to all 75 districts by 2014.

5.3 Iron supplementation program for adolescents – 2016

The program targets adolescent girls aged 10–19, providing weekly supplementation IFA for three-month cycles followed by three months of rest (Khanal, 2024). In schools, nurse distribute supplements, while Female

After piloting adolescent IFA supplementation in eight districts in 2016, the program continued in the same districts in 2017. In 2018, piloting expanded to twenty-four districts. By 2021, adolescent IFA supplementation was scaled up nationwide.

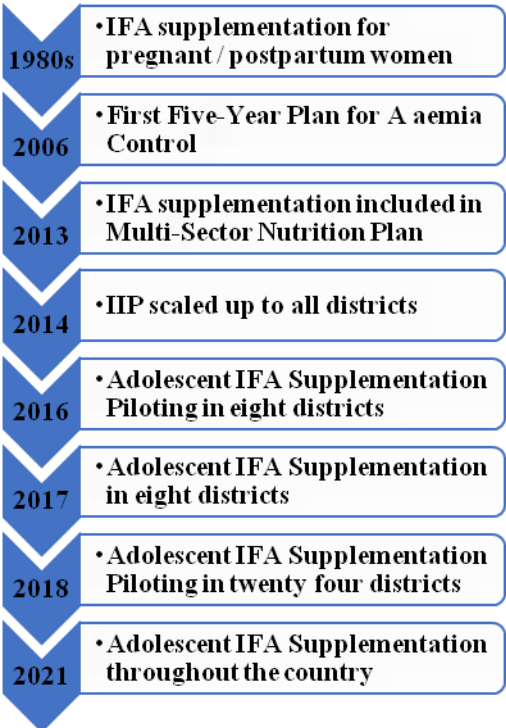


Figure 4. Policy milestones and scale-up timeline

Community Health Volunteers manage it in the community to out-of-school adolescents. In schools without nurses, the program is managed by the school teachers. Monitoring is conducted through the HMIS indicator, tracking IFA supplementation for 13 weeks.

Table 4. IFA supplementation program

Particular	Adolescents (Schoolchildren)	Adolescents (out of school)
Target group	Adolescents (10-19 years)	Adolescents (10-19 years)
Dose	Elemental Iron 60 mg Folic Acid 400 mg	Elemental Iron 60 mg Folic Acid 400 mg
Frequency of supplementation	Once a week	Once a week
Place of supplementation	Schools (both Government and private)	Ward office, community
Supplementation timetable	First stage; Supplementation for 13 weeks; July, Aug, Sept. No supplementation for 13 weeks; Oct, Nov, Dec Second stage; Supplementation for 13 weeks; Jan, Feb, Mar No supplementation for 13 weeks; Apr, May, June	(Supplementation protocol same as school children) Explanation; Three months supplementation then rest for three months again three months supplementation and then rest again three months
Responsible person	Nurse (school teacher where nurses are not available)	FCHV
Supplementation day	Sunday	Sunday
Monitoring indicator (HMIS Indicator)	Percentage of adolescent girls who received IFA supplementation for 13 weeks	Percentage of adolescent girls who received IFA supplementation for 13 weeks

6. GOVERNMENT POLICY AND PROGRAMS ON SOCIAL BEHAVIOR CHANGE

The Nepal Health Education, Information and Communication Centre (NHEICC) promotes public health through education and behavior change. It runs national campaigns on nutrition, maternal and child health, and adolescent health, indirectly addressing anemia prevention and management. (NHEICC, 2025).

NHEICC is mainly responsible to create awareness in community level and is not responsible for IFA supplementation. Ministry of Health nutrition program tackles adolescent anemia through school-based education, IFA supplementation, dietary awareness, and community engagement, aligning with Nepal's national strategy to reduce anemia especially among girls. The SBC program is integrated into adolescent nutrition policies through multi-sector collaboration, using schools, communities, media, and peer education to promote healthy

eating and prevent anemia, focusing on equity, training, and behavior change monitoring. (Government of Nepal, 2012).

Social and behavior change (SBC) policies for adolescents in Nepal predominantly target sexual and reproductive health, with anemia reduction included as a component. The Government of Nepal does not maintain a standalone SBC policy for nutrition, relying instead on its overarching nutrition intervention programs. Nevertheless, NHEICC has developed SBC materials on adolescent anemia, such as posters, booklets, and audio-visual resources. Current social and behavior change interventions are conducted through localized campaigns with minimal centralized outreach: daily IFA supplementation and deworming depend on community-level implementation, lacking a unified national awareness strategy and formalized anemia counselling.

6.1 GALIDRAA approach

The Government of Nepal utilizes the GALIDRAA approach, which is a structured model used for Social and Behavior Change Communication (SBCC) in public health and nutrition. It stands for Greet, Ask, Listen, Identify, Discuss, Recommend, Act, and Agree. Though GALIDRAA is not a behavior change theory, it is a counseling and communication tool that guides facilitators

through the stages of behavior change in a structured, respectful, and effective manner (Cunningham, 2019). It is a communication process that aligns with social and behavior change stages, often used in behavior change into interactive, person-centered steps. (FANTA, 2016: Government of Nepal 2014 ; CNSI 2022)

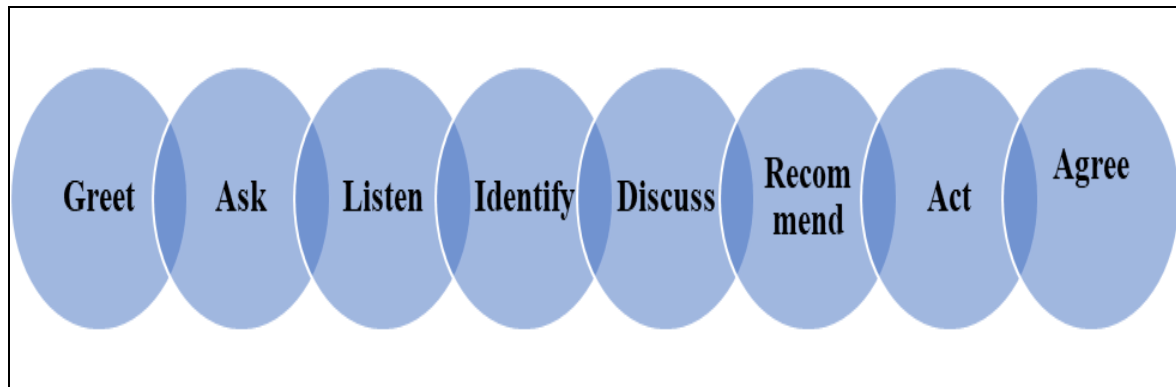


Figure 5. GALIDRAA approach

7. INTERNATIONAL EVIDENCE ON HBM-GUIDED SBC FOR SCHOOL-BASED ANEMIA CONTROL

The US Public Health Service developed the Health Belief Model (HBM) in the 1950s, and health educators and professionals have widely used it as a framework for understanding health behavior (Champion & skinner, 2008; Murphy, 2005). It helps individuals assess the benefits of changing their behavior to reduce disease risk and prompts them to take action (Green & Gryboski, 2020).

Several studies have demonstrated the effectiveness of HBM-based interventions in improving anemia prevention behaviors among adolescents. In Indonesia, studies among female students showed that iron tablet consumption correlated with HBM components like perceived benefits, barriers, cues to action, and self-efficacy (Ferina et al., 2025), while HBM-based counseling significantly improved attitudes toward anemia prevention (Aidah & Palupi, 2023) and animated video education enhanced knowledge and behaviors (Aisch &

Marsawati, 2022). Similarly, in Iran, HBM-based education improved perceived susceptibility, benefits, self-efficacy, and preventive behaviors among high school girls (Mirzaei et al., 2018) and increased knowledge and performance in both students (Ghaderi et al., 2017) and mothers regarding IDA prevention (Mohammadzadeh, 2021). In Iraq, perceived susceptibility, age, and cues to action were predictors of self-efficacy for anemia prevention among female secondary students, highlighting the need for tailored educational programs (Faraj, 2024). Complementary findings from Ethiopia showed that integrating HBM with TPB among pregnant women improved hemoglobin levels (Beressa et al., 2025). Broader applications of HBM were also noted in Indonesia, combining HBM strategies with education on food preparation improved adolescents' iron intake (Hidayanti, 2022), while in Iran, HBM-based interventions enhanced dietary calcium intake (Naghashpour et al., 2014), underscoring the model's versatility across health behaviors and populations.

Multiple studies across Indonesia, Iraq, Iran, and the US highlight the significant role of the Health Belief Model (HBM) in preventing iron deficiency anemia (IDA),

particularly among female adolescents. Research consistently shows that HBM components—especially perceived benefits, barriers, cues to action, and self-efficacy—are strongly linked to improved iron tablet consumption, preventive behaviors, and dietary practices, while perceived severity and vulnerability show mixed influence. Interventions such as HBM-based counseling, animated videos, and education on healthy food preparation have effectively enhanced knowledge, attitudes, and practices related to anemia prevention.

8. EXISTING INTERVENTION AND RESEARCH GAP

The Government of Nepal has demonstrated well-intentioned commitment to addressing adolescent iron deficiency anemia (IDA) through various multisectoral strategies and programs. Strengths include the development and national scaling of key policies such as the National School Health and Nutrition Strategy, the Adolescent Health and Development Strategy, and the Multi-Sector Nutrition Plan (2022–2030), all of which emphasize dietary diversification, iron-folic acid (IFA) supplementation, and school-based nutrition education. These programs are supported by inter-ministerial collaboration involving health, education, agriculture, and water and sanitation sectors, along with contributions from external development partners like UNICEF, WHO, and WFP. The integration of nutrition education into the school curriculum from grade four onwards and the nationwide school meal program further reflect the government's efforts to promote nutrition-sensitive educational environments. Notably, the use of nurses and Female Community Health Volunteers (FCHVs) for IFA distribution demonstrates a strategic approach to reach both in-school and out-of-school adolescents. Regardless of the steps undertaken, critical weaknesses and gaps remain in designing and implementing government interventions (Chitekwe & Aguayo, 2022). Despite numerous policies and programs, anemia rates remain unacceptably high, underscoring the need for more sustainable, behavior-focused interventions.

9. CONCLUSION

Adolescent anemia reduction is critical, as it enhances learning potential and academic performance and lays the foundation for healthier adulthood while also reducing vulnerability to infections and childbirth-related risks. Improved iron status benefits individual and family health and contributes to the prevention of major health issues ultimately increasing productivity, lowering healthcare costs, and generating long-term economic gains.

Existing international evidence supports HBM's effectiveness in similar contexts, but its application in Nepal remains underexplored and underutilized. Generating local evidence on the effectiveness of HBM-based, school-centered interventions can inform more targeted, scalable, and sustainable strategies that empower adolescents to adopt iron-rich diets, adhere to supplementation, and influence their peers and communities, ultimately supporting national and global anemia reduction targets.

ACKNOWLEDGMENTS

The authors extend their sincere gratitude to Mr. Lila Bikram Thapa (Chief, Nutrition Section, Ministry of Health and Population, Nepal), Shiv Ranjan Baral (Under Secretary, National Planning Commission, Nepal) and Mr. Bishnu Hari Devkota (Under Secretary, Ministry of Agriculture and Livestock Development, Nepal), Mr. Resham Kandel (Under Secretary, Ministry of Federal Affairs and General Administration) and Mr. Govinda Prasad Aryal, (Under Secretary, Ministry of Education Science and Technology) for their critical insights into national policy frameworks. We acknowledge the Health and Education Section Staff of Godavari Urban Municipality, Lalitpur, for their on-ground technical assistance in program implementation. Their contributions were vital in shaping the interdisciplinary focus of this review.

REFERENCES

- Aidah, H., Bachri, S., & Palupi, J. (2023). Changes in attitudes toward anemia prevention through counseling based on health belief model theory in early adolescent children at junior high school Nurul Islam Jember. *D Nursing and Health Journal*, 4(2), 89–98. <https://doi.org/10.53555/DNHJ.v4i2.710>
- Aisch, S., Ismail, S., & Margawati, A. (2022). Animated educational video using health belief model on the knowledge of anemia prevention among female adolescents: An intervention study. *Malaysian Family Physician*, 17(3), 97–104. <https://doi.org/10.51866/oa.136>
- Beressa, G., Whiting, S. J., & Belachew, T. (2025). Effect of nutrition education on hemoglobin level of pregnant women in Southeast Ethiopia: A cluster randomized controlled trial. *BMC Public Health*, 25, 507. <https://doi.org/10.1186/s12889-025-21699-3>
- Champion, V. L., & Skinner, C. S. (2008). The health belief model. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (4th ed., pp. 45–65). Jossey-Bass.
- Chaparro, C. M., & Suchdev, P. S. (2019). Anemia epidemiology, pathophysiology, and etiology in low-and middle-income countries. *Annals of the new York Academy of Sciences*, 1450(1), 15–31.
- Child Nutrition and School Initiative (CNSI), Nepal. (2022.). CNSI manual, Nepal. Ministry of Health and Population, Nepal.
- Chitekwe, S., Torlesse, H., & Aguayo, V. M. (2022). Nutrition in Nepal: Three decades of commitment to children and women. *Maternal & Child Nutrition*, 18, e13229.
- Cunningham K, Suresh S, Kjeldsberg C, Sapkota F, Shakya N, Manandhar S. From didactic to personalized health and nutrition counselling: A mixed-methods review of the GALIDRAA approach in Nepal. *Matern Child Nutr*. 2019 Apr;15(2):e12681. doi: 10.1111/mcn.12681. Epub 2018 Sep 28. PMID: 30136371; PMCID: PMC7198967.
- Curriculum Development Centre (CDC). (2021). Health, physical, and creative arts curriculum Ministry of Education, Science, and Technology, Government of Nepal. <https://moecdc.gov.np/en/curriculum>
- Ekasanti, I., Adi, A. C., Yono, M., Nirmala, G. F., & Isfandiari, M. A. (2020). Determinants of anemia among early adolescent girls in Kendari City. *Amerta Nutr*, 4(4), 271.
- Faraj, R. K. (2024). Using the health belief model to understand anemia preventive behavior among secondary school female students. *African Journal of Biomedical Research*, 27(4s), 1351–1359. <https://doi.org/10.53555/AJBR.v27i4S.3398>
- Ferina, A. R., Setyarini, D. I., & Yuliani, I. (2025). The correlation between health belief model and consumption of iron tablets in adolescence girl. *Jurnal Ners*, 9(1), 862–872. <https://journal.universitaspahlawan.ac.id/index.php/ners>
- Food and Nutrition Technical Assistance III Project. (2016). Nutrition assessment, counseling, and support (NACS): A user's guide—Module 3: Nutrition education and counseling (Version 2). FHI 360/FANTA.
- Gardner, W., & Kassebaum, N. (2020). The global prevalence of anemia by severity and causes: A systematic review and spatiotemporal Gaussian process regression. *The Lancet Global Health*, 8(4), e627–e639. [https://doi.org/10.1016/S2214-109X\(20\)30060-6](https://doi.org/10.1016/S2214-109X(20)30060-6)
- Ghaderi, N., Ahmadpour, M., Saniee, N., Karimi, F., Ghaderi, C., & Mirzaei, H. (2017). Effect of education based on the Health Belief Model (HBM) on anemia preventive behaviors among Iranian girl students. *International Journal of Pediatrics*, 5(6), 5043–5052. <https://doi.org/10.22038/ijp.2017.22051.1844>
- Ghimire, M., Bhandari, S., & Rajbanshi, M. (2024). Prevalence of anemia and its associated factors among school-going adolescent girls in schools of Dhankuta municipality, Nepal. *PLOS Global Public Health*, 4(9), e0003684.
- Government of Nepal, Ministry of Health & Population. (2012). National communication strategy for maternal, newborn and child health (2012–2016). Department of Health Services. <https://nheicc.gov.np>
- Government of Nepal. (2014). Joint advocacy and communication strategy to support the multi-sector nutrition plan (MSNP) 2013–2017. National Planning Commission, Government of Nepal. Unpublished internal document <https://nnfsp.gov.np/>
- Government of Nepal. (2019). National health policy 2019. Ministry of Health and Population.
- Green, E. C., Murphy, E. M., & Gryboski, K. (2020). The health belief model. In *The Wiley encyclopedia of health psychology* (pp. 211–214). Wiley. <https://doi.org/10.1002/9781119057840.ch68>
- Haider B A, Olofin I, Wang M, Spiegelman D, Ezzati M, Fawzi W et al (2013) Anaemia, prenatal iron use, and risk of adverse pregnancy outcomes: systematic review and meta-analysis *BMJ* 2013; 346 :f3443 doi:10.1136/bmj.f3443

- Hidayanti, A. (2022). Implementing Health Belief Model strategies for improving adolescent dietary iron intake: A case study from Indonesia. *Asian Journal of Public Health*, 14(3), 112-127.
- Jonker, F. A. M., & van Hensbroek, M. B. (2014). Pathogenesis and pathophysiology of anemia in *Plasmodium falciparum* malaria. *The Journal of Infection*, 69(Supplement 1), S61–S67.
- Khanal, A., Paudel, R., Wagle, C. N., Subedee, S., & Pradhan, P. M. S. (2024). Prevalence of anemia and its associated factors among adolescent girls on Weekly Iron Folic Acid supplementation (WIFAS) implemented and non-implemented schools at Tokha municipality, Kathmandu. *PLOS Global Public Health*, 4(1), e0002515.
- Khanal, P. (2023). Malnutrition and anemia prevalence in adolescent women of Nepal. *Patan Prospective Journal*, 3(2), 97–104. <https://doi.org/10.3126/ppj.v3i2.66164>
- Ministry of Education, Science and Technology, & World Food Programme. (2018). School meals programme: Cost benefit analysis report. <https://www.wfp.org/publications/nepal-school-meals-programme-cost-benefit-analysis-report-2018>
- Murphy, K. (2005). Behavioral science and public health: Applying the Health Belief Model. *Journal of Public Health Research*, 9(2), 109-125.
- Mirzaei, H., Shojaeizadeh, D., Tol, A., Ghasemi Ghale Ghasemi, S., & Shirzad, M. (2018). Application of health belief model (HBM) to promote preventive behaviors against iron-deficiency anemia among female students of high school Fereydan city: A quasi-experimental study. *Iranian Journal of Health Education and Health Promotion*, 5(4), 260–269. <https://doi.org/10.30699/ijhehp.5.4.260>
- Mohammadzadeh Iarijani, M., Khorsandi, M., Shamsi, M., & Ranjbaran, M. (2021). The effect of education based health belief model on preventive behaviors of mother about iron deficiency anemia in children: An educational controlled trial. *Research Square*. <https://doi.org/10.21203/rs.3.rs-750417/v1>
- Ministry of Education, Nepal. (2006). National school health and nutrition strategy. Ministry of Education.
- Ministry of Health and Population, Nepal. (2006). National anemia control strategy. Ministry of Health and Population.
- Ministry of Health and Population, Nepal. (2018). Adolescent health and development strategy. Ministry of Health and Population.
- Ministry of Health and Population, Nepal. (2018). National strategy for reproductive, maternal, newborn, child, and adolescent health (RMNCAH) 2018–2030. Ministry of Health and Population.
- Ministry of Health and Population (MOHP), New ERA/Nepal, Macro International. Nepal Demographic and Health Survey 2006. Kathmandu, Nepal: MOHP/Nepal, New ERA/Nepal, and Macro International; 2007.
- Ministry of Health and Population (MOHP), New ERA/Nepal, ICF International. Nepal Demographic and Health Survey 2011. Kathmandu, Nepal: MOHP/Nepal, New ERA, and ICF International; 2012.
- Ministry of Health (MOH), New ERA/Nepal, ICF International. Nepal Demographic and Health Survey 2016. Kathmandu, Nepal: MOH/Nepal, New ERA, and ICF; 2017.
- Ministry of Health and Population (MOHP), New ERA/Nepal, ICF International. Nepal Demographic and Health Survey 2022. Kathmandu, Nepal: MOHP/Nepal, New ERA/Nepal, and Macro International; 2023
- Ministry of Health and Population, Nepal. (2022). Multi-sector nutrition plan (2022–2030). Ministry of Health and Population.
- Naghashpour, M., Shakerinejad, G., Lourizadeh, M. R., Hajinajaf, S., & Jarvandi, F. (2014). Nutrition education based on health belief model improves dietary calcium intake among female students of junior high schools. *Journal of health, population, and nutrition*, 32(3), 420.
- National Planning Commission, Nepal. (2023). Sixteenth development plan (2023–2030). National Planning Commission.
- Nepal Health Education, Information and Communication Centre (NHEICC). (2025). Ministry of Health and Population, Government of Nepal. Retrieved [April 20, 2025], from <https://nheicc.gov.np/ne/>
- Paudyal, N., Parajuli, K. R., Garcia Larsen, V., Adhikari, R. K., Devkota, M. D., Rijal, S., ... & Torlesse, H. (2022). A review of the maternal iron and folic acid supplementation programme in Nepal: Achievements and challenges. *Maternal & child nutrition*, 18, e13173.
- Riazi, N., et al. (2024). Social behavior change interventions for iron-deficiency anemia: Lessons from Health Belief Model applications. *Global Journal of Nutrition & Health*, 18(1), 33-49.
- Sethi, V., Murira, Z., Yadav, K., Mishra, P., Chowdhury, I. A., & Aminee, A. (2025). Supporting policy action to reduce adolescent anaemia in South Asia. *BMJ*, 388, e080813. <https://doi.org/10.1136/bmj-2024-080813>
- United Nations Educational, Scientific and Cultural Organization (UNESCO). (2004). FRESH tools for effective school health (1st ed.). UNESCO. Retrieved from <http://www.unesco.org/education/fresh>

- UNICEF. (2023). Adolescent nutrition: Accelerating progress for a healthier future. <https://www.unicef.org/reports/adolescent-nutrition>
- UNICEF (2025.). Nourishing South Asia @2030: Tackling the triple burden of adolescent girls' malnutrition in South Asia, Conference presentation on March 4th, 2025, <https://www.unicef.org/rosa>
- World Food Programme. (2023). Why invest in school feeding? Global evidence on the multisectoral benefits of school feeding World Food Programme.
- World Food Programme. (2024). Baseline study of USDA McGovern-Dole International Food for Education and Child Nutrition Programme in Nepal FY23 cycle (2024–2028). WFP Nepal Country Office. <https://docs.wfp.org/api/documents/WFP-0000156253/download/>
- World Bank. (2020). Nepal SABER-SF country report: School feeding policies. World Bank. <https://www.worldbank.org/education/saber>
- World Health Organization (WHO). (1997). Promoting health through schools: Report of a WHO expert committee on comprehensive school health education and promotion (WHO Technical Report Series No. 870). World Health Organization.
- Zaitun, Z., & Rivai, A. F. (2024). Prevention of Anemia with Iron in Adolescent Girls. Jurnal Medisci, 1(5).

PRODUCTION ECONOMICS AND MARKETING OF POTATO (*Solanum tuberosum* L.) IN ROLPA, NEPAL

Shuvechchha Dhakal^{1,*}, Jeevan RC², Nabin Bhandari³, Naran Prasad Devkota¹, Mahesh Kumar Thapa¹ and Aasish Bhandari¹

- ¹ Agriculture and Forestry University, Rampur, Chitwan, Nepal
- ² Department of Agricultural Economics and Agribusiness Management, CNRM, Madichaur, Agriculture and Forestry University, Rampur, Chitwan, Nepal
- ³ Ministry of Agriculture and Livestock Development, Singhadurbar, Kathmandu, Nepal

ARTICLE INFO

Keywords:

BC ratio
Gross margin
Potato
Price spread
Rolpa

*Correspondence:
shuvechchhad@gmail.com
Tel: +977-9866619195

ABSTRACT

Rolpa has a high potential for potato production due to its ideal climate and terrain. A survey of 120 farmers was conducted, and the collected data were entered in Excel, and analyzed using STATA software, respectively. The study purposively selected wards 9 and 10 of Rolpa Municipality and 1, 2, and 3 of Thawang Rural Municipality, incorporating a simple random sampling technique. Agriculture was the primary occupation (73.33%), with an average cultivation area of 4.16 ropani. The average potato productivity in the study area was 15.16 mt/ha, with Cardinal and Desiree being the most preferred varieties. Semi-commercial farming and intercropping were common practices. The gross margin was NRs. 241,413.6/hectare, the price spread was NRs. 23.21/kg and the benefit-cost ratio was 1.93, confirming a profitable business. However, high seed costs, diseases, and pest infestations were key production challenges. Low pricing, inadequate transportation, and improper cold storage facilities were found as major marketing constraints. Mechanization, proper irrigation, and quality supply of inputs can significantly enhance potato profitability in Rolpa.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.), one of the staple crops of people of mid and high hills of Nepal, holds significant importance due to its role on food security, nutrition, and economic prosperity (Ghimire, 2022). It is the fourth most important crop worldwide, and in Nepal, it ranks fifth in area coverage, second in production, and first in productivity when compared to other staple crops (MoAD, 2021; FAO, 2023). Rolpa, a hilly district in Lumbini Province, has high potential for potato cultivation due to its climatic suitability and terrain. The district's average yield of 16.70 mt/ha is close to the national average of 17.2 mt/ha (AKC Rolpa, 2024). Despite this potential, the increasing demand for potatoes in the region has outpaced domestic production, mostly due to high labor costs, insect infestations, irrigation challenges, and the unavailability of high-quality off-season varieties (Aryal *et al.*,

2023). Furthermore, marketing inefficiencies—such as transportation issues, high expenses, variable prices, and the dominance of intermediaries—have undermined the profitability of potato farming (Sapkota *et al.*, 2019; Khadka *et al.*, 2023; Dahal *et al.*, 2023). However, despite favorable conditions for production and increasing market demand, farmers in Rolpa face numerous challenges, relating to production and marketing, that hinder the profitability of potato farming. Therefore, this study was conducted to analyze the production economics and marketing methods of potato farming in Rolpa, as well as to identify the factors influencing profitability, thereby providing recommendations to improve the economic sustainability of the potato sector in Rolpa.

2. MATERIALS AND METHODS

2.1 Area of study

Rolpa district is located at the latitude of 28.8° to 28.38°N and longitude of 82.10° to 83.9°E with elevations ranging from 701m to 3639m and an average annual temperature variance of 3.6 °C to 31.2 °C suitable for potato farming (AKC Rolpa, 2024). Command areas of Prime Minister Agriculture Modernization Project (PMAMP) under Thawang rural municipality (1, 2, and 3) and Rolpa municipality (9, 10) were purposively selected for the study.

2.2 Preliminary study

A preliminary study was carried out to gather information regarding the conditions and the constraints of potato production.

2.3 Sample and sampling techniques

The sampling frame of the potato-producing farmers was obtained from the PMAMP, Potato Zone, Rolpa, Nepal. Different wards of Rolpa municipality (9, 10) and Thawang rural municipality (1, 2, and 3) were purposively selected as they are potential potato cultivating area. A simple random sampling procedure was employed to determine a sample size, 120, at 95% confidence level so the error is 5%, using Yamane's formula (1967).

$$n = \frac{N}{1+N(e^2)}$$

Where N is the size of population

e is the error margin (5% error margin)

n is the sample size

2.4 Research instruments

2.4.1 Interview schedule

The semi-structured interview schedule was prepared based on the specific objectives of the study.

2.4.2 Pretesting

Pretesting was done with seven respondents of the study area, especially Rolpa municipality, but with respondents who were not part of the main data collection sample to test the validity and effectiveness and allow for necessary amendments.

2.4.3 Household survey

A household survey was carried utilizing a pre-tested interview schedule.

2.4.4 Key informant interview

Key informant interview was held with the beneficiaries, PMAMP officers, and progressive farmers to obtain the relevant information.

2.5 Data and data types

2.5.1 Primary data

Primary data was collected directly from farmers that were involved in potato production. It was collected through a semi-structured interview schedule targeted to the respondents by household survey and KII.

2.5.2 Secondary data

A detailed review of literature was carried out to acquire information on the research topic, which included various sources like newspapers, articles, PMAMP Potato Zone annual reports, journals from the National Potato Development Program, NARC, government websites, various NGOs and INGOs, relevant books, documentaries, etc.

2.6 Data analysis techniques

Initial data collected from the field was organized, processed, coded, entered into excel, tabulated, and analyzed using STATA 14.2.

2.6.1 Economic and marketing analysis

2.6.1.1 Total variable cost of production

It is the total variable cost involved in the production of a certain output or product.

2.6.1.2 Gross return

It is the total revenue obtained by selling the produced item, which is calculated as follows:

Gross Return= Quantity of marketed product
× Per-unit price of the product

2.6.1.3 Benefit-cost ratio

According to Karki *et al.* (2023), the benefit-cost ratio is the proportion of gross return by total variable cost.

$$\text{Benefit-cost Ratio} = \frac{\text{Gross return}}{\text{Total variable cost}}$$

2.6.1.4 Price spread

As used by Dahal *et al.* (2023), price spread is the difference between the amount spent by the customer and the price earned by the producer for unit of product.

Price spread = Price paid by consumer – Farm gate price

2.6.2 Problems in potato production and marketing

The identified problems were ranked using the force ranking technique as used by Karki *et al.* (2023).

$$I = \sum \frac{Si Fi}{N}$$

Where I= Index value

$\sum$ = Summation

Si= Scale value at ith intensity

Fi= Frequency of the ith intensity

N= Number of the respondents

3. RESULTS AND DISCUSSIONS

3.1 Socio-economic and demographic characteristics

As presented in Table 1, the study revealed that more than half of the households in Rolpa were headed by females, implying the importance of women in household decision-making. Majority of the respondents followed Hinduism, signaling the predominant religious distinctions in the study area. In terms of ethnicity, 92.50% of respondents were from the Janjati group. Agriculture turned out to be the principal occupation of household heads (73.33%), in addition to being the primary source of

revenue for 67.50% of families, establishing an agrarian nature of livelihoods. Regarding family structure, 80% of households were nuclear, highlighting a shift towards a smaller family. Moreover, 74.17% of farmers practiced semi-commercial farming, showing that a majority of them engaged in market-oriented agricultural operations while also practicing some level of subsistence farming. These demographic characteristics aid to explain farmers' production and marketing behaviors.

Table 1. Socio-economic characteristics (categorical variable) of potato-producing households in Rolpa, 2024

Variables	Frequency	Percentage
Gender of household head (Female)	71	59.16
Ethnicity (Janjati)	111	92.50
Religion (Hindu)	118	98.33
Major occupation of the household head (Agriculture)	88	73.33
Major income source of the family (Agriculture)	81	67.50
Family type (Nuclear)	96	80.00
Type of farming (Semi-commercial)	89	74.17

Table 2 illustrates that the average age of the household head was 46.42 years, and the average years of schooling of the households was 4.20 years, with a wide range of variations. The average family size was 5.32 members, with wide variations of 2 to 10, reflecting both nuclear and extended family structures. In terms of livestock ownership, the mean Livestock Holding Unit (LHU) was 2.70, signifying a moderate level of livestock assets among the respondents. Regarding

land ownership, households owned an average of 8.34 ropani. Specifically, 4.16 ropani of land, on average, was allocated for potato cultivation, with a range of 1 to 15 ropani, indicating the varying scale of potato farming among respondents.

Table 2. Socio-economic characteristics (continuous variable) of potato-producing households in Rolpa, 2024

Variables	Mean	Range
Age of household head	46.42±13.10	23-83
Years of schooling of household head	4.20±3.40	0-18
Family size	5.32±1.86	2-10
Livestock holding unit (LHU) ¹	2.70±1.17	0.99-4.39
Total owned land (ropani)	8.34±4.67	2-22
Land under potato cultivation (ropani)	4.16±2.98	1-15

Note: ¹LHU: 1.5 (no. of buffalo) + 1 (no. of cow/bull) + 0.6 (no. of swine/pig) + 0.4 (no. of sheep/ goat) + 0.2 (no. of poultry) (Bist *et al.*, 2024)

3.2 Economics of potato production

3.2.1 Variable cost of production

As presented in Table 3, the average total variable cost for potato production in the study area was found to be NRs.258,146.8 per hectare (NRs.12907.34 per ropani), with Rolpa averaging NRs.342,724.6/ha and Thawang NRs.215,857.8/ha. Similar findings were revealed by Bhandari, Sharma, and Parajuli(2016), who calculated the average cost of producing potatoes in the Myagdi district as NRs.243,687.60 per hectare. Furthermore, the cost of producing potato in the Achham district was also similar to our findings as NRs.256,285.293 per hectare (Sapkota *et al.*, 2019). The major cost incurred comprised organic manure cost (38.89%), tuber cost (37.57%), and labor expenses (21.38%) in the study area. Similar

findings were reported by Acharya and GC(2024), where labor cost was followed by seed tubers, and FYM. Subedi *et al.*(2019) indicated that seed expenses account for a large 42% of overall production costs. Labor was mostly employed for land preparation and planting, intercultural activities (earthing up, weeding), and harvesting of potatoes. Bajracharya and Sapkota (2017) also identified the cost of farm-yard manure (FYM), seeds, and labor as major costs incurred in potato production. Similarly, Chauhan *et al.* (2022) found that the cost of seeds, labor, and FYM account for a large portion of the cost of potato production in Nepal's western highlands.

Table 3. Comparative variable cost of production incurred across the study area, Rolpa, 2024

Particulars (NRs./ Ropani)	Overall	Rolpa	Thawang	Mean difference	t-value	p-value
Tuber	3643.62(2115.91)	5374.31(2541.94)	2778.27(1131.02)	2596.03	7.750***	<0.001
FYM	3452.67(2190.40)	4330.83(3266.72)	3013.59(1171.85)	1317.25	3.226***	<0.001
Chemical fertilizer	258.01(421.52)	774.04(363.97)	0(0.00)	774.04	19.102***	<0.001
Pesticide	350.19(715.45)	1050.56(142.07)	0(0.00)	1050.56	10.502***	<0.001
Land preparation	1097.16(939.16)	1240.49(572.88)	1025.5(1072.84)	214.99	1.184	0.239
Labor	3055.96(1204.40)	2874.79(1596.78)	3156.55(949.42)	-271.76	-1.167	0.246
Irrigation	38.60(133.43)	69.65(162.14)	23.09(114.49)	46.56	1.819*	0.071
Grading, packaging, and transportation	678.56(49.74)	1009.83(739.46)	512.93(306.68)	496.90	5.198***	<0.001
Miscellaneous cost	332.56(284.29)	411.74(250.64)	292.97(293.21)	118.77	2.191**	0.030
Total variable cost	12907.34(5631.46)	17136.23(7129.43)	10792.89(3015.89)	6343.34	6.847***	<0.001

Note: Figure in parentheses indicates standard deviation, ***, **, and * indicate 1%, 5%, and 10% level of significance respectively, and one ropani equals 1/20 hectare.

3.2.2 Productivity, gross return, BC ratio, and gross margin

From table 4, the overall average productivity was found to be 758.17 kg/ropani (15.16 mt/ha), which is nearly the same as the productivity of Lumbini province (15.91 mt/ha) (MoALD, 2023), but lower than the average productivity of Rolpa district (16.70mt/ha). Thawang rural municipality is suited at a higher altitude, so it has high productivity (15.62mt/ha) than Rolpa municipality (14.24mt/ha) as longer period of maturity is preferred for potato cultivation, notably for higher tuber yield and higher quality goods (Islam, 2020). Similar potato productivity was observed by Karki *et al.* (2023) in Mustang (15.67 mt/ha). Also, it was near to the findings of Acharya & GC (2024), i.e., 13.55mt/ ha. Farmers in Rolpa municipality earn an average of NRs. 28,452.64 per ropani (NRs. 569,052.8 per hectare), while those in Thawang average NRs. 23,240 per ropani (464,800 per hectare). The mean difference of NRs. 5,212.64 indicates that farmers in Rolpa have significantly higher incomes compared to their counterparts in Thawang. The gross return was statistically significant at a 1% level. It was more in Rolpa municipality as the market is located near and farmers themselves sell their product to market while due to difficult road facilities, lack of transportation, and distant market, respondents of Thawang have low gross return. The findings were higher than those

observed by Bajracharya and Sapkota (2017) and Subedi *et al.* (2019), who found NRs. 13,402.35 and NRs.18, 681.6 in the Bajhang and Terai regions, respectively. Farmers in Rolpa achieve an average gross margin of NRs. 11,316.41 per ropani (NRs.226,328.2 per hectare), while those in Thawang average NRs. 12,447.81 per ropani (NRs.248,956.2 per hectare). According to Timsina (2013), the gross margin of potatoes per ropani was NRs. 15, 504. Similarly, Subedi *et al.* (2019) reported a margin of NRs.6604.4 for potatoes in Nepal. Potato farming was found to be profitable, with a B: C ratio of 1.93. The highest B: C ratio (2.15) was observed at Thawang rural municipality, followed by Rolpa municipality (1.66). The Benefit Cost (B:C) ratio of our study surpasses the findings by Dahal and Rijal(2019) in Nuwakot (1.71); however, it is lower than the findings by Timsina (2013) in Taplejung (2.9). Similarly, the Benefit-Cost ratio of potato production in Rolpa was more than in other hills and high hills regions of Nepal as reported by Karki *et al.* (2023) in Mustang as 1.59, Dahal *et al.* (2023) in Bhaktapur as 1.68, Phulara *et al.* (2021) in Okhaldhunga as 1.23, Sapkota *et al.* (2019) in Achham as 1.47, Bajracharya & Sapkota (2017) in Baglung as 1.44, and Chauhan *et al.* (2022) in Darchula as 1.62.

Table 4.Productivity, gross return, gross margin, and BC ratio across the study area, Rolpa, 2024

Economic variables	Overall	Rolpa	Thawang	Mean difference	t-value	p-value
Productivity (kg/ropani)	758.17	712.43	781.04	-68.61	0.104	0.103
Gross return (Per ropani)	24978.01	28452.64	23240	5212.64	3.300***	<0.001
Gross margin (Per ropani)	12070.68	11316.41	12447.81	-1131.4	-0.935	0.352
BC ratio	1.93	1.66	2.15	-0.49	-0.948***	<0.001

Note: Figure in parentheses indicates standard deviation and *** indicates a 1% level of significance.

3.3 Marketing of potato

3.3.1 Source of marketing information

As shown in Table 5, the findings indicate that 46.7% of farmers rely on farmers' groups or cooperatives for marketing information-prevailing market prices, market demand and trends, and government

programs and subsidies, closely followed by 43.3% who turn to friends and family members. Government organizations, such as AKC and PMAMP, were mentioned by 6.7% respondents, while media sources

account for just 3.3%. These results underscore the importance of community and peer networks in disseminating agricultural information, highlighting

potential areas for enhancing communication and support through formal channels.

Table 5. Source of market information in the study area, Rolpa, 2024

Source of marketing information	Frequency	Percentage
Friends and family members	52	43.3
Government organization (AKC, PMAMP)	8	6.7
Medias	4	3.3
Farmers' group/ Co-operatives	56	46.7

3.3.2 Farm gate price, market price, and price spread

According to Table 6, the average farm gate price in the study area was NRs. 33.38 per kg, with a significantly higher price in Rolpa municipality (NRs. 40 per kg) compared to Thawang rural municipality (NRs. 30.06 per kg). The mean difference was statistically significant at a 1% level. Conversely, the market price was higher in Thawang rural municipality (NRs. 60 per kg) compared to Rolpa municipality (NRs. 50.75 per kg), resulting in a significant mean difference at a 1% level. The price differentiation between Rolpa municipality and Thawang rural municipality is mainly due to differences in market accessibility and production scale. Rolpa, being more easily accessible to

markets outside the districts, allows farmers to fetch a higher farm gate price. In contrast, Thawang is the hub of potato production, but its remote location and poor market access result in a lower farm gate price. The price spread was notably higher in Thawang rural municipality (NRs. 29.94 per kg) compared to Rolpa municipality (NRs. 10.75 per kg), suggesting that farmers in Thawang received a lower share of the final market price. The price spread was also statistically significant at a 1% level. The higher price spread in Thawang reflects higher marketing costs and intermediary dominance, leading to farmers receiving a smaller share of the final market price.

Table 6. Comparative economic variables across the study area, Rolpa, 2024

Economic variables	Overall	Rolpa	Thawang	Mean difference	t-value	p-value
Farm gate price	33.38(5.65)	40(5.18)	30.06(1.25)	9.94	16.265***	<0.001
Market price	56.91(5.15)	50.75(4.74)	60(0.00)	-9.25	-17.520***	<0.001
Price spread	23.53(9.41)	10.75(1.80)	29.94(3.73)	-18.69	-29.920***	<0.001

Note: Figure in parenthesis indicates standard deviation and *** indicates a 1% level of significance.

3.3.3 Market dynamics and price determination in the potato value chain

According to Table 7, transportation facility was a major factor governing the price of potatoes in the study area. Similarly, local traders were the major factor in price determination. According to Bajracharya and Sapkota (2017), the quantity sold, availability of market information, and distance to the nearest market have a direct relationship with market channel selections, which have impacted the pricing of potatoes in the study

area. Collectors were one of the significant buyers of potatoes produced. A similar finding was reported by Chauhan *et al.* (2022) in Darchula. Jeep was the dominant means of transportation for potatoes to the market, similar to Liwang, Dang, Butwal, and Kathmandu. All sorts of variables were statistically significant at a 1% level of significance.

Table 7. Market dynamics and price determination in Potato value chain, Rolpa, 2024

Variables	Overall	Rolpa	Thawang	Chi-value	p-value
Factor governing price					
Transportation facility	48(40.00)	3(7.50)	45(56.25)	78.224***	<0.001
Major factor in price determination					
Local trader	48(40.00)	2(5.00)	46(57.50)	100.383***	<0.001
Potato buyers					
Collectors	79(65.85)	0(0.00)	79(98.75)	115.875***	<0.001
Means of transportation					
Jeep	94(78.33)	14(35.00)	80(100.00)	66.383***	<0.001

Note: Figure in parentheses indicates standard deviation, and *** indicates significant at a 1% level of significance.

3.3.4 Grading, packing and storage

As shown in Table 8, the study revealed that about 98% of producers perform grading before selling. Grading was done manually by discarding potatoes smaller than egg size. Dahal *et al.* (2023), in their study, also found that before packing, almost all the respondents performed grading and sorting.

About 45.80% of potato producers use normal bags (bora) as packing materials for potatoes. The finding was in contrary with Dahal *et al.* (2023), where farmers of Bhaktapur used modern sacks for packing. Almost all the respondents use the floor as a means of storage.

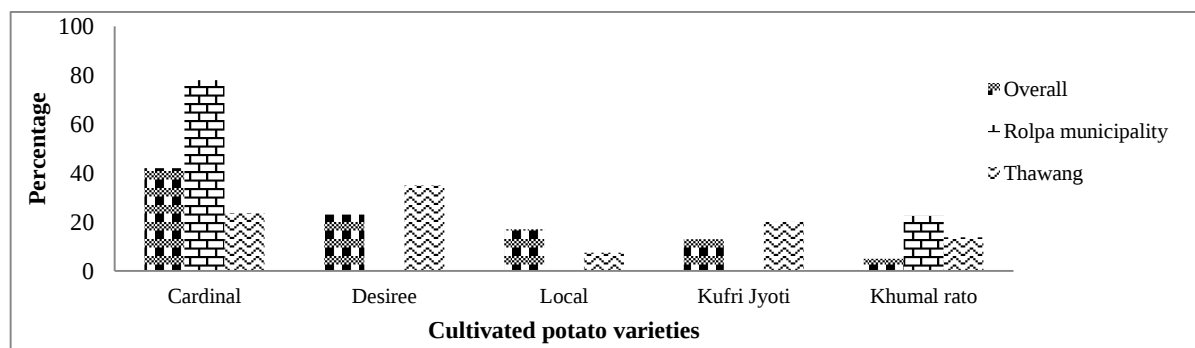
Table 8. Grading, packing, and storage of potato in Rolpa, 2024

Grading, Packing and Storage	Frequency	Percentage
Packing materials (Normal bags)	55	45.80
Performance of grading (Yes)	118	98.30
Storage (Floor)	119	99.20

3.4 Preference of potato variety

Figure 1 illustrates the preference for different potato varieties in Rolpa, comparing Rolpa municipality, Thawang rural municipality, and the overall study area. Cardinal (42%) was the most preferred variety across all areas. Location-wise, Desiree (35%) was most popular among potato producers in Thawang rural

municipality, while Cardinal (78%) and Khumal Rato (22.50%) were popular in Rolpa municipality. Kufri Jyoti and the local variety had the lowest preferences. A study in Okhaldhunga also found Khumal Rato to be one of the most preferred potato varieties (Phulara *et al.*, 2021).

**Figure 1.** Comparison of different potato varieties across study area, Rolpa, 2024

3.5 Status of intercropping in potato

Figure 2 shows that intercropping was practiced by about three-fourths of the potato producers in the study area. All respondents in Thawang rural municipality practiced intercropping, while only one-fifth of those in Rolpa municipality did. Bhango was the most popular intercrop, followed by maize,

legumes, radishes, apples, and kiwis. Maize was observed as a dominant intercrop with potatoes in Okhaldhunga (Phulara *et al.*, 2021). Similarly, Karki *et al.* (2023) also observed apple as an intercrop with potatoes in the high hills of Nepal.

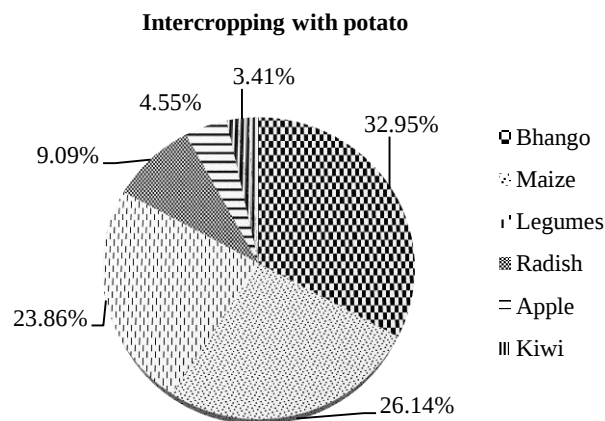


Figure 2. Different intercrops with potato across study area, Rolpa, 2024

3.6 Problem associated with potato in Rolpa

As indicated in Table 9, the incidence of diseases and pests was identified as the significant concern in potato production, with the highest index value of 0.813. Lack of irrigation ranked second (0.675), followed by unavailability of inputs (0.513), poor technical knowledge (0.57), and costly inputs (0.435). The incidence of disease and pests was identified as the primary concern in potato production (Karki *et al.*, 2023; Subedi *et al.*, 2019; Bajracharya & Sapkota, 2017). According to Neupane(2024), disease/insect incidence and inadequate irrigation facilities were the primary concerns for reduced potato production in Rolpa. Pokhrel (2018)

concluded that inadequate transportation was considered a serious problem in Rolpa, which was to our findings. A similar finding was reported in Mustang by Karki *et al.* (2023), where price fluctuation was observed as the major problem, followed by lack of transport. Phulara *et al.* (2021) also reported more middlemen, a lack of adequate market information, and price fluctuation as major constraints in the marketing of potatoes in the Okhaldhunga district. In Bhaktapur, price fluctuations, storage problems, and lack of marketing knowledge, were major problems among potato producers (Dahal *et al.*, 2023).

Table 9. Major production and marketing problems in the study area, Rolpa, 2024

Production problems	Sifi	Index Value	Rank
Unavailability of input	61.6	0.513	III
Inadequate irrigation	81.0	0.675	II
Poor technical knowledge	68.4	0.570	IV
Disease pest damage	97.6	0.813	I
Costly inputs	52.2	0.435	V
Marketing problems	Sifi	Index Value	Rank
Lack of marketing knowledge	64.8	0.540	IV
Inappropriate market price	96.2	0.802	I
Shortage of cold storage	77.6	0.647	III
Lack of transportation	83.4	0.695	II
Low volume of production	37	0.308	V

4. CONCLUSION

This study showed that the average potato productivity was 15.16 mt/ha, and the gross return was NRs. 499,560.2 per hectare, gross margin was NRs. 241,413.6 per hectare, and the benefit-cost ratio of 1.93, demonstrating that potato farming in Rolpa was profitable. Price variations were observed between Rolpa and Thawang, with farmers in Thawang facing a larger marketing margin due to market inefficiencies. Existing marketing methods, such as grading, contract farming, organic farming, and employing Thawang's comparative advantage, contributed to market accessibility. Management practices such as enhanced disease management, stable pricing mechanisms, pronounced market

connections, and governmental assistance for farmers are indispensable to improve the sustainability of potato farming. Strengthening cooperative marketing, improving infrastructure, ensuring price stability, promoting value addition, support organic and contract farming, enhance disease management, and facilitate targeted governmental support to boost the profitability and sustainability of potato farming in Rolpa.

ACKNOWLEDGEMENTS:

The authors would like to thank PMAMP, CNRM Madichaur, and AFU, Rampur, Chitwan, for their support to do the research. Similarly, all the respondents are highly acknowledged for their cooperation and sharing reliable data.

REFERENCES

- Acharya, B.P., & GC, A. (2024). Economics Analysis of Potato Production in Sindhupalchok District. *Nepalese Journal of Agricultural Sciences*. 26. 158-169.
- AKC Rolpa. (2024). *Annual Agricultural Development Program and Statistics*. Agriculture Knowledge Centre Rolpa.
- Aryal, M., Pandey, K. R., Dhakal, S., Tumbapo, S., & Joshi, Y. (2023). Performance of Potato Variety Rolpa Local (*Solanum tuberosum* L.) under Different Mulching Conditions and Zinc Levels at Rolpa, Nepal. *Peruvian Journal of Agronomy*. 7(1). 27-41. <https://doi.org/10.21704/pja.v7i1.1979>
- Bajracharya, M., & Sapkota, M. (2017). Profitability and Productivity of Potato (*Solanum tuberosum*) in Baglung District, Nepal. *Agriculture and Food Security*. 6. <https://doi.org/10.1186/s40066-017-0125-5>
- Bhandari, N. B., Sharma, G., & Parajuli, K. (2016). *Production Cost & Marketing of Cereal, Cash, Vegetable & Industrial Crops in Nepal*. Agribusiness Promotion and Marketing Development Directorate. <http://caidmp.gov.np/downloadsfiles/Crop-book-2073-1690693248.pdf>
- Bist, D., Joshi, G.R., Chapagae, P., Mandal, A., RC, P., Awasthi, R., Rawal, R., Bist, G., & Bohara, R. (2024). Socioeconomic Impact of Livestock Production in Gokuleshowor, Baitadi, Nepal. *Archives of Agriculture and Environmental Science*. 9. 561-567. <https://doi.org/10.26832/24566632.2024.0903022>
- Chauhan, B., Joshi, D., Banjade, D., Bhatta, B. D., Awasthi, P., Paneru, M., Shrestha, M., & Chand, P.B. (2022). Economics of Potato (*Solanum tuberosum* L.) Production and Marketing in Darchula District of Nepal. *Archives of Agriculture and Environmental Science*. 7(3). 393-401. <https://doi.org/10.26832/24566632.2022.0703013>
- Dahal, B. R., & Rijal, S. (2019). Production Economics and Determinants of Potato Production in Nuwakot, Nepal. *International Journal of Applied Sciences and Biotechnology*. 7(1). 62-68. <https://doi.org/10.3126/ijasbt.v7i1.23304>
- Dahal, S., Regmi, B., Panta, H.P., Timalsina, P., Chaudhary, R., Khadka, T. Khadka., & Poudel, A. (2023). Analysis of economic, production, and marketing aspects of potato farming in Changunarayan Municipality of Bhaktapur, Nepal. *Archives of Agriculture and Environmental Science*. 8(4). 545-552. <https://doi.org/10.26832/24566632.2023.0804013>
- FAO. (2023). Retrieved from FAOSTAT. <https://www.fao.org/faostat>
- Ghimire, S.R. (2022). Potential Role of Traditional Underutilized Food Crops in Achieving Food and Nutrition Security in Nepal.
- Islam, J. C.-S. (2020). Evaluation of Tuber Yield and Marketable Quality of Newly Developed Thirty-Two Potato Varieties Grown in Three Different Ecological Zones in South Korea. *Agriculture*. 10(8). <https://doi.org/10.3390/agriculture10080327>
- Karki, A., Bhusal, N., Bhandari, N., Bastakoti, B., Shrestha, K., & Sharma, B. (2023). Economics of Potato Production in Mustang District of Nepal. *The Journal of Agriculture and Environment*. 24. 59-67. <https://doi.org/10.3126/aej.v24i01.58128>
- Khadka, T., Chauhan, D., Tiwari, A., Regmi, B., Dahal, S., & Manandhar, S. (2023). Value Chain Analysis of Potato in Bajhang District, Nepal. *Archives of Agriculture and Environmental Science*. 8(4). 516-523. <https://doi.org/10.26832/24566632.2023.080409>
- Mishra, K. (2023, February 23). Impediments in the Agriculture Sector of Nepal. *Nepal Economic Forum*.
- MoAD. (2021). *Unnat Aalu Kheta Prabadi*. Retrieved from <http://www.npdp.gov.np/eng/page/notices>
- Ministry of Agriculture and Livestock Development. (2023). *Statistical Information on Nepalese Agriculture 2078/79 (2021/22)*. <https://moald.gov.np/wp-content/uploads/2023/08/Statistical-Information-on-Nepalese-Agriculture-2078-79-2021-22.pdf>
- Neupane S., Katel, S., Bist, N., Yadav, S.P.S., & Dahal, B. (2024). Analysis of Resource Use Efficiency and Profitability of Maize Seed Production in the Rolpa District of Nepal. *Selcuk Journal of Agriculture and Food Sciences*. 38(1). 53-63. <https://doi.org/10.15316/SJAFS.2024.005>
- Phulara, B., Acharya, B., Adhikari, S., Ojha, B., & Sigdel, U. P. (2021). Production Economics and Marketing of Potato in Okhaldhunga, Nepal. *Innovare Journal of Agricultural Science*. 5(9). <https://doi.org/10.26480/faer.01.2022.26.33>

- Pokhrel, S. (2018). Economics of Maize Seed and Grain Production in Rolpa. *Acta Scientific Agriculture*. 2(11). 43-50.
- Sapkota, S., Rokaya, P., Acharya, H., & Uprety, S. (2019). An Economic Analysis of Potato Production in Achham District of Nepal. *International Journal of Horticulture & Agriculture*. 4(2). 1-9. <https://doi.org/10.15226/2572-3154/4/2/00131>
- Subedi, S., Ghimire, Y. N., Gautam, S., Poudel, H. K., & Shrestha, J. (2019). Economics of Potato (*Solanum tuberosum* L.) Production in Terai Region of Nepal. *Archives of Agriculture and Environmental Science*. 4(1). 57-62. <https://doi.org/10.26832/24566632.2019.040109>
- Timsina, K. P. (2013). Economics of Potato Production in Taplejung District of Nepal. *Agronomy Journal of Nepal*. 2. 173-181.
- Yamane, T. (1967). *Statistics: An Introductory Analysis*. Harper & Row.

EFFECT OF DIFFERENT MULCHING MATERIALS ON GROWTH AND YIELD OF CAULIFLOWER (*Brassica oleracea* var. *botrytis* L.) IN SALYAN, NEPAL

Pratiksha Tumbapo^{1*}, Deepika Timsina², Monika Thapa¹ and Prajala Badal¹

¹ Faculty of Agriculture, Agriculture and Forestry University, Chitwan, Nepal

² Department of Agronomy, Agriculture and Forestry University, Chitwan, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Cauliflower Growth Mulching Weed management Yield *Correspondence: pratikshatumbapo@gmail.com Tel: +9779862199531	A field experiment was conducted to evaluate the effect of different mulching materials on growth and yield of white put variety of cauliflower (<i>Brassica oleracea</i> var. <i>botrytis</i> L.) from April to July 2024 in Salyan district, Nepal. The experiment was carried out using a Randomized Complete Block Design (RCBD) with five treatments and four replications. The treatments included silver black plastic mulch (T1), rice straw mulch (T2), sawdust mulch (T3), asuro mulch (T4), and control (T5). Data regarding biometrical observations on growth, yield attributes, and yield were recorded at intervals of 15, 30, 45, and 55 days after transplanting. Results indicated that different mulching practices significantly affected growth and yield attributes. Notably silver black plastic mulch (T1) exhibited significantly increased growth parameters such as leaf number (6.40 cm), plant height (49.63 cm), leaf width (8.29cm) and canopy diameter (24.84 cm) along with yield (43.70 t/ha) and yield attributes such as fresh curd weight (0.89 kg), curd diameter (19.68 cm) and fresh biomass (1.86 kg) compared to the control group. Thus, based on the findings of this study, the application of Silver black plastic mulch is recommended for the farmers in Salyan district for increasing growth and yield of cauliflower crops.

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the economically important cole crops grown in the winter season in the hills and terai of Nepal. It is a cool-season crop and one of the essential winter vegetables, rich in nutrients like vitamins C and E, magnesium, iron, zinc, sodium, calcium, and high-quality proteins (USDA, 2013). Cauliflower can be grown in various climatic conditions, from tropical to temperate regions. It can thrive in all types of soil with good fertility and moisture levels. Maintaining optimal moisture supply is crucial during both growth and curd

development stages to prevent water stress and ensure maximum growth and yield. Limited water availability during curd formation can delay harvesting and reduce curd weight and diameter significantly (Fadilah & Lakitan, 2021). The first 30 days after planting are critical for managing weed competition, after which cauliflower can better compete with weeds, shading the soil and inhibiting weed seed germination (Dimson, 2001). Prolonged periods of weed-crop (cauliflower) competition significantly reduce crop growth and head yield. A reduction in shoot dry weight of about 81% and about 89% reduction in head yield on average was observed in cauliflower (Qasem, 2009).

Mulching involves covering the soil surface with organic or inorganic materials like plastic, sawdust, leaves, grass, twigs, crop residues, or straw (Iqbal et al., 2020). The use of different mulching materials has different effects on vegetable production. Organic mulches like straw reduce the appearance and growth of weeds and make the soil more fertile (Patil et al., 2013). The use of sawdust increases the C: N ratio, which means slower decomposition, less nutritional decay, and longer-lasting moisture retention (Chopra & Koul, 2020). Grass clippings use enhances the percentage of nitrogen in the soil as it decomposes easily (Chopra & Koul, 2020). The use of inorganic mulches like black plastic mulch showed changes in the plant's growing environment by increasing soil moisture and soil temperatures (Gordon, 2006). Silver mulch use increases moisture conservation and availability, increases

temperature, enhances soil microorganisms, and controls insect and pest infestation (Jha et al., 2018).

Cauliflower is sensitive to water stress and weed competition, especially during the early vegetative and curd formation stages. Mulching practices can be an effective method for conserving soil moisture and managing weeds. However, there is a lack of knowledge about weed management practices like mulching and insufficient data and information on using different mulch materials for cauliflower production in Nepal. Furthermore, there is a lack of research on how different mulching materials affect cauliflower production, specifically in the Salyan district. Therefore, the research experiment aimed to identify advantageous mulching materials that could be more efficient for better growth, and higher yield of cauliflower in Salyan district of Nepal.

2. MATERIALS AND METHODS

2.1 Location and period

The experiment was conducted in a farmers' field in Tribeni rural municipality, Salyan from the 25th of April to the 1st week of July 2024. It is situated at 28°17'12"N latitude and 82°17'32"E longitude at an altitude of 963 masl. The region is characterized by average annual precipitation of 974.2 mm, maximum temperature of 25.3°C, and minimum temperature of 13.9°C (Environment Statistics of Nepal, 2024).

2.2 Plant materials and treatments of the experiment

A hybrid cauliflower variety white put was used as plant material for this experiment. Five treatments were used for the experiment: T1= Silver black plastic, T2= Rice straw, T3= Sawdust, T4= Asuro, and T5= Control. A silver black plastic mulch of 25-micron thickness was laid tightly in respective plots. At respective plots, a 2.5-inch-thick layer of Rice straw, sawdust and asuro mulch was laid for experimenting.

2.3 Design and layout of the experiment

The research experiment was structured according to a Randomized Complete Block Design (RCBD), with 5 treatments and 4

replications. Each plot covered a 4.05 m² (1.8 m* 2.25 m) area. The distance between replications was maintained at 1 m, while the separation between treatments was set at 0.5 m. Each plot accommodated 20 plants, with 45 cm* 45 cm spacing.

2.4 Raising of seedlings

A nursery bed of 3 meters in length and 1 meter in width was prepared by ploughing the land thoroughly with the help of a mini-tiller and incorporating well-decomposed Farm Yard Manure (FYM) at a rate of 20 tons per hectare into the soil. The seeds were sown at a depth of about 2-3 cm, maintained in a line spaced 5 cm apart. The seeds were sown in March 2024 under protected conditions.

2.5 Land preparation and seedling transplanting

Land preparation was done 2 weeks before transplanting twice with a mini-tiller, followed by the incorporation of well-decomposed FYM (20 mt/ha) and leveling. Besides FYM, N: P: K was applied at the rate of (120kg: 60kg: 60kg) per hectare in the form of urea, DAP and MoP, respectively. Half a dose of nitrogen and a full dose of phosphorous and potash was given at the time of transplanting as basal application and

the remaining half dose of nitrogen was given at 30 days after transplanting as a top dressing by ring method. 24-day-old seedlings with 3-4 true leaves were used for transplanting.

2.6 Intercultural operations and harvesting

Gap-filling, irrigation, and pest control were performed whenever necessary. The flood-in-the-furrow method was used for irrigation. Micronutrient mix liquid was used for micronutrient support through foliar spray 30 and 45 days after transplanting. King Hunter (Cyromazine 70% WP) was applied for pest control 30 and 45 days after transplanting. Blanching was performed a week before harvesting. Harvesting was done at 55 days after transplanting.

2.7 Data collection

For data collection, 5 randomly selected plants excluding border plants for potential border effects were chosen from each plot of 20 plants. Data were recorded for three categories of parameters: growth parameters, including the number of leaves per plant, plant height, length of leaves per plant, width of leaves per plant, and canopy diameter per plant; yield parameters, including curd height, curd diameter, curd weight with leaves, yield per hectare, and biomass per plant; and economic parameters, including the cost of cultivation, net return, and benefit-cost ratio.

2.8 Statistical analysis

MS Excel was used for data entry, tabulation and graphs. R-studio (version 4.4.2) was used for data analysis. One-way ANOVA with Duncan's Multiple Range Test (DMRT) and LSD (Least Significant Difference) tests were used to find out the significant differences between the mean values at a 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Growth parameters

Leaf number

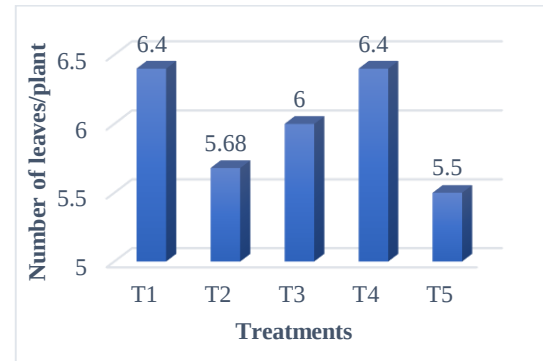


Figure 1. Effect of different treatments on the number of leaves/plant of cauliflower at 15 DAT

The highest leaf numbers were observed in plots mulched with Silver black plastic mulch (6.40) and asuro (6.40), followed by sawdust mulch (6), while the lowest was observed in rice straw (5.68) at 15 DAT. Non-significant results were observed on 30, 45 and 55 DAT. Polyethylene mulching raises the soil temperature, which, in turn, increases soil microorganism activity and improves the physical and chemical characteristics of the soil (Tawfeeq and Abdulrhman, 2021). Similar outcomes were obtained in cucumber (Karki et al., 2020) and in tomato (Rajablariani et al., 2012). Organic mulches like sawdust and asuro improve soil quality and increase crop production by drastically lowering soil temperature and moisture content, weed density, and increasing the number of plant nutrients available in the soil (Sinkeviciene et al., 2009).

Plant height

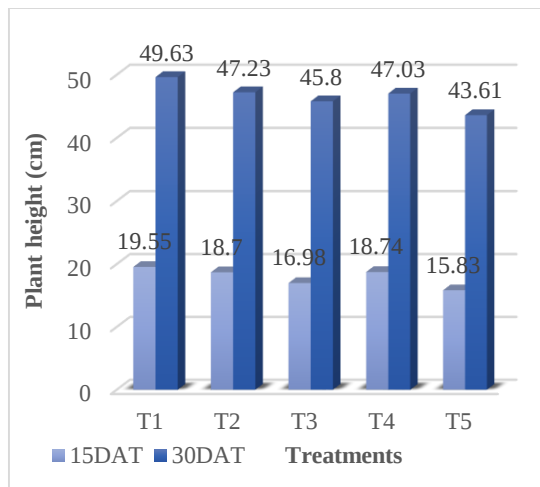


Figure 2. Effect of different treatments on the Plant height of cauliflower at 15 DAT and 30 DAT

Maximum plant height was observed in silver black plastic mulch (19.55 cm) followed by asuro mulch (18.74 cm), whereas minimum plant height was observed in the control (15.83 cm) at 15 DAT. At 30 DAT, silver black plastic mulched plots (49.63 cm) showed maximum plant height among different treatments whereas minimum plant height was observed under the control plot (43.61 cm). Non-significant results were obtained 45 and 55 days after transplanting. The rise in plant height might be due to better availability of moisture and optimum soil temperature provided by polyethylene mulch, which leads to an increase in crop growth (Patel et al., 2023). These results are in accordance with other researchers (Rajablariani et al., 2012) in tomato and (Karki et al., 2020) in cucumber. Straw mulching has a significant impact on the regulation of soil temperature and moisture content. It can lower soil temperatures and keep soil moisture levels within a stable range (Qin et al., 2022).

Leaf length

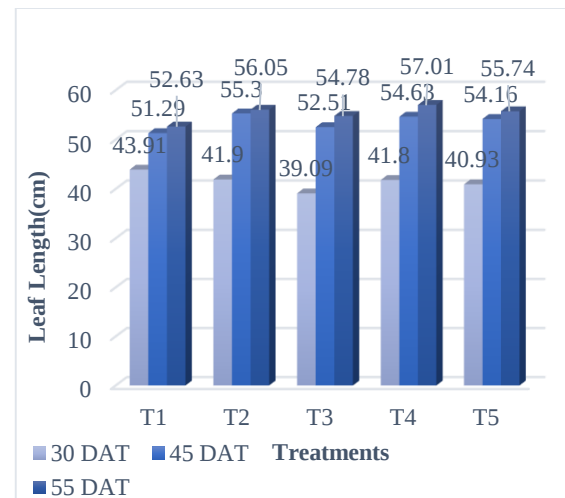


Figure 3. Effect of different treatments on the leaf length of cauliflower at 30, 45 and 55 DAT

Non-significant results were obtained at 15 DAT. Maximum leaf length was observed in silver black plastic mulched plots (43.91) while minimum leaf length was observed in sawdust mulched plots (39.09) at 30 DAT. At 45 DAT, Maximum leaf length was observed in rice straw mulch (55.30) while minimum was observed in silver black plastic mulched plots (51.29). At 55 DAT, asuro mulch (57.01) and rice straw mulched plots (56.05) showed maximum leaf length while silver black plastic mulch (52.63) showed minimum. Maximum leaf length was observed in silver black mulch early at 30 DAT which might be due to better moisture retention and optimum soil temperature maintenance by silver black mulch which leads to an increase in the length of cauliflower leaves. Higher length of leaves was reported under silver black plastic mulch in cauliflower (Patel et al., 2023). However, at 45 DAT and 55 DAT maximum leaf length was observed with rice straw mulching. The favorable soil temperature and moisture content may have contributed to this outcome, leading to increased mineralization of the soil and the addition of essential nutrients such as N, Ca, Si, and others necessary for the proper growth and development of plants. These results are similar to another researcher (Kumar et al., 2019) in cauliflower.

Leaf width

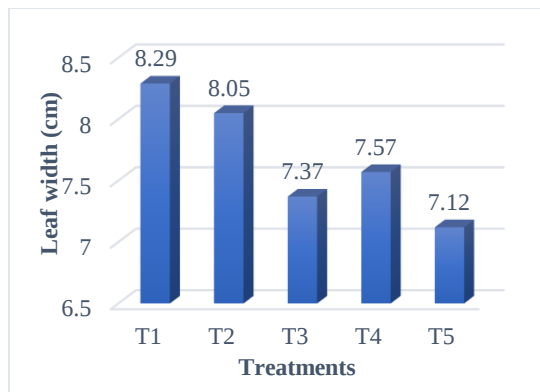


Figure 4. Effect of different treatments on the leaf width of cauliflower at 15 DAT

Mulching materials showed significant results at 15 DAT. Silver black mulched plastic plots (8.29) showed maximum width of leaves followed by rice straw mulch (8.05) whereas sawdust (7.37) and asuro (7.57) mulch showed the minimum width of leaves. Non-significant results were observed on 30, 45 and 55 DAT. The light microenvironment is altered as upwardly reflected light from silver mulches reduces the ratio of red to far-red light when compared to black mulches. It had been thought that plants grown on reflective silver mulches would develop larger leaf areas than those grown on black plastic (Decotcau, 2007). Plastic mulch offers a favorable root zone temperature that encourages the uptake of water and mineral nutrients, improving the growth of plants and foliage (Tindall et al., 1990).

Canopy diameter

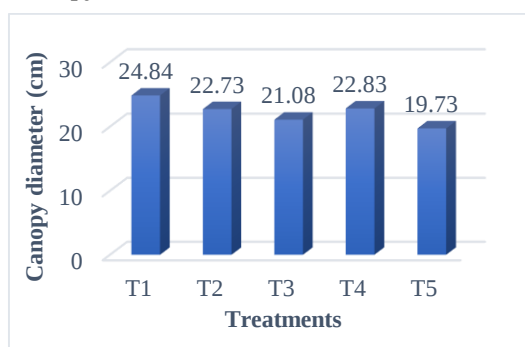


Figure 5. Effect of different treatments on the canopy diameter of cauliflower at 15 DAT

Different mulching materials had a significant effect on canopy diameter at 15

DAT. Silver black mulched plots (24.84) showed maximum canopy diameter followed by rice straw mulch (22.73) and asuro mulch (22.83) while minimum canopy diameter was observed under control plots (19.73) at 15 DAT. Non-significant results were observed at 30, 45, and 55 days after transplanting. Polyethylene mulch decreases evaporation and nutrient losses, and weed control, and enhances hydrothermal regimes in the soil caused, which positively impacts plant growth parameters (Patel et al., 2023). Higher plant spread (cm) under silver black plastic mulch was observed by (Patel et al., 2023) in cauliflower and high leaf area m² plant⁻¹ was reported by (Ibarra-Jiménez et al., 2011) in potato. High canopy diameter with organic mulches like rice straw and asuro mulch might be due to an increase in the amount of plant nutrients available in the soil by organic mulches along with providing favorable temperature and moisture content and reduced weed density improving plant growth parameters and crop production (Sinkeviciene et al., 2009). Higher canopy diameter under organic mulching is reported in cauliflower (Kumar et al., 2022).

3.2 Yield parameters

Curd weight with leaves

The analysis result showed that the maximum curd weight with leaves was observed under Silver black plastic mulch (0.89), followed by sawdust mulch (0.81) and asuro mulched plots (0.76). The lowest curd weight with leaves was observed under control plots (0.61), followed by rice straw mulch (0.71). Silver black plastic mulch prevents evaporation and secures optimum moisture of the soil which leads to more effective use of available water. It retains heat in the soil during the night and secures favorable microclimate conditions in the root zone which results in increased early and total yields of crops. High curd: plant (w/w) ratio of 0.40 was observed under silver black plastic mulch by (Patel et al., 2023) in cauliflower. According to (Sinkeviciene et al., 2009) organic mulches enhance soil quality and boost crop productivity by significantly reducing soil temperature and moisture content, weed density, and the amount of plant nutrients available in the

soil. Higher curd weight of cauliflower under organic mulching was reported (Kumar et al., 2022).

Yield (t/ha)

Mulching materials showed significant results on the yield of cauliflower var. White put. Maximum yield was observed under silver black plastic mulching (43.70) followed by sawdust mulch (39.98) and asuro mulch (37.57) while minimum yield was observed under control plots (29.79) which were at with rice straw mulching (34.82). The enhanced microclimate below and above the soil surface, greater weed control and moisture conservation provided by silver black plastic mulch were likely the reasons for the mulched plot's higher production (Rajablariani et al., 2012). Similar results of highest yield under silver black mulch are reported in tomato (Rajablariani et al., 2012), (Karki et al., 2020), in cucumber and (Timsina et al., 2019) in winter maize. High yield under organic mulches was reported by (Sinkeviciene et al., 2009) and (Kumar et al., 2019).

Curd diameter

Maximum curd diameter was observed under silver black plastic mulching (19.68) which was at par with asuro mulching (18.45) whereas minimum curd diameter was observed under sawdust mulch (17.28) which was statistically similar to rice straw mulching (17.29). This result was revealed that the curd diameter increased with mulching application. These results showed that the curd diameter increased significantly with silver black plastic mulch. This might be due to polyethylene mulch that increased soil temperature more than control, which increases soil microbial activity and enhances the physical and chemical properties of the

soil. Because of this improvement, the majority of soil elements are easier for plant roots to absorb (Tawfeeq and Abdulrhman, 2021). According to (Sil et al., 2022) when organic mulches are used instead of synthetic or no mulch at all, cauliflower growth and yield are greatly increased. Similar results were obtained with higher curd diameter in cauliflower by (Sil et al., 2022) under organic mulching.

Curd height

Different mulching materials showed a non-significant result on the curd weight of cauliflower var. White put.

Biomass

Maximum biomass was observed under silver black plastic mulching (1.86) followed by rice straw mulching (1.58) which was at par with sawdust mulch (1.57). Minimum biomass was observed under control plots (1.44) which were statistically similar to asuro mulch (1.53). This result showed increased biomass by silver black plastic mulching which might be due to better availability of moisture and optimum soil temperature provided by polyethylene mulch which leads to an increase in crop growth (Patel et al., 2023). According to (Noertjahyani et al., 2019) the application of straw mulch increases the biomass and biological yield of cauliflower by preserving soil moisture, which is essential for cauliflower growth in low-water conditions, and by enhancing nutrient absorption and general plant health, which in turn improves yield. Straw mulching can raise the amount of organic matter in the soil, improve crop yield and soil water use efficiency, and promote dry matter accumulation (Xie et al., 2022).

Table 1. Effect of mulching materials on curd weight with leaves, yield, curd diameter, curd height, and biomass

Treatments	Curd weight (kg)	Yield (t/ha)	Curd diameter (cm)	Curd height (cm)	Biomass (kg)
Silver black plastic mulch	0.89 ^a	43.70 ^a	19.68 ^a	12.60	1.86 ^a
Rice straw mulch	0.71 ^{bc}	34.82 ^{bc}	17.29 ^c	12.30	1.58 ^b
Sawdust mulch	0.81 ^{ab}	39.98 ^{ab}	17.28 ^c	12.28	1.57 ^b
Asuro mulch	0.76 ^{ab}	37.57 ^{ab}	18.45 ^a	12.48	1.53 ^{bc}
Control	0.61 ^c	29.79 ^c	17.73 ^{bc}	11.78	1.44 ^c
Sem (±)	0.01	21.18	0.54	0.24	0.01
LSD (0.05)	0.14	7.09	1.13		0.12
F-probability	<0.05	<0.05	<0.01	NS	<0.001
CV (%)	12.37	12.38	4.05		5.07
Grand Mean	0.75	37.17	18.89	12.29	1.59

Note: CV= Coefficient of Variation, SEM= Standard Error of Mean, LSD= Least Significance Difference, DAT= Days After Transplanting, Letters a, b and c represent the ranking of treatments according to DMRT at 0.05 level of significance

3.3 Economic analysis

According to an economic analysis of cauliflower production, the highest benefit-to-cost ratio was observed with silver black plastic mulching (2.09), which was statistically similar to sawdust mulching (1.79), followed by asuro (1.7) and rice straw mulching (1.6). The lowest benefit-to-cost ratio was observed with control (1.42). The total cost of cultivation, which included general costs and treatment-wise costs, was somewhat similar among treatments, but the yield and gross return for silver black plastic mulch followed by sawdust mulch was

higher among all the other treatments, which led to a higher b/c ratio. Comparatively higher cost of cultivation incurred in organic mulches is greatly due to high price (rice straw), difficulty in the collection (asuro), and need for transport (sawdust) while easy availability and one-time use with affordable price along with good yield might have contributed to higher B/C in silver black plastic mulch. Similar results were reported with highest B/C ratio under silver black plastic mulch (Hermawati, 2023), (Karki et al., 2020) in cucumber.

Table 2. Effect of mulching materials on total cost of cultivation, Gross return, and B: C ratio in cauliflower

Treatments	Total cost of cultivation (NRs/ha) (000)	Gross return (NRs/ha) (000)	B/C Ratio
Silver black plastic mulch	418	874.07	2.09 ^a
Rice straw mulch	435.20	696.30	1.6 ^{bc}
Sawdust mulch	447.40	799.51	1.79 ^{ab}
Asuro mulch	442.04	751.48	1.7 ^{bc}
Control	419.73	595.80	1.42 ^c
SEM (±)			0.05
LSD (0.05)			0.33
F-probability			<0.01
CV (%)			12.36
Grand Mean			1.72

Note: CV= Coefficient of Variation, SEM= Standard Error of Mean, LSD= Least Significance Difference, DAT= Days After Transplanting, Letters a, b and c represent the ranking of treatments according to DMRT at 0.05 level of significance

4. CONCLUSION

Analysis of the results indicated that the growth and yield attributes of cauliflower were significantly influenced by the different mulching materials. Among the various treatments, silver black plastic mulch exhibited superior results followed by rice straw and asuro mulch for growth and yield parameters. Further, silver black plastic mulch showed the highest benefit-to-cost ratio, indicating its economic viability followed by other treatments. Hence, different mulching materials can be employed to enhance the growth and yield of cauliflower.

ACKNOWLEDGMENTS

We would like to acknowledge Agriculture and Forestry University, Rampur, Chitwan, and Prime Minister Agriculture Modernization Project, Project Implementation Unit, Salyan for providing support in carrying out this research.

REFERENCES

- Canali, S., Campanelli, G., Ciaccia, C., Diacono, M., Leteo, F., Fiore, A., & Montemurro, F. (2015). Living mulch strategy for organic cauliflower (Brassica oleracea L.) production in central and southern Italy. *Italian Journal of Agronomy*, 10(2), 90-96.
- Chopra, M., & Koul, B. (2020). Comparative assessment of different types of mulching in various crops: a review. *Plant Archives*, 20, 1620-1626.
- Choubé, K., Raidas, D. K., Jaiswal, R. K., & Chakraborty, S. (2020). Effect of different weed management practices on growth and yield of cauliflower (Brassica oleracea var. botrytis L.). *Journal of Pharmacognosy and Phytochemistry*, 9(3), 603-605.
- Decoteau, D. R. (2007). Leaf area distribution of tomato plants as influenced by polyethylene mulch surface color. *HortTechnology*, 17(3), 341-345.
- Dimson, E. V. (2001). Cauliflower production in Arizona, weeds. Web stranica <http://pestdata.ncsu.edu/cropprofiles/docs/azcauliflower.html>.
- Environment Statistics of Nepal 2024. (2024). In www.nsonepal.gov.np. National Statistics Office. <https://data.nsonepal.gov.np/id/dataset/environmental-statistics/resource/9d953003-e045-4ee3-ad4b-bb2dac3336f0>
- Fadilah, L. N., & Lakitan, B. (2021). Growth responses and yield of cauliflower (Brassica oleracea var. botrytis L.) to the delayed transplanting and drought stress. In E3S Web of Conferences (Vol. 306, p. 01007). EDP Sciences.
- Gordon, G. G. (2006). The effects of color plastic mulches and row covers on the growth and production of okra and summer squash.
- Hellqvist, S. (1996). Mulching with grass- clippings in cauliflower: Effects on yield and brassica root flies (Delia spp.). *International Journal of Pest Management*, 42(1), 39-46.
- Ibarra-Jiménez, L., Lira-Saldivar, R. H., Valdez-Aguilar, L. A., & Río, J. L. (2011). Colored plastic mulches affect soil temperature and tuber production of potato. *Acta Agriculturae Scandinavica Section B - Soil & Plant Science*, 61(4), 365-371.
- Iqbal, R., Raza, M. a. S., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, S., Toleikiene, M., Haider, I., Aslam, M. U., & Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches—a review. *Bulletin of the National Research Centre/Bulletin of the National Research Center*, 44(1).
- Jha, K. R., Neupane, R. B., Khatriwada, A., Pandit, S., & Dahal, B. R. (2018). Effect of different spacing and mulching on growth and yield of Okra (Abelmoschus esculentus L.) in Chitwan, Nepal. *Journal of Agriculture and Natural Resources*, 168-178.
- Karki, A., Sapkota, B., Bist, P., Bista, K., Dutta, J. P., Marahatta, S., Shrestha, B. (2020). Mulching materials affects growth and yield characters of cucumber (Cucumis sativus cv. Malini) under drip irrigation condition in Chitwan, Nepal. *Journal of Agriculture and Forestry University*, Vol. 4, 153-159.
- Kumar, A., Baghla, S., Kaur, N., Gangmei, T. P., Rana, S. S., & Manuja, S. (2022). Effect of irrigation levels and weed management practices on weeds, water productivity and yield of cauliflower.
- Kumar, V., 1, Sharma, J. C., Kumar, M., Singh, S. K., & Kumar, A. (2019). Mulches and nutrients affect the soil environment, crop performance and profitability of cauliflower. In *The Journal of Animal & Plant Sciences* (Vol. 29, Issue 1, pp. 194-204).
- MOALD. (2078-79). Nepal Agriculture Statistics 2078-79
- Mohammad Abdul Kader, A. S. (2019). Mulching as a water-saving technique in dryland agriculture: review article. *Bulletin of the National*, 143-147
- Montenegro, A. A., Abrantes, J. R., Lima, J. L., & Singh, V. P. (2013, May). Impact of mulching on soil and water dynamics under intermittent simulated rainfall
- Muhammad, A., Ali, M., Shakeel, M., Buajan, S., & Ali, H. (2022). Comparative Effects of Living and Non-living Mulches on Insect Pest Management in Agroecosystems. In *Mulching in Agroecosystems: Plants, Soil & Environment* (pp. 231-248). Singapore: Springer Nature Singapore.
- Noertjahyani, N., Komariah, A., & Nurlenawati, N. (2019). Growth and Yield of Cauliflower (Brassica Oleracea. L.) as an Effect of Water Supply and the Dosages of Rice Straw Mulch. *Asian Journal of Agriculture and Rural Development*, 9(2), 231-241.
- Patel, N. A., Masaye, S., Chaudhari, V., Khasdar, Z., Gaikwad, S., (2023). Effect of different types of mulches on growth characteristics of cauliflower var. Pusa Snowball K-1. In *The Pharma Innovation Journal*, The Pharma Innovation Journal (Vols. 12-12, pp. 2594-2597) [Journal-article].
- Patil, S. S., Tushar, K. S., & Satish, B. A. (2013). Mulching: A Soil and Water Conservation Practice. *Research Journal of Agriculture and Forestry Sciences*, 1(3), 26-29.
- Qasem, J. R. (2009). Weed competition in cauliflower (Brassica oleracea L. var. botrytis) in the Jordan Valley. *Scientia horticulturae*, 121(3), 255-259.
- Qin, T., Wang, L., Zhao, J., Zhou, G., Li, C., Guo, L., & Jiang, G. (2022). Effects of Straw Mulching Thickness on the Soil Health in a Temperate Organic Vineyard. *Agriculture*, 12(11), 1751.
- Rajablariani, H. R., Hassankhan, F., & Rafezi, R. (2012). Effect of colored plastic mulches on yield of tomato and weed biomass. *International Journal of Environmental Science and Development*, 590-593.
- Sil, M., Haque, M., Shila, A., Howlader, M., & Ahmed, R. (2022). Effect of Different Mulches on Growth and Yield of Cauliflower in Southern Bangladesh. *Journal of Environmental Science and Natural Resources*, 13(1-2), 110-117.

- Sinkeviciene, A., Jodaugienė, D., Pupalienė, R., Urbonienė, M., & Lithuanian University of Agriculture. (2009). The influence of organic mulches on soil properties and crop yield. *In Agronomy Research* (Vol. 7, Issue Special issue I, pp. 485–491).
- Tawfeeq, A. M., & Abdulrhman, H. B. (2021, May). Effect of mulching type on growth and yield of two cauliflower varieties (*Brassica oleracea* L. Var. Botrytis). In IOP Conference Series: *Earth and Environmental Science* (Vol. 761, No. 1, p. 012056). IOP Publishing.
- Timsina, D., Marahattha S., Sah S.K., Adhikari J.B., & Shrestha A. (2019). Evaluation of different types of mulching practices on weed management and productivity of winter maize in Chitwan, Nepal. *Journal of Research in Weed Science*, 2, 65–77.
- Tindall, J. A., Beverly, R. B., & Radcliffe, D. E. (1991). Mulch effect on soil properties and tomato growth using Micro- Irrigation. *Agronomy Journal*, 83(6), 1028–1034. USDA 2013 Agricultural research service National nutrient database for standard reference release 27
- Xie, Y., Li, J., Jin, L., Wei, S., Wang, S., Jin, N., Wang, J., Xie, J., Feng, Z., Zhang, G., Lyu, J., & Yu, J. (2022). Combined Straw and Plastic Film Mulching Can Increase the Yield and Quality of Open Field Loose-Curd Cauliflower. *Frontiers in Nutrition*, 9.

MONITORING AND MANAGEMENT OF FALL ARMYWORM, *Spodoptera frugiperda* (J.E. SMITH) (LEPIDOPTERA: NOCTUIDAE) ON MAIZE IN ROLPA, NEPAL

Biroj Belbase*, Kapil Kafle, Resham Bahadur Thapa and Dipak Khanal

Department of Entomology, Institute of Agriculture and Animal Science, Tribhuvan University, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Biopesticides, maize, monitoring, spinosad, <i>Spodoptera frugiperda</i> *Correspondence: brosebelbase@gmail.com Tel: +977 9843797804	A study was carried out in Rolpa Municipality-01, Mewang, Rolpa, Nepal, focusing on the monitoring and management of the fall armyworm, <i>Spodoptera frugiperda</i> (J.E. Smith) in 2023. The experiment was laid out in factorial RCBD having three biopesticides viz. spinosad 45% SC (0.3ml/liter), <i>Bacillus thuriangiensis</i> var. <i>kurstaki</i> 0.5% WP (2gm/liter) and <i>Metarhizium anisopliae</i> 2.0% A.S. (2×10^8cfu/ml) (5ml/liter) and frequency of application viz. spraying once, twice and thrice including control. Each treatment was replicated three times. Average moth count was calculated weekly on CropG1 Nazo-FAW lure trap and the results revealed that highest moth count (24 adults) was recorded on June 28 (i. e. 4 weeks after sowing). On completion of sprays, the lowest damage percentage was recorded on spinosad, spraying thrice (3.60%), but was statistically similar with spinosad, spraying twice (5.38%). The lowest larval count was recorded on spraying thrice (1.17) and cob damage was also recorded the lowest (1.07%). The highest yield was recorded with spinosad, spraying thrice (3.54 mt/ha) which was statistically similar with spinosad, spraying twice (3.49 mt/ha). Thus, spinosad, spraying twice was the most economic as well as effective treatment to manage <i>S. frugiperda</i>.

1. INTRODUCTION

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) is a notorious insect pest known for its high dispersal capacity, voracious feeding behavior, extensive host range, and high fecundity. These traits make it one of the most serious economic pests. It has the capability to attack over 353 plant species across 76 plant families, with a particular preference for the Poaceae family (106 species), Asteraceae family (31 species), and Fabaceae family (31 species) (Montezano et al., 2018). Native to the America, the fall armyworm predominantly targets cereal crops, with maize being a preferred host, though it can also cause significant damage to other crops such as rice, sorghum, sugarcane, cabbage, beet, groundnut, soybean, alfalfa, onion, pasture grasses, millet,

tomato, potato, and cotton (Prasanna et al., 2018).

The invasive nature of *S. frugiperda* has led to its rapid spread beyond the American continent (Early et al., 2018). First detected in Africa in 2016, it had spread to over 40 countries by 2018 (Goergen et al., 2016). In Asia, the fall armyworm was first identified in 2018, affecting maize crops in Karnataka, India (Shylesha et al., 2018). The Nepal Agricultural Research Council (NARC) reported the first sighting of *S. frugiperda*, locally known as American Fauji Kira, in the Nawalparasi district of western Nepal on May 9, 2019 (Bajracharya et al., 2019). Since its initial detection, *S. frugiperda* has rapidly spread to various countries including Bangladesh, Indonesia, Japan, Korea, Laos,

Therefore, to address the negative impacts of chemical pesticides, promoting the scientifically validated use of biopesticides

The experiment was conducted in Rolpa Municipality-01, Mewang, Rolpa, Nepal which has coordinates of latitude: 28.3000° N, longitude: 82.6333° E and elevation of 1500masl (Figure 1). As per Prime Minister Agriculture Modernization Project guidelines, Rolpa district is listed under maize zone. It has been identified as potential district for maize production both for grains and seed (Dhakal *et al*, 2022). Additionally, Rolpa is recognized as a potential site for *S. frugiperda* infestation (Sah et al., 2020). The texture of soil in experimental field was sandy loam with pH of 6.2.



2.2. Experimental design

Experiment was laid out in two factorial randomized complete block design RCBD having 12 treatments where factor one had 3 levels and factor two had 4 levels. The variety used was Manakamana-3. Individual plot size was 2.4m*3m=7.2m². There were four rows per plot. Row to row spacing was 60 cm and plant to plant spacing was maintained at 25 cm. There were 12 hills per row. Individual plots were spaced at 0.75m. Spacing between replications was 1m. In this way, gross area of experimental field was 11.2m*46.25m i.e. 518m² and the net cropped area was 259.20m².

2.3. Treatment details

The treatment details shown in the Table 1 outline three different biopesticides used for pest management, including their respective dosages and trade names.

Table 1. Biopesticides and their spray concentration

Factor 1	Biopesticide	Dosage	Trade name
A	Spinosad 45% SC	0.3ml/liter	Tracer
B	<i>Bacillus thuriangiensis</i> var. <i>kurstaki</i> 0.5 % WP	2gm/liter	Mahastra
C	<i>Metarhizium anisopliae</i> 2.0% A.S. (2× 10 ⁸ cfu/ml)	5ml/liter	Kalichakra

- Spinosad* 45% SC: This biopesticide, marketed under the trade name **Tracer**, was applied at the rate of 0.3 ml per liter of water.
- Bacillus thuriangiensis* var. *kurstaki* 0.5% WP: It is known commercially as **Mahastra**, which was used at a concentration of 2 grams per liter.
- Metarhizium anisopliae* 2.0% A.S.: This fungal biopesticide, with the trade name **Kalichakra**, was applied at the rate of 5 ml per liter.

The Table 2 details different spraying frequencies and their application timings.

Table 2. Frequency of spraying biopesticides

Factor 2	Spray frequency	Time
0	Control	
1	Spraying once	25 DAS (at VE–V5 stage)
2	Spraying twice	25, 38 DAS (at VE–V5, V6–V12 stage)
3	Spraying thrice	25, 38 and 52 DAS (at VE–V5, V6–V12 and V12–VT stages)

For the control, no spraying was applied. For one spray, it was done once at 25 days after sowing during the early growth stages. For two sprays, the first was at 25 days after sowing and the second at 38 days after sowing during later growth stages. For three sprays, applications were made at 25 DAS, 38 DAS, and 52 DAS across multiple growth stages. The treatment details and their frequency sprays are presented in Table 3.

Table 3. Details of treatments

Treatment number	Factors		Treatments (Combination)
	Insecticides	Frequency	
T1	A	0	A0 (Spinosad, control)
T2	A	1	A1 (Spinosad, Spraying once)
T3	A	2	A2 (Spinosad, Spraying twice)
T4	A	3	A3 (Spinosad, Spraying thrice)
T5	B	0	B0 (<i>Bacillus thuriangiensis</i> , control)
T6	B	1	B1 (<i>Bacillus thuriangiensis</i> , Spraying once)
T7	B	2	B2 (<i>Bacillus thuriangiensis</i> , Spraying twice)
T8	B	3	B3 (<i>Bacillus thuriangiensis</i> , Spraying thrice)
T9	C	0	C0 (<i>Metarhizium anisopliae</i> , control)
T10	C	1	C1 (<i>Metarhizium anisopliae</i> , Spraying once)
T11	C	2	C2 (<i>Metarhizium anisopliae</i> , Spraying twice)
T12	C	3	C3 (<i>Metarhizium anisopliae</i> , Spraying thrice)

The Table 3 presents different treatments based on insecticides and spraying frequencies. It categorizes treatments into three insecticide types-spinosad, *B. thuringiensis*, and *M. anisopliae*-with varying spray frequencies. Each treatment combines one of the insecticides with a specific frequency of spraying: none (control), once, twice, or thrice.

2.4. Statistical analysis

Data collection and analysis were conducted using the R programming language. The significance of the results was assessed through a one-way Analysis of Variance (ANOVA). Mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at a 5% significance level to determine statistically significant differences.

2.5. Monitoring Techniques

Fall armyworm (FAW) monitoring was conducted using the CropG1 Nazo-FAW lure in combination with a funnel trap. Traps were deployed immediately after planting, with moth counting initiated following seedling

emergence to ensure early detection. Each trap was placed in an open area near the field, suspended from a pole or branch approximately 1.5 meters above ground level. The trap density was maintained at one trap per 0.5 hectares. Moth counts were recorded at weekly intervals to track population dynamics and inform pest management decisions.

3. RESULTS AND DISCUSSION

3.1. Monitoring of fall armyworm

Pheromone lure monitoring revealed the highest fall armyworm incidence on June 28. As shown in Figure 2, weather conditions during this period included total precipitation of 70.49 mm, a maximum temperature of 28.5°C, a minimum temperature of 21°C, humidity at 77.86%, and a wind speed of 4.3 km/h. The moth population gradually declined from June 28 to July 19, followed by an increase until late July, with no recorded moth counts after the second week of August.

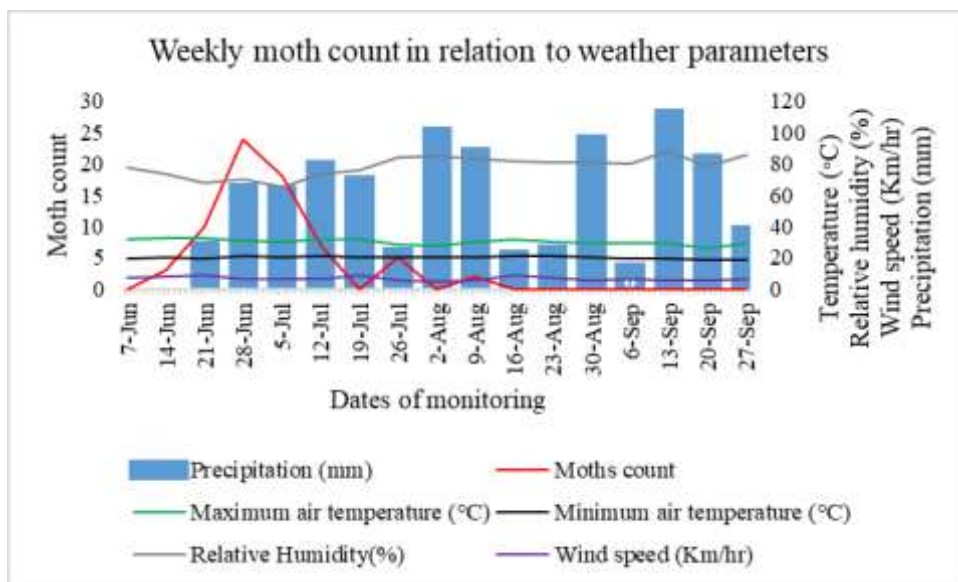


Figure 2. Graphical representation of weather parameters and moth count

3.2. Leaf damage percentage

Table 4 illustrates the interaction effects of biopesticides and spray frequencies on maize

leaf damage, revealing significant variations across treatments.

Table 4. Effect of interaction between biopesticides and spray frequencies on damage percentage of maize leaf after 1st spray

Treatment	Damage percentage		
	After 1 st spray	After 2 nd spray	After 3 rd spray
A0 (Spinosad, control)	18.65±0.25 ^a	21.14±0.26 ^a	20.62±0.94 ^a
A1 (Spinosad, Spraying once)	10.55±1.19 ^d	9.65±0.45 ^d	10.62±0.52 ^c
A2 (Spinosad, Spraying twice)	11.01±0.36 ^d	7.08±1.03 ^e	5.38±0.62 ^d
A3 (Spinosad, Spraying thrice)	10.55±0.21 ^d	7.09±1.02 ^e	3.60±0.42 ^d
B0 (<i>Bacillus thuriangiensis</i> , control)	18.36±0.31 ^a	20.91±0.64 ^a	20.15±0.23 ^a
B1 (<i>Bacillus thuriangiensis</i> , Spraying once)	17.12±0.21 ^{ab}	15.25±0.90 ^b	13.63±0.47 ^b
B2 (<i>Bacillus thuriangiensis</i> , Spraying twice)	17.25±0.34 ^{ab}	13.71±0.55 ^{bc}	11.91±0.59 ^{bc}
B3 (<i>Bacillus thuriangiensis</i> , Spraying thrice)	17.13±0.21 ^{ab}	13.67±0.69 ^{bc}	9.78±0.23 ^c
C0 (<i>Metarrhizium anisopliae</i> , control)	18.99±1.41 ^a	20.61±0.68 ^a	19.25±0.17 ^a
C1 (<i>Metarrhizium anisopliae</i> , Spraying once)	15.03±0.51 ^c	13.06±0.42 ^{bc}	13.80±0.05 ^b
C2 (<i>Metarrhizium anisopliae</i> , Spraying twice)	15.48±0.61 ^c	12.24±1.40 ^c	11.13±0.56 ^{bc}
C3 (<i>Metarrhizium anisopliae</i> , Spraying thrice)	14.68±0.34 ^c	11.99±0.54 ^c	9.78±0.60 ^c
F-test	***	**	**
LSD _{0.05}	1.90	2.17	2.65
CV%	7.30	9.26	12.46

LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability

After the initial application, the lowest leaf damage (10.55%) was observed in plots treated with spinosad (one and three sprays), showing no statistical difference from spinosad (two sprays), whereas the highest damage was recorded in the untreated control plots.

Following the second application, the least damage (7.08%) occurred in the spinosad

(two-spray) treatment, statistically comparable to spinosad (three sprays), while the control plots exhibited the highest damage. After the third spray, spinosad (three sprays) resulted in the lowest damage (3.60%), with no significant difference from the two-spray treatment, whereas the control plots consistently sustained the highest damage levels.

3.3. Damage scoring

Table 5 presents the damage scores recorded across different treatments.

Table 5. Damage score from scoring scale where score ranges from 0 to 5

Treatment	AFS	ASS	ATS
A0 (Spinosad, control)	3	4	3
A1 (Spinosad, Spraying once)	3	3	2
A2 (Spinosad, Spraying twice)	2-3	2	1
A3 (Spinosad, Spraying thrice)	3	1-2	0
B0 (<i>Bacillus thuriangiensis</i> , control)	3-4	3	2
B1 (<i>Bacillus thuriangiensis</i> , Spraying once)	3-4	3	3
B2 (<i>Bacillus thuriangiensis</i> , Spraying twice)	3	2-3	2
B3 (<i>Bacillus thuriangiensis</i> , Spraying thrice)	3	2	2
C0 (<i>Metarrhizium anisopliae</i> , control)	3-4	3	3
C1 (<i>Metarrhizium anisopliae</i> , Spraying once)	2-3	3	2
C2 (<i>Metarrhizium anisopliae</i> , Spraying twice)	3	2	1
C3 (<i>Metarrhizium anisopliae</i> , Spraying thrice)	2-3	2	0

AFS: After 1st spray, ASS: After 2nd spray, ATS: After 3rd spray

Following the first spray, the lowest damage score (2–3) was observed in plots treated with spinosad (one spray), *M. anisopliae* (one spray), and *M. anisopliae* (three sprays). In contrast, the highest damage score (3–4) was recorded in treatments with *B. thuringiensis* than no spray and one spray, and *M. anisopliae* than no spray.

After the second application, the maximum damage score (4) was observed in the untreated spinosad control plots, while the lowest score (2) was recorded in treatments with spinosad (two sprays), *B. thuringiensis* (three sprays), *M. anisopliae* (two sprays), and *M. anisopliae* (three sprays). Following the third spray, a damage score of zero was recorded in plots treated with spinosad (three sprays) and *M. anisopliae* (three sprays). Conversely, the highest damage score (3) was observed in the untreated, no spinosad spray, *B. thuringiensis* (one spray), and *M. anisopliae* no spray.

3.4. Larval count

Tables 6-9 present the impact of different biopesticides on the total larval count of *S. frugiperda*. The results indicate no significant differences in larval count among the biopesticide treatments. The total larval count was recorded as 1.58 in plots treated with spinosad, while treatments with *B. thuringiensis* and *M. anisopliae* yielded counts of 1.45.

Table 6. Effect of different bio-pesticides on total larval count of *S. frugiperda*

Factor 1 (Biopesticide)	Total larval count (No)
A (Spinosad)	1.58±0.18
B (<i>Bacillus thuringiensis</i>)	1.45±0.15
C (<i>Metarhizium anisopliae</i>)	1.45±0.17
F-test	ns
LSD _{0.05}	0.40
CV%	31.62

LSD: Least significant difference, CV: Coefficient of variation, ns= Non-significant

Table 7. Effect of spray frequencies on larval count of *S. frugiperda*

Factor 2 (Spray frequency)	Total larval count (No.)
0 (Control)	2.14±0.18 ^a
1 (Spraying once)	1.45±0.09 ^b
2 (Spraying twice)	1.21±0.13 ^b
3 (Spraying thrice)	1.17±0.13 ^b
F-test	***
LSD _{0.05}	0.46
CV%	31.62

LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. ns= Non-significant, *=significant at 5% probability level, **=significant at 1% probability, ***=significant at 0.1% probability, Values after ± indicate standard error.

Table 7 illustrates the impact of different spray frequencies on the larval count of *S. frugiperda*. A notable variation in the total larval count was observed across the various spray frequencies. The lowest larval count was recorded with three applications (1.17), which was statistically comparable to the counts observed with one (1.45) and two (1.21) spray applications.

3.5. Cob damaged percentage

Table 8 illustrates the impact of various biopesticides on the percentage of cob damage. No significant differences were observed in the cob damage percentages across the different biopesticides. The damage percentages were recorded as 1.95 for spinosad, 1.81 for *B. thuringiensis*, and 1.43 for *M. anisopliae*.

Table 8. Effect of biopesticides on cob damaged percentage

Factor 1 (Biopesticide)	Cob damaged (%)
A (Spinosad)	1.95±0.28
B (<i>Bacillus thuringiensis</i>)	1.81±0.21
C (<i>Metarhizium anisopliae</i>)	1.43±0.22
F-test	ns
LSD _{0.05}	0.65
CV%	44.93

LSD: Least significant difference, CV: Coefficient of variation, ns= Non-significant

Table 9. Effect of spray frequencies on cob damaged percentage

Factor 2 (Spray frequency)	Cob damaged (%)
0 (Control)	2.34±0.23 ^a
1 (Spraying once)	2.00±0.20 ^{ab}
2 (Spraying twice)	1.50±0.30 ^{bc}
3 (Spraying thrice)	1.07±0.19 ^c
F-test	*
LSD _{0.05}	0.76
CV%	44.93

LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. ns= Non-significant, *=significant at 5% probability level, **=significant at 1% probability, ***=significant at 0.1% probability, Values after ± indicate standard error.

Table 9 illustrates the effect of different spray frequencies on the percentage of cob damage. A significant variation in cob damage percentages was observed across the various

spray frequencies. The lowest damage percentage was recorded with three spray applications (1.07%), while the highest percentage (2.34%) was observed in the control group.

3.6. Yield of maize

Table 10 illustrates the impact of the interaction between biopesticides and spray frequencies on maize yield. Significant variations in maize yield were observed across the different combinations of biopesticides and spray frequencies. The highest yield (3.54 mt/ha) was recorded with spinosad applied three times, which was statistically comparable to spinosad applied twice (3.49 mt/ha). This was followed by *M. anisopliae* with three spray applications (2.23 mt/ha) and spinosad applied once (2.01 mt/ha).

Table 10. Effect of interaction between biopesticides and spray frequencies on yield of maize

Treatments (Combination)	Yield (mt/ha)
A0 (Spinosad, control)	0.93 ^{gh}
A1 (Spinosad, Spraying once)	2.01 ^d
A2 (Spinosad, Spraying twice)	3.49 ^a
A3 (Spinosad, Spraying thrice)	3.54 ^a
B0 (<i>Bacillus thuringiensis</i> , control)	0.88 ^h
B1 (<i>Bacillus thuringiensis</i> , Spraying once)	1.09 ^{fg}
B2 (<i>Bacillus thuringiensis</i> , Spraying twice)	1.23 ^f
B3 (<i>Bacillus thuringiensis</i> , Spraying thrice)	1.55 ^e
C0 (<i>Metarhizium anisopliae</i> , control)	0.86 ^h
C1 (<i>Metarhizium anisopliae</i> , Spraying once)	1.27 ^f
C2 (<i>Metarhizium anisopliae</i> , Spraying twice)	1.81 ^d
C3 (<i>Metarhizium anisopliae</i> , Spraying thrice)	2.23 ^b
F-test	***
LSD _{0.05}	0.18
SEm(±)	0.0144
CV%	5.85

SEm: Standard error of means. LSD: Least significant difference. CV: Coefficient of variation. Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance. ns= Non-significant, *=significant at 5% probability level, **= significant at 1% probability, ***=significant at 0.1% probability

3.7. Benefit-cost ratio

Table 11 presents the benefit-cost ratio, highlighting the highest ratio of 1.99 for spinosad applied twice, despite the highest yield of 3.54 mt/ha being observed with

spinosad applied three times. The lowest benefit-cost ratio of 0.55 was recorded with *B. thuringiensis* in the control group, followed closely by spinosad in the control group with a ratio of 0.58.

Table 11. Benefit-cost ratio

Treatments	Yield (mt/ha)	Gross return (NPR)	Cost of cultivation (NPR)	B:C ratio
A0 (Spinosad, control)	0.93	23250	39932.97	0.58
A1 (Spinosad, Spraying once)	2.01	50250	41821.74	1.20
A2 (Spinosad, Spraying twice)	3.49	87250	43733.28	1.99
A3 (Spinosad, Spraying thrice)	3.54	88500	45452.81	1.95
B0 (<i>Bacillus thuriangiensis</i> , control)	0.88	22000	39932.97	0.55
B1 (<i>Bacillus thuriangiensis</i> , Spraying once)	1.09	27250	40828.51	0.67
B2 (<i>Bacillus thuriangiensis</i> , Spraying twice)	1.23	30750	41323.49	0.74
B3 (<i>Bacillus thuriangiensis</i> , Spraying thrice)	1.55	38750	42626.68	0.89
C0 (<i>Metarhizium anisopliae</i> , control)	0.86	21500	39932.97	0.91
C1 (<i>Metarhizium anisopliae</i> , Spraying once)	1.27	31750	41421.33	0.77
C2 (<i>Metarhizium anisopliae</i> , Spraying twice)	1.81	45250	42978.29	1.05
C3 (<i>Metarhizium anisopliae</i> , Spraying thrice)	2.23	55750	44182.72	1.26

Maize @ Rs. 25 per kg as per local market price, NPR= Nepalese Rupees

3.8. Discussion

3.8.1. Monitoring of fall armyworm

Severe outbreaks of fall armyworm often coincide with the onset of the wet season, particularly when the new cropping season follows a prolonged drought. This pattern aligns with the findings of Niassy *et al.* (2021). These outbreaks frequently occur during the early vegetative stage of the crop. The highest moth count in the last week of June indicates the peak abundance of fall armyworm adults four weeks after sowing, when the crop is at the eight-leaf stage (V8 stage). The high adult population at this stage signifies that the crop is highly susceptible to damage by fall armyworm larvae. Interestingly, although rainfall remains high after this stage, the fall armyworm population does not increase correspondingly. This suggests that the crop stage also affects the pest outbreak. Similar results were found in a study conducted in the Noakhali region of Bangladesh, which reported that major pest infestations on soybean crops peaked during the flowering and pod formation stages (Biswas, 2013). Therefore, applying biopesticides during the early vegetative stage is crucial to prevent crop damage. Skipping pesticide application during this stage would be ineffective.

3.8.2. Effect of different treatments on damage percentage and damage scoring

An increase in the spray frequency of each biopesticide significantly reduces damage percentage, indicating a stronger impact on pest management. Damage percentage reflects the overall severity of field damage, while the damage score quantifies the intensity of larval damage. After the third spray, fall armyworm damage was minimal with spinosad (applied three times), and the least intense damage was observed with both spinosad and *M. anisopliae* (each applied three times). Spinosad was found to be the most effective among all and similar result was obtained by Bajracharya *et al.* (2020). Spinosyns disrupt nicotinic acetylcholine receptors and the resistance phenomenon is uncommon (Bacci *et al.*, 2016). Nepal lacks a standardized extraction method for biological insecticides, leading to reliance on imports from India. Improper temperature and humidity during storage and transportation reduce their viability. Establishing domestic biopesticide production with standardized extraction methods could enhance efficiency and effectiveness.

3.8.3. Effect of different treatments on larval count and cob damaged percentage

The larval counts did not vary significantly among biopesticides, however, spray frequency had a notable impact. Even a single application of each biopesticide reduced larval count. Similarly, cob damage percentage did not differ significantly among biopesticides, but spray frequency had a significant effect. Thus, increased application frequency effectively reduced larval presence in silk and cobs, minimizing cob damage.

3.8.4. Effect of different treatments on yield and benefit-cost ratio (B:C ratio)

Damage to vegetative as well as reproductive parts contribute to reduction in yield. Damage to vegetative stage reduces the amount of photosynthates formed by reducing the area of photosynthesis. Similarly, damage to reproductive parts by *S. frugiperda* impacts on fertilization and grain formation and thus reduction in yield (Tambo et al., 2020). Plots treated with spinosad, spraying thrice resulted in highest yield but because of its higher price, spinosad, spraying twice was found to be most economic.

4. CONCLUSION

The highest moth count (24 adults) was recorded on June 28 (i. e. 4 weeks after sowing) which coincided with the onset of the wet season when the new cropping season followed a long period of drought. On completion of three sprays, the lowest damage percentage (3.60%) was recorded on three sprays of spinosad which was statistically similar with spinosad, spraying twice representing them least severely affected by *S. frugiperda* larvae and the highest damage percentage was recorded on control treatment of each biopesticides suggesting them the most severely affected by fall armyworm larvae. Zero damage score was recorded on spinosad, spraying thrice and *M. anisopliae*, spraying thrice representing them the least intensely damaged plots while maximum damage score (3) was recorded on treatments spinosad, control, *B. thuriangiensis*, spraying once and *M. anisopliae*, control. Larval count decreased with increase in spray frequency of biopesticides. Although, the highest yield was recorded with three sprays of spinosad, b:c ratio was found to be the highest on two sprays of spinosad revealing it to be the most economic.

REFERENCES

- Bacci, L., Lupi, D., Savoldelli, S., & Rossaro, B. (2016). A review of spinosyns, a derivative of biological acting substances as a class of insecticides with a broad range of action against many insect pests. *Journal of Entomological and Acarological Research*, 48(1), 40–52.
- Bajracharya, A.S.R., Bhat, B., & Sharma, P. (2020). Field efficacy of selected insecticides against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in maize. *Journal of the Plant Protection Society*, 6, 127–133. <https://doi.org/10.3126/jpps.v6i0.36479>
- Bajracharya, A.S.R., Bhat, B., Sharma, P., Shashank, P. R., Meshram, N. M., & Hashmi, T. R. (2019). First record of fall army worm, *Spodoptera frugiperda* (J. E. Smith) from Nepal. *Indian Journal of Entomology*, 81(4), 635.
- Biswas, G. (2013). Insect pests of soybean (*Glycine max* L.), their nature of damage and succession with the crop stages. *Journal of the Asiatic Society of Bangladesh Science*, 39(1), 1–8. <https://doi.org/10.3329/jasbs.v39i1.16027>
- Brar, S. K., Verma, M., Tyagi, R. D., & Valéro, J. R. (2006). Recent advances in downstream processing and formulations of *Bacillus Thuringiensis* Based Biopesticides. *Process Biochemistry*, 41(2), 323–342. <https://doi.org/10.1016/j.procbio.2005.07.015>
- Day, R., Abrahams, P., Bateman, M., Beale, T., Clotley, V., Cock, M., Colmenarez, Y., Corniani, N., Early, R., Godwin, J., Gomez, J., Moreno, P. G., Murphy, S. T., Oppong-Mensah, B., Phiri, N., Pratt, C., Silvestri, S., & Witt, A. (2017). Fall armyworm: Impacts and implications for Africa. *Outlooks on Pest Management*, 28(5), 196–201. https://doi.org/10.1564/v28_oct_02
- Early, R., González-Moreno, P., Murphy, S. T., & Day, R. (2018). Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. *NeoBiota*, 40, 25–50. <https://doi.org/10.3897/neobiota.40.28165>
- Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A., & Tamò, M. (2016). First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), A new alien invasive pest in West and Central Africa. *PLoS ONE*, 11(10), 1–9. <https://doi.org/10.1371/journal.pone.0165632>
- Jiang, Y., & Wang, J. (2023). The registration situation and use of mycopesticides in the world. *Journal of Fungi*, 9(9), 940. <https://doi.org/10.3390/jof9090940>
- Khanal, D., Subedi, D., Banjade, G., Lamichhane, M., Shrestha, S., & Chaudhary, P. (2024a). Efficacy of different pesticides against fall armyworm (*Spodoptera frugiperda* (J.E. Smith) Lepidoptera: Noctuidae) under laboratory conditions in Rupandehi, Nepal. *International Journal of Agronomy*, (1). <https://doi.org/10.1155/2024/7140258>
- Khanal, D., Kunwar, M., Bista, P., Kandel, P., Thapa, S., Pun Magar, S., Lamsal, K., Chaudhary, P., & Pandey, P. (2024b). Farmer's knowledge and management practices of fall armyworm in major maize-producing districts of Nepal. *The Journal of Agriculture and Environment*, 25, 179–188
- Montezano, D. G., Specht, A., Sosa-Gómez, D. R., Roque-Specht, V. F., Sousa-Silva, J. C., Paula-Moraes, S. V., Peterson, J. A., & Hunt, T. E. (2018). Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *African Entomology*, 26(2), 286–300. <https://doi.org/10.4001/003.026.0286>
- Niassy, S., Agbodzavu, M. K., Kimathi, E., Mutune, B., Abdel-Rahman, E. F. M., Salifu, D., Hailu, G., Belayneh, Y. T., Felege, E., Tonnang, H. E. Z., Ekesi, S., & Subramanian, S. (2021). Bioecology of fall armyworm *Spodoptera frugiperda* (J. E. Smith), its management and potential patterns of seasonal spread in Africa. *PLoS ONE*, 16, 1–24. <https://doi.org/10.1371/journal.pone.0249042>
- Prasanna, B., Huesing, J. E., Eddy, R., & Peschke, V. M. (2018). Fall armyworm in Africa: A guide for integrated pest management. *Mexico*.
- Sah, L. P., Lamichhane, D., KC, H. B., Acharya, M. C., Humagain, S. P., Bhandari, G., & Maniappan, R. (2020). Fall armyworm (*Spodoptera frugiperda*) in maize: Current status and collaborative efforts for its management in Nepal. *Journal of the Plant Protection Society*, 6, 53–64. <https://doi.org/10.3126/jpps.v6i0.36472>
- Shylesha, A. N., Jalali, S. K., Gupta, A., Varshney, R., Venkatesan, T., Shetty, P., Ojha, R., Ganiger, P. C., Navik, O., Subaharan, K., Bakthavatsalam, N., Ballal, C. R., & Raghavendra, A. (2018). Studies on new invasive pest *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) and its natural enemies. *Journal of Biological Control*, 32(3), 145–151. <https://doi.org/10.18311/jbc/2018/21707>
- Sparks, A. N. (1979). A review of the biology of the fall armyworm. *The Florida Entomologist*, 62(2), 82–87. <https://doi.org/10.2307/3494083>
- Tambo, J. A., Day, R. K., Lamontagne-Godwin, J., Silvestri, S., Beshe, P. K., Oppong-Mensah, B., Phiri, N. A., & Matimelo, M. (2020). Tackling fall armyworm (*Spodoptera frugiperda*) outbreak in Africa: An analysis of farmers' control actions. *International Journal of Pest Management*, 66(4), 298–310. <https://doi.org/10.1080/09670874.2019.1646942>
- Thapa, S., Piras, G., Thapa, S., Goswami, A., Bhandari, P., & Dahal, B. (2021). Study on farmers' pest management strategy, knowledge on pesticide safety and practice of pesticide use at Bhaktapur district, Nepal. *Cogent Food and Agriculture*, 7(1). <https://doi.org/10.1080/23311932.2021.1916168>

KNOWLEDGE AND ADOPTION OF RECOMMENDED TECHNOLOGY BY
WHEAT FARMERS IN SUNWAL, NAWALPARASI WEST, NEPAL

Pratikshya Pandey¹, Pankaj Raj Dhital², Puspa Raj Dulal¹ and Naran Prasad Devkota^{1,*}

¹ Agriculture and Forestry University, Rampur, Chitwan
² Department of Agricultural Extension and Rural Sociology, Agriculture and Forestry University, Rampur, Chitwan, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Adoption, Binary logit regression, Profitability, Recommended technology, Wheat *Correspondence: devkotanarayan0403@gmail.com Tel: +977-9840518856	<i>Adoption of resource-efficient and sustainable wheat cultivation technologies is crucial for enhancing agricultural sustainability and increasing productivity. However, these practices are still in their nascent stage among Nepalese wheat farmers. This study was conducted to comprehend the factors influencing adoption, adoption levels, and knowledge of recommended wheat cultivation technologies among 146 randomly sampled wheat farming households in Sunwal. Wheat growers were segregated into high and low adopter groups. It was found that 32.19% of respondents were aware of recommended practices like improved seeds, optimum sowing dates, fertilizer application, irrigation scheduling, and weeding. The average wheat farming area for the respondents was 0.50 ha, about 80 percent of household heads were male, and 57.53 percent were cooperative members. Membership in cooperatives and access to subsidies demonstrated a direct relationship with the adoption of recommended technology in the binary logit regression model, as cooperatives serve key platforms for knowledge distribution and resource sharing. The study demonstrated that high adopters significantly improved their application of FYM, sowing dates, and seed rates as well as their irrigation scheduling. Resolving irrigation infrastructure issues, alongside improving access to fertilizers, quality seeds, and enhanced extension services, would boost wheat productivity and profitability in Sunwal.</i>

1. INTRODUCTION

One of the most pertinent cereals for Nepalese agricultural producers is wheat (*Triticum aestivum* L.) (Bhatta *et al.*, 2020). It ranks after rice and corn in production, despite its widespread cultivation in diverse climatic regions from hot and humid zones to frigid areas (Poudel *et al.*, 2021). It is harvested in March or April after being grown in November or December, according to Bastakoti & Poudel (2022). The extensive spread of wheat fails to satisfy the increasing food demand because farms in Nawalparasi are decreasing and farmers maintain traditional agricultural methods (Poudel *et*

al., 2021). Modern agricultural technologies face limited adoption mainly because of farmers' social and economic challenges coupled with their lack of awareness and lack of technical expertise. To enhance agricultural sustainability, productivity, and profitability, recommended wheat cultivation technologies have been developed (Joshi *et al.*, 2019). These technologies contains a set of scientifically verified techniques, including integrated pest management (IPM) and soil fertility management besides sufficient fertilizer application along with efficient water scheduling, all aimed to enhance wheat productivity without

compromising environmental and financial viability (Singh *et al.*, 2022). The adoption of such technology brings three main benefits, which include improvements in soil organic matter levels, reductions in chemical fertilizer use, and increased financial gains and wheat yield for farmers (Kharel *et al.*, 2022). However, adoption of such technology in Nepal remains at a low level due to inadequate knowledge, which hinders the possible benefits (Joshi *et al.*, 2019). Limited irrigation systems, combined with insufficient extension services, act as a barrier for farmers to adopt resilient wheat cultivation technology (Dhakal, 2019). Although, an international framework such as Good Agricultural Practices (GAP) prioritizes similar principles, this study specifically focuses on nationally recommended wheat cultivation technology by National Wheat Research Programme (NWRP). This study thus examines the recommended technology adoption practices of wheat farmers residing in Sunwal, Nawalparasi West, while investigating factors influencing adoption and major wheat production barriers. The results will help sustain wheat farming through improved resource efficiency together with modern farming methods, which enable higher productivity along with profitability.

2. MATERIALS AND METHODS

2.1 Research site

This study was conducted in wards 2, 6, 9, 11, and 12 of Sunwal Municipality, Nawalparasi West, Nepal. These sites were purposively selected due to their prominence as major wheat-producing areas.

2.2 Sampling techniques

Sunwal municipality offered a sampling frame for wheat-growing farmers from the pocket and zone areas. A combination of purposive and random sampling techniques was used to select respondents. A total of 146 sample size was calculated using Yamane's formula (1967);

$$n = \frac{N}{1+N(e^2)}$$

Where N = population size

e = margin of error

n = sample size

2.3 Sources of data

Primary data were acquired via surveying households and key informant interviews. Secondary data were collected from relevant research papers, annual reports, journals, statistical yearbooks, and other published materials.

2.4 Techniques of data acquisition

Data were collected through pre-tested semi-structured interview schedules with wheat farmers. The information about socio-economic conditions, knowledge of recommended technology, factors affecting recommended technology, and constraints associated with wheat production were discussed.

2.5 Data analysis techniques

2.5.1 Test of independence

The chi-square test of independence was conducted to assess the relationship between the high-adopter and low-adopter farmer groups and other variables.

According to Nepal *et al.* (2023),

$$X^2 = \sum \frac{(O_{ij} - e_{ij})^2}{e_{ij}}$$

Where X^2 = Chi-square,

O_{ij} = Observed frequency of each ij^{th} term

e_{ij} = Expected frequency of each ij^{th} term

$i = 1, 2, 3, \dots, r$

$j = 1, 2, 3, \dots, k$

2.5.2 Recommended wheat cultivation technology

A framework for wheat cultivation, developed by the National Wheat Research Programme (NWRP) in Bhairahawa, was utilized as the standard criterion to assess the level of recommended technology adoption among the wheat growers. This framework outlines recommended practices in key management areas such as sowing period, seed rate, fertilizer application, irrigation, and weeding, as shown in Table 1. Although, sowing date and seed rate may differ by variety, the 2nd week to the last week of November and 120 kg/ha represents the optimal sowing window and seed rate, respectively, for the majority of wheat varieties predominantly grown in Sunwal.

Table 1. Recommended cultivation technology based on NWRP guidelines used for assessment

Management practices	Recommended practices	References
Sowing period	2 nd week of Nov. to last week of Nov	(Bastakoti & Poudel, 2022)
Seed rate	120 kg/ha	(Akhter <i>et al.</i> , 2017)
Fertilizer application	100:50:50 NPK kg/ha	(Maiti <i>et al.</i> , 2006)
Irrigation	6-7 irrigation	(Aryal <i>et al.</i> , 2020)
Weeding Time	20 and 40 DAS	(Aryal <i>et al.</i> , 2020)

2.5.3 Determinants of awareness of recommended technology among wheat growers

A binary logit regression model was applied to identify factors influencing adoption of recommended technology, following Shrestha *et al.* (2024). The dependent variable was technology adopters (1 = high adopters, 0 = low adopters), and explanatory variables included ethnicity, family size, years of schooling, training, cooperative membership, subsidy receipt, and access to irrigation.

According to Shrestha *et al.* (2024),

$$Y_i (\text{adoption}=1) = b^0 + b^1X^{1i} + b^2X^{2i} \dots + b^kX^{ki} + e^i$$

Where Y_i = i th observation of dependent variables, Y_i = Technology adoption level (dummy)

$X_1 \dots X_7$ = explanatory variables

b_0 = intercept term (constant)

b_j = coefficient for each of the independent variables

e_i = error

X_{ji} = i^{th} observation of j^{th} independent variables

$i = n$ = number of observation = 146

2.5.4 Problem ranking for major constraints in wheat cultivation

To prioritize the major constraints faced by farmers in wheat cultivation, a force-ranking technique was employed using the following formula:

$$I = \sum \frac{Sifi}{N}$$

Where I = Index of problem

$\sum$ = Summation

S_i = Scale value (0.2, 0.4, 0.6, 0.8, & 1.0)

f_i = Frequency of responses for each problem

N = Total sample size

2.5.5 Categorization of farmers into high and low adopters

Following the data collection from a total of 146 respondents, wheat farmers were categorized into high adopters ($n = 47$) and low adopters ($n = 99$) groups of recommended technology. This classification was conducted after data entry, based on each farmer's adherence to the nationally recommended wheat cultivation practices outlined by the NWRP (as in Table 1). Farmers were categorized based on the number of recommended practices adopted—such as appropriate sowing time, seed rate, fertilizer application, irrigation scheduling, and weeding. Those adopting more than half (≥ 3 practices out of 5) were classified as high adopters, while those adopting (< 3 practices out of 5) were categorized as low adopters.

3. RESULTS AND DISCUSSION

3.1 Demographic and socio-economic information

As presented in Table 2, the research revealed that the degree of knowledge of recommended technology among farmers is directly connected to three variables, including the major occupation of the household head, cooperative involvement, and subsidy benefits. The study showed that awareness of recommended technology did not show any meaningful relationships with either the gender of the household head or training participation. Farmers who engage in agricultural activities and join cooperatives, along with receiving subsidies, tend to exhibit greater awareness of recommended technology. Male household heads predominated across both farmer categories, and these families mainly depended on agricultural activities for their livelihood. A majority of respondents have received both subsidies and participated in agriculture cooperatives, yet many had received minimal training, regardless of their technology adoption.

The research findings matched the results presented in earlier studies. During their research, Adhikari and Thapa (2023) determined that occupation and institutional involvement play essential roles in Nepalese farmers' adoption of improved agricultural technologies, aligning with the recommended wheat cultivation technology in this study. The research from Ojha *et al.* (2024) demonstrated how farmers' access to training

and extension programs improved their knowledge of improved agricultural practices. However, our study did not observe a similar correlation with the adoption of recommended technology. This discrepancy may be attributed to inadequate wheat-specific focus in training and farmers relying more on peer influence than formal education.

Table 2. Bivariate analysis of the categorical variables with farmers’ category in Sunwal, 2024

Variables	Overall (n=146)	Farmer’s category		Chi-square value	p-value
		High-adopters (n=47)	Low-adopters (n=99)		
Gender of HHH					
Male	116(79.45)	38(80.85)	78(78.79)	0.083	0.773
Female	30(20.55)	9(19.15)	21(21.21)		
Major Occupation of HHH					
Agriculture	114(79.45)	45(95.74)	69(69.70)	17.92***	<0.001
Others	30(20.55)	2(4.26)	30(30.30)		
Training received					
Yes	45(30.82)	16(34.04)	29(29.29)	0.337	0.561
No	101(69.18)	31(65.96)	70(70.71)		
Membership in Cooperatives					
Yes	84(57.53)	42(89.36)	42(42.42)	28.73***	<0.001
No	62(42.47)	5(10.64)	57(57.58)		
Subsidy received					
Yes	108(73.97)	43(91.49)	65(65.66)	11.04***	<0.001
No	38(26.03)	4(8.51)	34(34.34)		

Note: Figures in parenthesis indicate standard deviation, *** indicate 1% level of significance and HHH: Household Head

Table 3 illustrates that high adopters of recommended technology have longer farming experience and achieve superior crop yields, with significant differences at a 1% level compared to low-adopters. These farmers tend to have extensive farming backgrounds and achieve better crop yields.

The research data demonstrate that experience in farming, combined with higher productivity, enhances awareness regarding recommended technology. In contrast, family size, education level, and land ownership practices do not have any significant impact on the adoption of recommended technology.

Table 3. Bivariate analysis of the continuous variables with farmers’ category in Sunwal, 2024

Variables	Overall (n=146)	Farmer’s category		Mean difference	t-value	p-value
		High-adopters (n=47)	Low-adopters (n=99)			
Total Family Member	7.17(2.93)	6.97 (3.39)	7.26 (2.70)	-0.28	-0.54	0.586
Year of Schooling (Year)	8.32(2.52)	8.61(2.44)	8.11(2.58)	0.49	0.84	0.402
Farming experience (Year)	12.70(5.81)	16.12(6.21)	11.08(4.86)	5.04	5.34***	<0.001
Yield (ton/ha)	1.30(1.25)	2.56(1.91)	1.19(1.17)	1.37	5.32***	<0.001
Total owned khet (ha)	1.05(0.90)	1.04(0.91)	1.05(0.90)	-0.01	-0.05	0.956
Wheat cultivated land (ha)	0.50(0.49)	0.51(0.46)	0.50(0.51)	0.01	0.05	0.956
Irrigated land (Wheat)	0.53(0.56)	0.62(0.72)	0.48(0.46)	0.14	-1.32	0.188
Rainfed land (Wheat)	0.44(0.48)	0.33(0.16)	0.29(0.28)	0.04	0.20	0.837

Note: Figures in parenthesis indicate standard deviation and *** indicate 1% level of significance

3.2 Cultivation practices between high-adopters and low-adopter farmers

Table 4 presents the extent of farmers' adoption of recommended technology, emphasizing varied farming practices. Evidence from the study established important relationships between recommended technology adoption and various agricultural practices. High-adopters sowed their crops during the 4th week of October and followed the Rice-Wheat-Maize cropping pattern and obtained their fertilizer from organic sources. These farmers also applied MOP, participated in weeding activities, and performed weeding manually. According to Shah *et al.* (2019), manual weeding techniques play a significant role in affecting wheat productivity. High-adopters of recommended technology irrigated their fields twice and used Chlorpyrifos for controlling chewing and soil pests, and

Imidacloprid for sap-sucking pests, respectively. These farmers conducted their crop harvest during March, yet low-adopters split their harvest time between March and April. Soil testing was done more frequently by high-adopters than by low-adopters. High-adopters utilize wheat straw consistently for residue management. The result demonstrates technology adoption remains vital, as it supports sustainable agricultural systems and promotes long-term productivity (Safety Culture, 2024). Conversely, no notable variations were found in the choice of varieties, top dressing of urea, application of zinc, and harvesting methods, indicating that awareness of recommended technology does not uniformly influence all aspects of cultivation. Similar to Nepal *et al.* (2023), farmers aware of recommended technology perform better cultivation practices.

Table 4. Assessment of cultivation practices by adoption level in Sunwal, 2024

Cultivation practices	Overall (n=146)	Farmer's category		Chi-square value	p-value
		High-adopters (n=47)	Low-adopters (n=99)		
Variety					
Local	11(7.53)	5(10.64)	6(6.06)	2.73	0.255
Hybrid	3(2.05)	2(4.26)	1(1.01)		
Improved	132(90.41)	40(85.11)	92(92.93)		
Sowing Date					
4 th week of October	117(80.14)	25(53.19)	92(92.93)	31.61***	<0.001
2 nd week of November	29(19.86)	22(46.81)	7(7.07)		
Cropping pattern					
Rice-Wheat-Maize	140(95.89)	47(100)	93(93.94)	2.97*	0.085
Rice-Wheat-Mustard	6(4.11)	0(0.00)	6(6.06)		
Organic fertilizer					
Yes	116(79.45)	47(100.00)	69(69.70)	17.92***	<0.001
Urea top dressing					
25 DAS	1(0.68)	0(0.00)	1(1.01)	0.47	0.489
30 DAS	145(99.32)	47(100.00)	98(98.99)		
MOP used					
Yes	82(56.16)	47(100.00)	35(35.35)	54.09***	<0.001
Zinc used					
No	131(89.73)	42(89.36)	89(89.90)	0.010	0.920
Weeding practices					
Yes	137(93.84)	47(100.00)	90(90.91)	4.55**	0.033
Weeding method					
Manual	119(88.15)	45(100.00)	74(82.22)	9.07***	<0.001
Chemical	16(11.85)	0(0.00)	16(17.78)		
Irrigation practices					
Yes	123(84.25)	43(91.49)	80(80.81)	2.73*	0.098
Irrigation frequency					
Once	80(59.26)	11(23.91)	69(77.53)	36.10***	<0.001
Twice	55(40.74)	35(76.09)	20(22.47)		
Pesticide used					
Choloropyrifos	46(63.89)	21(44.68)	25(100.00)	21.64***	<0.001
Imidacloprid	26(36.11)	26(55.32)	0(0.00)		

Harvesting time					
March	95(65.07)	47(100.00)	48(48.48)	37.21***	<0.001
April	51(34.93)	0(0.00)	51(51.52)		
Harvesting method					
Manual	76(52.05)	23(48.94)	53(53.54)	0.27	0.603
Crop residue management					
Field incorporation	6(4.11)	0(0.00)	6(6.06)	2.97*	0.085
Wheat straw	140(95.89)	47(100.00)	93(93.94)		
Frequency of soil test					
Never	84(57.53)	13(27.66)	71(71.72)	25.31***	<0.001

Note: Figures in parenthesis indicate standard deviation and ***, **, * indicate 1%, 5%, and 10% level of significance respectively

3.3 Comparison of agricultural practices and input usage between high and low adopter farmers

As presented in Table 5, it was found that high-adopters of recommended technology did less tillage operation. It is simple to preserve soil health from minimum soil disturbance, and this helps improve crop yields (Adil *et al.*, 2024). Results reveal that high-adopters use lower seed rates per hectare compared to low-adopters. The seed rates need to be optimized for high-yield potential to be achieved (Gebrehiwot *et al.*,

2022). The tillage frequency and seed rate were statistically significant at a 1 % level. For high-adopters, the applied doses of FYM and DAP were higher compared to that of low-adopters. There were statistically significant differences at a 1% level. Regarding the application rates of MOP and urea, there were no significant differences between the two groups of farmers. Farmers are advised to adopt recommended practices in accordance with the principles of sustainable agriculture and improve crop productivity.

Table 5. Agricultural practices and input usage among high and low adopters of recommended wheat cultivation technology in Sunwal, 2024

Agricultural practices	Overall(n=146)	Farmer's category		Mean difference	t-value	p-value
		High-adopters (n=47)	Low-adopters (n=99)			
Tillage frequency	1.63(0.549)	1.19(0.39)	1.84(0.48)	0.65	8.12***	<0.001
Seed rate (kg/ha)	151.33(56.42)	114.25(11.93)	168.93(60.59)	54.68	6.12***	<0.001
FYM Dose(kg/ha)	1107(2568.2)	12000(2074.69)	10315.79(2700.25)	-1684.21	-3.50***	<0.001
Urea Dose(kg/ha)	120.99(43.35)	123.72(32.07)	119.69(47.88)	-4.02	-0.52	0.601
DAP Dose(kg/ha)	62.84(31.21)	81.91(24.28)	53.78(30.12)	-28.12	-5.59***	<0.001
MOP Dose(kg/ha)	60(16.03)	58.06(18.87)	62.30(2.30)	-4.24	-0.99	0.320

Note: Figures in parenthesis indicate standard deviation and *** indicate 1% level of significance

3.4 Factors impacting the adoption of recommended technology

Utilizing a binary logistic regression model, various factors that determine the adoption of recommended technologies among wheat farmers in Nawalparasi West, Nepal, were analyzed as shown in Table 6. The decisions of respondents (146) on adoption were coded (high-adopters were coded 1, low-adopters were coded 0). For instance, the model included the variables of ethnicity, the number of family members, years of schooling, training received, cooperative participation, receipt of a subsidy, and access to irrigation facilities. Cooperative participation was shown to have a favorable and statistically significant impact on

recommended technology adoption at the 1% level (coefficient = 2.295, $p < 0.001$), thus, farmers within cooperatives have a higher chance of knowing about recommended technology. Likewise, the receipt of subsidies was found to be positively associated with awareness of recommended technology at the 5% level (coefficient = 1.240, $p = 0.048$), suggesting that financial assistance might promote farmers' awareness of recommended practices. For awareness of recommended technology, other variables such as ethnicity, family size, year of schooling, training received, and irrigation facilities were not significantly associated with the adoption of recommended technology. The model as a whole showed a significant relationship with

adoption, as indicated by the Chi-square value of 43.31 and the associated log-likelihood ratio of -70.079. The awareness of recommended technology was explained by approximately 23.60% by the model (Pseudo $R^2 = 0.236$), showing the need for cooperative involvement and subsidies to encourage technology adoption among farmers. As in Yu *et al.* (2023), the findings

were in accordance that cooperative members are more likely to adopt recommended technology because of increased opportunities to participate in training and extension programs offered by them. Moreover, Laosutsan *et al.* (2019) also found that participation in cooperatives has a positive effect on the adoption of recommended technology.

Table 6. Major factor influencing adoption of recommended technology among wheat growers in Nawalparasi, 2024

Determinants	Coefficient	Standard Error	P> z	z
Ethnicity	0.251	0.199	0.207	1.26
Total family members	0.008	0.073	0.906	0.12
Years of schooling	0.060	0.046	0.193	1.30
Received Training (1= Yes 0 = No)	-0.777	0.475	0.102	-1.64
Involvement in Cooperatives (1= Yes 0 = No)	2.295***	0.568	0.000	4.04
Received Subsidy (1= Yes 0 = No)	1.240**	0.627	0.048	1.98
Irrigation facility (1= Yes 0 = No)	1.112	0.704	0.114	1.58
CONSTANT	-5.192	1.372	0.000	-3.78
Summary statistics				
Number of observations (N)	146			
Log likelihood	-70.079			
LR Chi ² (7)	43.31 (Prob > chi ² = 0.0000)			
Pseudo R ²	0.236			

Note: ***, ** indicates a 10% and 5% level of significance respectively, and z is the marginal effect after logit.

3.5 Major constraints in Wheat cultivation

The farmers faced several critical challenges, the severity of which was ranked by the study as presented in Table 7. The study area faced several significant problems in wheat cultivation, including inadequate irrigation, unavailability of fertilizer and quality seed, inadequate of knowledge and training, unavailability of machinery, and pest and disease incidence. This can be compared with

findings by Dawadi *et al.* (2023) who found irrigation as the major problem followed by insufficient nutrient accessibility, prevalence of diseases and pests, limited access to training and extension services, and absence of mechanization in Nawalparasi West. In the same way, Poudel *et al.* (2021) also pointed out the lack of agricultural machinery as the primary obstacle to the cultivation of wheat.

Table 7. Ranking of the problems in wheat cultivation in Sunwal, 2024

Problems	Index	Rank
Unavailability of fertilizers and quality seed	0.67	II
Problem of Irrigation	0.71	I
High incidence of insect pest and diseases	0.42	V
Inadequate knowledge and training	0.64	III
Unavailability of machinery	0.55	IV

4. CONCLUSION

The vast majority of wheat farmers in Sunwal are still reliant on traditional practices, and they do not fully implement recommended technologies, although there are no constraints preventing full implementation. The adoption of

recommended technologies is facilitated by cooperative involvement and access to subsidies, which helps to improve knowledge sharing and resource availability for farmers. Wheat farmers aware of recommended technologies tend to implement certain practices like the use of improved seed,

optimal sowing dates, proper irrigation scheduling, proper harvesting time, appropriate tillage frequency, optimum seed rates, sufficient fertilizer usage, and so forth. Issues such as the unavailability of appropriate irrigation infrastructure, improper supply of fertilizers, and the need for quality seeds must be overcome to accelerate the further adoption of recommended technology. Building up outreach programs

and ensuring reliable access to the critical agricultural inputs in Sunwal can enhance the productivity and profitability of wheat farmers in Sunwal, Nawalparasi West, Nepal.

ACKNOWLEDGEMENTS:

The authors would like to acknowledge Department of Agriculture of Sunwal Municipality and all the respondents for their support and cooperation during the study.

REFERENCES

- Adhikari, J. & Thapa, R. (2023). Determinants of the Adoption of Different Good Agricultural Practices (GAP) in the Command Area of PMAMP Apple Zone in Nepal: The Case of Mustang District. *Heylion*. 9(7). <https://doi.org/10.1016/j.heyliion.2023.e17822>
- Adil, M., Lv, F., Cao, L., Lu, H., Lu, S., Gul, I., Bashir, S., Wang, Z., Li, T., & Feng, W. (2024). Long-Term Effects of Agronomic Practices on Winter Wheat Yield and NUE in Dryland Regions of USA and China: A Long-Term Meta-Analysis. *Scientific Reports*. 14. <https://doi.org/10.1038/s41598-024-74910-7>
- Akhter, M. M., Sabagh, A. E., Alam, M. N., Hasan, M. K., Hafez, E., Barutcular, C., & Islam, M. S. (2017). Determination of Seed Rate of Wheat (*Triticum aestivum* L.) Varieties with Varying Seed Size. *Scientific Journal of Crop Science*. 6(3). 161-167. <https://doi.org/10.14196/sjcs.v6i3.2384>
- Aryal, S., Dhungel, B., Subedi, K. R., Lamichhane, P., & Bhattarai, S. (2020). Response of Wheat Parameters to Sowing Date and Irrigation Supplied in Terai Region of Nepal. *Tropical Agrobiodiversity*. 2(1). 07-09. <https://doi.org/10.26480/trab.01.2021.07.09>
- Bastakoti, B. & Poudel, A. (2022). Impacts of Sowing Time on Wheat in Nepal: A Detailed Review. *Tropical Agrobiodiversity*. 3(1). 06-07. <https://doi.org/10.26480/trab.01.2022.06.07>
- Bhatta, R. D., Amgain, L. P., Subedi, R., Kandel, B. P. (2020). Assessment of Productivity and Profitability of Wheat Using Nutrient Expert-Wheat Model in Jhapa District of Nepal. *Heylion*. 6(6). <https://doi.org/10.1016/j.heyliion.2020.e04144>
- Dawadi, B., Ghimire, S., & Gautam, N. (2023). Assessment of Productivity, Profit, and Problems Associated with Wheat (*Triticum aestivum* L.) Production in West Nawalparasi, Nepal. *AgroEnvironmental Sustainability*. 1(2). 122-132. <https://doi.org/10.59983/s2023010205>
- Dhakal, B. N. (2019). Socio-Economic Consequences of Agricultural Land Use Change in Tarai of Nawalparasi District. *The Third Pole Journal of Geography Education*. 18-19. 21-34. <https://doi.org/10.3126/tpj.v18i0.27991>
- Gebrehiwot, H. G., Aune, J. B., Eklo, O. M., Torp, T., & Brandsaeter, L. O. (2022). Effect of Tillage Frequency, Seed Rate, and Glyphosate Application on Teff and Weeds in Tigray, Ethiopia. *Experimental Agriculture*. 58. <https://doi.org/10.1017/S001447972200028X>
- Joshi, A., Kalauni, D., & Tiwari, U. (2019). Determinants of Awareness of Good Agricultural Practices (GAP) among Banana Growers in Chitwan, Nepal. *Journal of Agriculture and Food Research*. 1. <https://doi.org/10.1016/j.jafr.2019.100010>
- Kharel, M., Dahal, B. ., & Raut, N. (2022). Good Agriculture Practices for Safe Food and Sustainable Agriculture in Nepal: A Review. *Journal of Agriculture and Food Research*. 10(1). <https://doi.org/10.1016/j.jafr.2022.100447>
- Laosutsan, P., Shivakoti, G. P., & Soni, P. (2019). Factors Influencing the Adoption of Good Agricultural Practices and Export Decision of Thailand's Vegetable Farmers. *International Journal of the Commons*. 13(2). 867-880. <https://doi.org/10.5334/ijc.895>
- Maiti, D., Das, D. K., & Pathak, H. (2006). Fertilizer Requirement for Irrigated Wheat in Eastern India Using the QUEFTS Simulation Model. *The Scientific World Journal*. 6(4). 231-245. <https://doi.org/10.1100/tsw.2006.43>

- Nepal, A., Khanal, K., & Parajuli, N. (2023). Adoption Status of Good Agricultural Practices among Vegetable Growers in the Arghakhanchi District of Nepal. *Journal of Agriculture and Natural Resources*. 6(1). 74-84. <https://doi.org/10.3126/janr.v6i1.71924>
- Ojha, B., Regmi, B., & Bhattarai, D. (2024). Citrus Growers' Knowledge, Attitudes, and Implementation Towards Good Agricultural Practices (GAPs) in Palpa, Nepal. *Archives of Agriculture and Environmental Science*. 9(3). 481-489. <https://doi.org/10.26832/24566632.2024.0903011>
- Poudel, D., Yadav, R. K., Gauli, B., Chhetri, A., & Poudel, S. (2021). Assement of Adoption of Improved Wheat Production Technology in Nawalparasi (West) District, Nepal. *International Journal of Agricultural and Applied Sciences*. 2(2). 69-74. <https://doi.org/10.52804/ijaas2021.2211>
- Safety Culture (2024). *Good Agricultural Practices*. <https://safetyculture.com/topics/good-agricultural-practices/>
- Shah, A. M., Ali, S., Ahmad, I., Wazir, G., Shafique, O., Hanif, M. A., Khan, B. A., & Zareen, S. (2019). Weeds population Studies and Wheat Productivity as Influenced by Different Sowing Techniques and Herbicides. *Pakistan Journal of Agricultural Research*. 32(1). 87-94. <https://doi.org/10.17582/journal.pjar/2019/32.1.87.94>
- Shrestha, S., Amgain, L. P., Pandey, P., Bhandari, T., & Khatiwada, S. (2024). Adoption Status of Integrated Pest Management (IPM) Practices among Vegetable Growers of Lamjung District of Nepal. *Heylion*. 10. <https://doi.org/10.1016/j.heyliion.2024.e37999>
- Singh, S., Singh, S., Vishwakarma, S., & Shukla, R. (2022). *Good Agricultural Practices-Plant Growth Regulators*. Bright Sky Publications
- Yamane, T. (1967). *Statistics: An Introductory Analysis*. Harper & Row.
- Yu, L., Nilsson, J., Li, Y., & Guo, M. (2023). Cooperative Membership and Farmers' Environment-Friendly Practices: Evidence from Fujian, China. *Heylion*. 9(10). <https://doi.org/10.1016/j.heyliion.2023.e20819>

MONITORING SCARAB BEETLES IN HORTICULTURAL FIELD OF PAKLIHAWA CAMPUS USING LIGHT TRAP

Ganesh G.C.^{1*}, Puja Roka¹ and Dipak Khanal²

¹ Institute of Agriculture and Animal Science, Paklihawa, Rupandehi

² Department of Horticulture and Plant Protection, Tribhuvan University, IAAS, Paklihawa Campus

ARTICLE INFO

Keywords:

Insect monitoring,
Light trap,
Scarab beetles

***Correspondence:**

ganeshghartic@gmail.com
Tel: +977 9867416769

ABSTRACT

Scarabaeidae is an economically important family of Coleoptera order. They are destructive during their both larval and adult stages with larvae damaging roots and adult beetles affecting leaves and fruits. In order to assess the abundance and diversity of Scarab beetles in the horticultural field of Paklihawa Campus, a single light trap (80kw) was installed. Data were collected weekly over 16 weeks, from 4th May to 17th August 2024. The population trend fluctuated throughout the study, with peak numbers recorded during week 3 to 9, corresponding to favorable environmental conditions. A total of 94 specimens representing six genus and nine species were recorded. *Cyclocephala lurida* was found dominating species compromising 23% which was followed closely by 20% of *Adoretus lasiopygus*, 16% of *Phyllophaga* spp. Whereas, *Heteronychus* spp and *Holotrichia serreta* accounted each for 9%. *Heteronychus lioderes* contributed 8% followed by *Maladera castanea* at 6%. *Onthophagus madoqua* arrow and *Onthophagus amphinasus* arrow were recorded in smaller proportions comprising 5% and 4% respectively. There was uneven distribution of beetle population which may be due to environmental factors such as temperature, rainfall or food availability. The manuscript below provides a foundation for understanding a beetle dynamic and offers a potential management strategy.

1. INTRODUCTION

Coleopteran, the order of beetles, is a diverse group with 3,50,000 described species, spanning terrestrial and freshwater environments worldwide with largest group of Scarabaeidae family with more than 30,000 species (New, 2007). Scarabaeid beetles are the adults in the life cycle of egg, grub, pupa and adult. They are frequently known as 'white grubs' and mostly reside in the soil. Most white grubs are similar in structure and color, with soft curving bodies, brown heads, and well-developed legs that are rarely employed for mobility (Mehta et al., 2010). They are common and can be found in different ecosystem for instance in trees, from their barks to the roots, while some inside the nest of ants, rodents and birds.

White grubs are the economical stage which feed on the underground roots and structures (Khanal et al., 2018). Scarabaeid beetles are popular insects because of their wide habitats, beautiful patterns, and economic value. They responds to changing environments and has a impactful role in integrity of environment (Yadav et al., 2024). They also have important role in controlling pest population (Satheesha et al., 2018). Scarabaeidae's effect on agricultural crops has caused significant economic losses, including devastation to the coconut industries in India, Indonesia, and Malaysia, as well as tourism in the Solomon Islands (Siddiqui et al., 2023). They have both harmful and beneficial importance. On the beneficial part the beetles contribute to water infiltration, soil fertility and nutrient recycling (Beynon et al., 2015). Scarabs beetles are also natural scavengers and can

bury human and bovine excreta into soil (Sullivan et al., 2016). Also, Scarabaeid beetles regulates the ecosystem processes impacting carbon and nutrient cycles as of their detritus-based food cycle. On the negative part they inflict agricultural losses, injure plants, break down trash, and show predatory nature (Pathania et al., 2015). Along with agricultural point of view, Scarabaeidae beetles are taken part of culinary purposes influenced by culture, taste and preferences (Siddiqui et al., 2023). Enriched with protein, minerals fatty acids and various bioactive compound, they are mostly edible in larval stage with significant nutritional value. Also, some dung beetles feeds on harmful parasites and pathogens of humans and animals, thus contributing to health (Shah & Shah, 2022).

Based on position of posterior spiracles, the Scarabaeidae is divided as Laparostici (Coprophagous, dung beetles) and Pleurostici (Agricultural pests, Chafers), (Martello et al., 2016). The distribution patterns of these beetles are highly influenced by factors such as fauna, temperature, pH and the quality of dung. In particular, Chafers are phytophagous with wide feeding habit, on the contrary some doesn't feed at all (Pinero & Dudenhoefler, 2018).

Most of the species of Scarabaeidae family are phototropic and are attracted to light. Due to their phototropic behavior, they can be monitored using light traps. These beetles carry significantly economic value in agriculture thus create a gap for assessment. With concerning sustainable farming practices and effective pest management, understanding of the diversity and distribution of these beetles becomes essential part. Also, there is limited study and information about beetles in this area. This manuscript aims to access seasonal influence of Scarabaeidae beetles and presents the findings on the species diversity of Scarabaeid beetles in Paklihawa horticultural field using light trap.

2. MATERIALS AND METHODS

The study location is located in Siddharthanagar Municipality-1, Rupandehi, Nepal, at an altitude of 116 meters above sea

level, within the latitude and longitude of 27° 3'0" N and 83° 27'0" E. The district is located in Nepal's southern region in Lumbini Province. Its borders are shared with the districts of Nawalparasi on the east, Kapilvastu on the west, Palpa on the north, and India on the south (Figure 1).

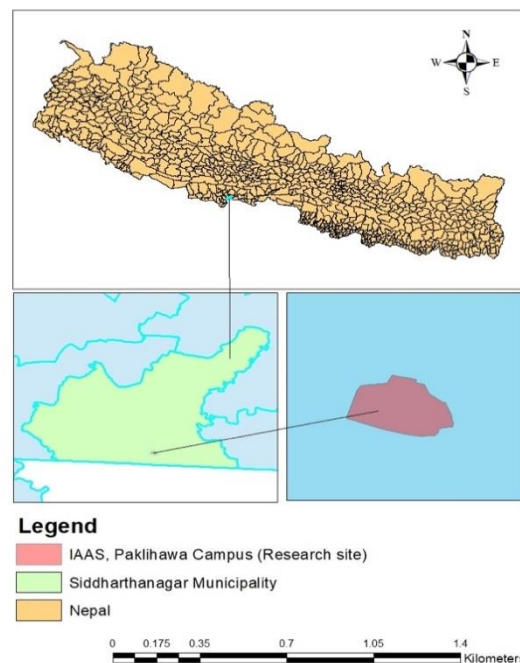


Figure 1. Map showing the study area in Siddharthanagar-1, Rupandehi District, Nepal, generated using ArcGIS.

Single light trap of 80watt vapor light was used for the study. The light trap was fixed in the middle of the farm area. Weekly collections of scarabaeid beetles were done in order to keep an eye on their condition and the presence of different species. The data was taken every saturday at the dawn for 16 weeks (May 4 to Aug 17, 2024). The light trap was operated from the previous day's sunset (about 5 PM) to the next day's dawn (around 8 AM). A nylon net was used as a trap to collect the insects that are lured to the light. The group of collected insects was separated into two categories: beetles and normal insects. Following that, beetles was gathered in a box and was directed to the Paklihawa campus' entomology lab. Formalin concentration (10%) was added to them for preservation.

The identification was done using a microscope and the scarab beetles were recognized based on their morphological characteristics such as body shape and size, elytra and antennal structures using the

3. RESULTS

The study conducted for 16 weeks, in the Horticultural field of Paklihawa using light traps resulted in the identification of 9 species with 94 total specimens of Scarabaeid beetles. *Cyclocephala lurida* was found dominant with 23% followed by *Adoretus lasiopygus* 20% and *Phyllophaga spp.* 16% (Figure 2). The strong presence of these three beetles' hints at the better adaptability in this ecosystem and has a significant role. Also, *Cyclocephala lurida* was found as most consistent species across the study and it was recorded in 10 weeks out of 16 weeks (Figure 3).

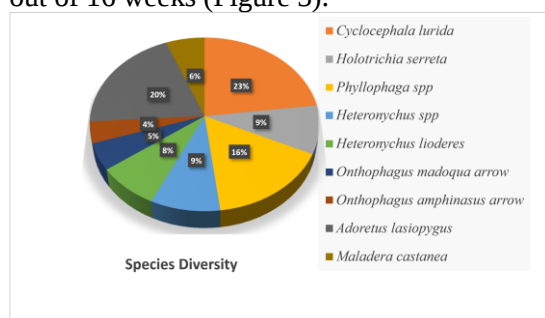


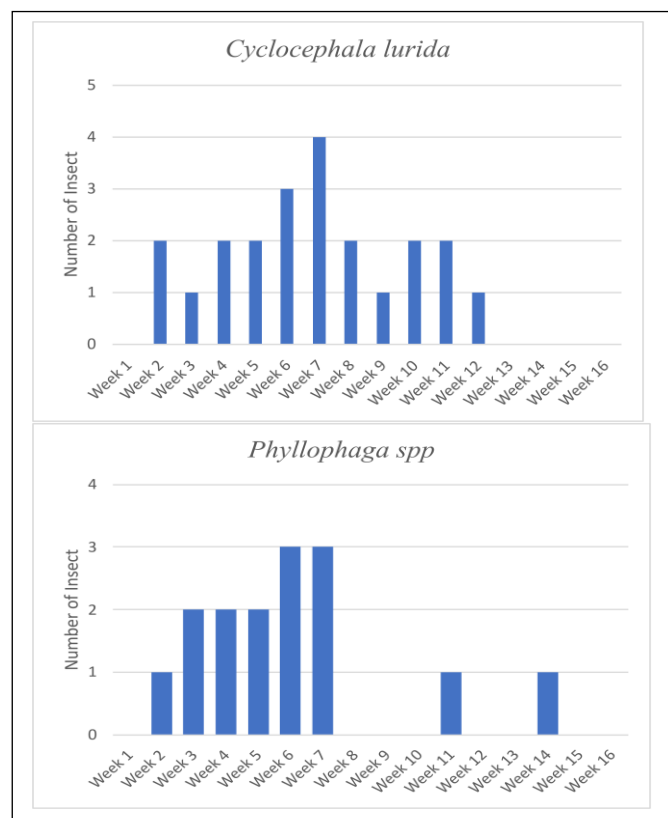
Figure 2. Pie chart illustrating the species diversity and relative abundance of scarabaeid beetles collected using light traps in the horticultural field of Siddharthanagar-1, Rupandehi, Nepal

Similarly, the proportion of *Holotrichia serreta* and *Heteronychus spp.* was identical sharing 9% each suggesting they may share common ecological preferences. Conversely, *Onthophagus madoqua arrow* and *Onthophagus amphinasus arrow* shared a least proportion of the total population with 5% and 4% respectively (Figure 3), limiting their presence to only about 5 weeks. This indicates these beetles might have more specialized requirement for reproduction or the environmental condition during the study period was less favorable for them. Furthermore, the dominance of *Cyclocephala lurida* shows the uneven distribution of Scarabaeidae species. As recorded, fewer

publications from the NARC, Google and various literatures from the web. The data was analyzed using the Microsoft Excel, 2019.

species such as *Cyclocephala*, *Adoretus* and *Phyllophaga* contributes to major population while other remains in much smaller proportions. The highest number of single species recorded in single week was 4 i.e., for *Cyclocephala lurida* and *Adoretus lasiopygus*. This suggests their shared habitat preferences and reproductive cycle and their dominance which makes them key species to study in that area.

The study further revealed the high activity of beetles was recorded in between week 3 to week 9, where week 5-7 showed highest species richness (Figure 3). During this week 7 different species were recorded. This suggest the distribution is highly influenced by environmental factors such as temperature, humidity and rainfall. The environmental influence and availability of beetles in this months is supported by the study done by (Price, 2009).



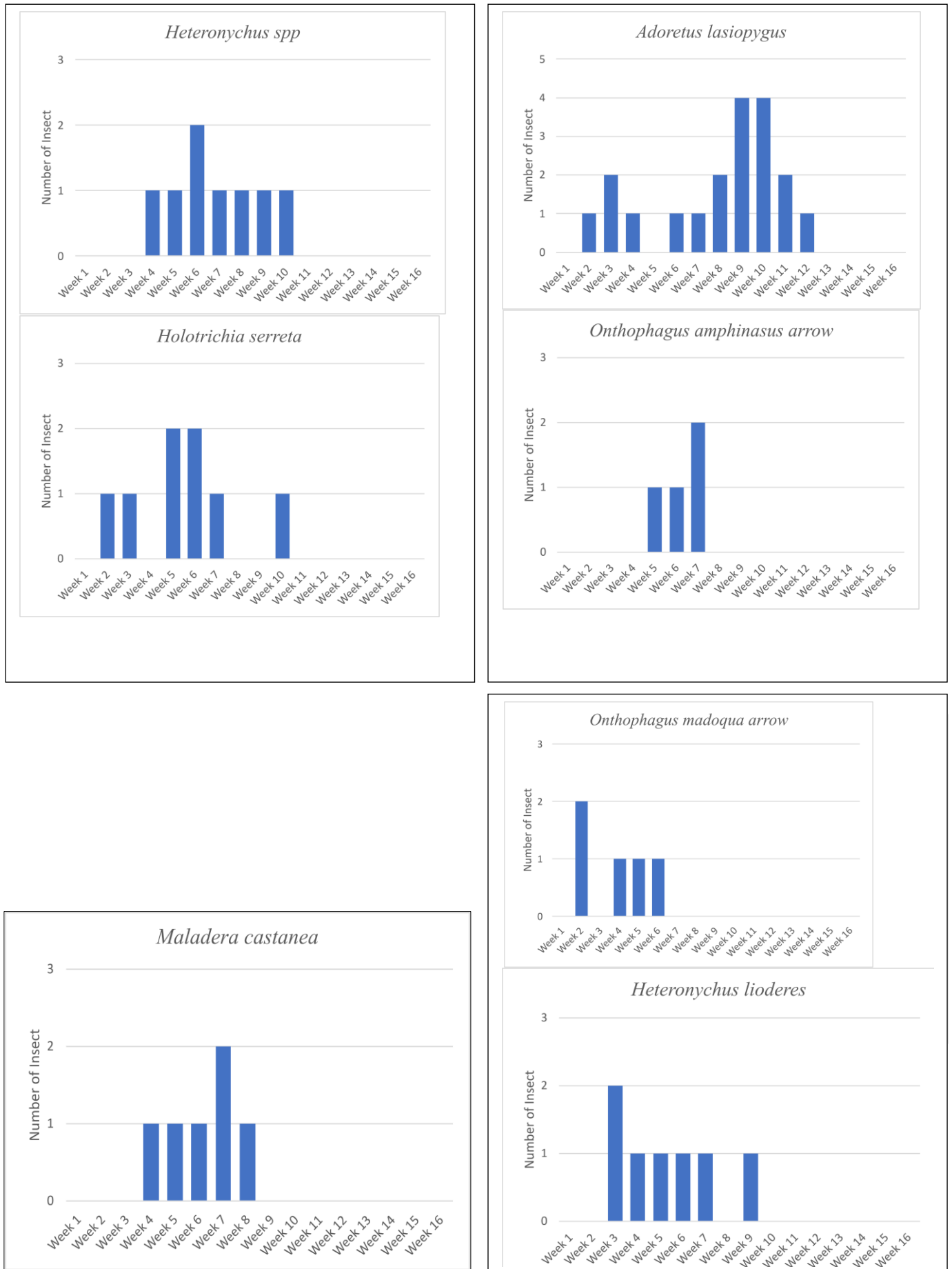


Figure 3. Weekly variation in the number of insects collected during the study period.

Table 1. Table showing species and its economic importance

S.N.	Species	Adult Description	Economic Importance
1	<i>Cyclocephala lurida</i> (Bland)	Shiny reddish brown with dark-chocolate head and are about 10.5-12mm-long and 6-7mm-wide.	Pollination and cycling of organic matter (Souza et al., 2023). They feed on wide range of root crops mainly maize and sugarcane.
2	<i>Holotrichia serreta</i> (Fabricius)	Brown in color, female beetles are larger than male with average length of 23-25mm	Important subterranean white grubs damaging roots severely in Kharif season (Parasharya et al., 1994). The root feeding nature of this beetles not only infest maize, rice, wheat and potatoes but also disturbs the soil structure.
3	<i>Phyllophaga</i> spp	Robust, 12-19mm-long and light to dark brown.	Soil-living pest with uncommon damaging habits (King, 1984).
4	<i>Heteronychus</i> spp	Shiny black to dark reddish brown, oval shaped 12-15mm.	Nocturnal and Polyphagous infesting potato, Cole crops, fruits, field crops (Chandel et al., 2023).
5	<i>Heteronychus</i> <i>lioderes</i> Redtenbacher	Black from dorsal view and deep reddish beneath, smooth and shining elongate oval in shape.	Nocturnal and Polyphagous infesting potato, Cole crops, fruits, field crops (Chandel et al., 2023).
6	<i>Onthophagus madoqua</i> Arrow	Black and shiny oval or convex body, short and broad head.	Coprophagous, Scavengers and are Paracoprid nesters (Kalawate et al., 2021).
7	<i>Onthophagus</i> <i>amphinasus</i> Arrow	Black and non-shiny with bright yellow antennae. Oval, highly convex, and deeply waisted.	Coprophagous, Scavengers and are Paracoprid nesters (Kalawate et al., 2021).
8	<i>Adoretus lasiopygus</i>	Brown body, elongate and oval in shape, pronotum less closely punctured at the sides than in the middle, 10-12mm long.	Night flying beetle which chews on leaves of various plants such as Tea, Palm, Coconut, Cocoa forming small holes in foliage (CHUNG, 2024).
9	<i>Maladera castanea</i> (Arrow)	Robust body brown to reddish brown body color, 8-9mm and hidden labrum.	Nocturnal, grubs overwinter in soil and feed seedlings in second and third instars with difficult management practices (Pekarcik, 2022).

Figure 4. Photographs of different collected insect specimens.



Cyclocephala lurida
(Bland, 1863)



Holotrichia serrata
(Fabricius, 1798)



Maladera castanea
(Arrow, 1913)



Onthophagus amphinasus
(Arrow, 1931)



Onthophagus madoqua
(Arrow, 1931)



Heteronychus lioderes
(Redtenbacher, 1867)



Adoretus lasiopygus
(Burmeister)



Heteronychus spp



Phyllophaga spp

4. DISCUSSION

The greater proportion of *Cyclocephala lurida* 23%, *Adoretus lasiopygus* 20% and *Phyllophaga* spp. 16% in agro ecosystem of Paklihawa horticultural farm highlights the greater adaptability of these beetles. These beetles are notorious in their larval phase mostly causing damage to root crops such as sugarcane, maize and Cole crops. Thus, it recommends the necessity of effective management strategy to mitigate the potential agricultural losses. Also, future studies should focus on their life cycle, peak emergence period and feeding habits. Moreover, the limited presence of *Onthophagus madoqua* arrow and *Onthophagus amphinasus* arrow in the ecosystem highlights the need to encourage the population growth of such beetles either by incorporating organic manures in the soil or by less use of harmful pesticides. As study done by (Wagner et al., 2021), grazing promotes dung incorporation in the soil which increases species diversity and abundance.

The highest species count was seen in Week 3 to 9. These weeks are likely to have more favorable environment for activity of these beetles. The increase of activity during this weeks or time of month also coincides with (Khanal, 2018). Additionally, (Yadav et al., 2024) study finds the higher activity of Scarabaeidae beetles during the monsoon season. However, the sharp decline in activity of scrabs beetles was seen after week 10. This could be due to the extreme weather of heavy rainfall and higher temperature. This has negative impact on their flight activity and reproduction behaviors. No beetles were recorded after week 13. The absence of beetles' emergence could be due to seasonal conditions or food availability. (Hewavithana et al., 2016) study also shows the significant differences in beetle population due to food availability and preferences. Also, the beetles may have specific environmental triggers for emergence as fluctuating trend was seen in abundance of species. Study done by (Araújo et al., 2022) shows the variation in abundance, diversity and significant shift of beetles in elevation due to seasonal influence. Also, the efficiency of light trap

depends upon species behavior and Scarabaeidae beetles exhibit varying degree of phototropism (Davies et al., 2013).

(Khanal, 2018) recorded 227 specimens from ten species within the same agrosystem, where *Phyllophaga* spp, *Onthophagus madoqua* (Arrow), *Maladera castanea*, *Holotrichia serreta*, and *Heteronychus lioderes* were common findings in both studies. In contrast, present study documented significantly lower number of specimen count than compared to (Khanal, 2018). The reduced species count observed in the present research may be due to the effects of climate change, unmanaged pesticide application or availability of food. Various studies such as, (Dawson, 2011; Hoffmann & Sgro, 2011) have indicated that climate change can significantly alter species distribution and genetic diversity. Furthermore, as per (Hewavithana et al., 2016) population of beetles is highly influenced food availability. These beetles are equally important in our ecosystem (Perrin et al., 2020). They contribute to soil fertility and nutrient recycling (Beynon et al., 2015) and also are natural scavengers (Sullivan et al., 2016). Thus, efficient integrated management practices should be focused to limit the beetle population below economic threshold level

5. CONCLUSION

The study successfully assessed the diversity and abundance of scarabaeid beetles within the time frame of 16 weeks. A total of 9 species and 94 specimens were identified. The significant increase in the activity of beetles was seen from week 3 to week 9 i.e., May 18 to June 19 in the summer of 2024. Meanwhile, no activity was seen after week 13 i.e., July 27. With concerning their role and importance in our ecosystem, the sustainable and conservative management practices of these beetles should be focused. These findings not only provide valuable insights into the seasonal dynamics of Scarabaeidae beetles but also emphasize the need for adaptive pest management strategies to mitigate their destructive impact on crops.

ACKNOWLEDGMENTS:

Author/s like to acknowledge Paklihawa campus for providing research area and various essential tools and materials, and a lab. Special thanks are extended to Asst. Prof. Rukmagat Pathak and Departmental

Head Asst. Prof. Manoj Basnet for helping me through the research and data analysis. The author is also thankful to peers and all others who contributed their time and assistance during the study

.

REFERENCES

- Araújo, C. de O., Hortal, J., de Macedo, M. V., & Monteiro, R. F. (2022). Elevational and seasonal distribution of Scarabaeinae dung beetles (Scarabaeidae: Coleoptera) at Itatiaia National Park (Brazil). *International Journal of Tropical Insect Science*, 42, 1579–1592. <https://doi.org/10.1007/s42690-021-00680-8>
- Beynon, S. A., Wainwright, W. A., & Christie, M. (2015). The application of an ecosystem services framework to estimate the economic value of dung beetles to the U.K. cattle industry. *Ecological Entomology*, 40(S1), 124–135. <https://doi.org/10.1111/een.12240>
- Chandel, R. S., Verma, K. S., Sanjta, S., & Thakur, H. (2023). Distribution, Biology and Management of White Grubs in North-Western Himalaya. *Himachal Journal of Agricultural Research*, 1–17.
- CHUNG, G. (2024). NIGHT-FLYING BEETLES, ADORETUS COMPRESSUS – PESTS OF OIL PALM. *The Planter*, 100. <https://doi.org/10.56333/tp.2024.005>
- Davies, T., Bennie, J., Inger, R., Hempel de Ibarra, N., & Gaston, K. (2013). Artificial light pollution: Are shifting spectral signatures changing the balance of species interactions? *Global Change Biology*, 19. <https://doi.org/10.1111/gcb.12166>
- Dawson, T. (2011). Beyond predictions: Biodiversity conservation in a changing climate (vol 332, pg 53, 2011). *Science*, 332, 664–664.
- Hewavithana, D. K., Wijesinghe, M. R., Dangalle, C. D., & Gayan Dharmarathne, H. A. S. (2016). Habitat and dung preferences of scarab beetles of the subfamily Scarabaeinae: A case study in a tropical monsoon forest in Sri Lanka. *International Journal of Tropical Insect Science*, 36(2), 97–105. <https://doi.org/10.1017/S1742758416000023>
- Hoffmann, A., & Sgro, C. (2011). Hoffmann AA, Sgr?? CM.. Climate change and evolutionary adaptation. *Nature* 470: 479–485. *Nature*, 470, 479–485. <https://doi.org/10.1038/nature09670>
- Kalawate, A., Mukhopadhyay, B., Pawar, S., & Shinde, V. (2021). Some new records of scarab beetles of the genus Onthophagus Latreille, 1802 (Coleoptera: Scarabaeidae) from northern Western Ghats, Maharashtra, with a checklist. *Journal of Threatened Taxa*, 13, 17580–17586. <https://doi.org/10.11609/jott.5695.13.1.17580-17586>
- Khanal, D. (2018). *Monitoring of Scarab Beetles using Light Trap in Horticulture Field of Paklihawa Campus, Rupandehi, Nepal*.
- Khanal, D., Pokhrel, M., & Dhoj, Y. (2018). PREVALENCE OF WHITE GRUBS (SCARABAEIDAE; COLEOPTERA) IN DIFFERENT AGRO-CLIMATIC REGIONS OF NEPAL. 19, 17–23.
- King, A. B. S. (1984). Biology and identification of white grubs (Phyllophaga) of economic importance in central America. *Tropical Pest Management*, 30(1), 36–50. <https://doi.org/10.1080/09670878409370850>
- Martello, F., Andriolli, F., Souza, T., Dodonov, P., & Ribeiro, M. (2016). Edge and land use effects on dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in Brazilian cerrado vegetation. *Journal of Insect Conservation*, 20. <https://doi.org/10.1007/s10841-016-9928-0>
- Mehta, P., Chandel, R., & Y.S.Mathur. (2010). Status of white grubs in North-western Himalaya. *Journal of Insect Science*, 23, 1–14.
- New, T. R. (2007). Beetles and conservation. *Journal of Insect Conservation*, 11(1), 1–4. <https://doi.org/10.1007/s10841-006-9022-0>
- Parasharya, B., Dodia, J., Mathew, K., & Yadav, D. (1994). Natural regulation of white grub (Holotrichia sp: Scarabidae) by birds in agroecosystem. *Journal of Biosciences*, 19, 381–389. <https://doi.org/10.1007/BF02703175>
- Pathania, M., Chandel, R., Verma, K., & Mehta, P. (2015). Studies on the Preliminary Ecology of Invasive Phytophagous Indian Scarabaeidae of North Western Himalaya. *Science, Technology and Arts Research Journal*, 4, 127–138. <https://doi.org/10.4314/star.v4i2.16>
- Pekarcik, A. J. (2022). *Ecology and Management of the Asiatic Garden Beetle, Maladera formosae, in Corn-Soybean Rotated Agroecosystems* [The Ohio State University]. https://etd.ohiolink.edu/acprod/odb_etd/etd/r/1501/10?clear=10&p10_accession_num=osu1650539901468311
- Perrin, W., Moretti, M., Vergnes, A., Borcard, D., & Jay-Robert, P. (2020). Response of dung beetle assemblages to grazing intensity in two distinct bioclimatic contexts. *Agriculture, Ecosystems & Environment*, 289, 106740.
- Pinero, J., & Dudenhoefter, A. (2018). Mass trapping designs for organic control of the Japanese beetle, Popillia japonica (Coleoptera: Scarabaeidae). *Pest Management Science*, 74. <https://doi.org/10.1002/ps.4862>
- Price, D. (2009). Species diversity and seasonal abundance of scarabaeoid dung beetles (Coleoptera: Scarabaeidae, Geotrupidae and Trogidae) attracted to cow dung in Central New Jersey. *Journal of the New York Entomological Society*, 112, 334–347. [https://doi.org/10.1664/0028-7199\(2004\)112\[0334:SDASAO\]2.0.CO;2](https://doi.org/10.1664/0028-7199(2004)112[0334:SDASAO]2.0.CO;2)

- Satheesha, D., Nikhath, A., Vrushali, M., Jayaraj, F., & Sreenivasa, G. (2018). Preliminary study on composition and diversity of beetles (Order-Coleoptera) in and around Davangere University Campus, Davangere, Karnataka. *Journal of Entomology and Zoology Studies*, 6(4), 1751–1758.
- Shah, N. A., & Shah, N. (2022). Ecological Benefits of Scarab beetles (Coleoptera: Scarabaeidae) on Nutrient Cycles: A Review Article. *Advances in Biochemistry and Biotechnology*. <https://www.gavinpublishers.com/article/view/ecological-benefits-of-scarab-beetles-coleoptera-scarabaeidae-on-nutrient-cycles-a-review-article>
- Siddiqui, S., Ampofo, K., Dery, E., Eddy-Doh, A., Castro-Muñoz, R., M., P., & Fernando, I. (2023). Scarabaeidae as human food – A comprehensive review. *Journal of Insects as Food and Feed*, 10, 699–732. <https://doi.org/10.1163/23524588-00001001>
- Souza, T. B. de, Albuquerque, L. S. C. de, Iannuzzi, L., Costa, F. C., Gibernau, M., & Maia, A. C. D. (2023). Egg development and viability in three species of Cyclocephala (Coleoptera: Scarabaeidae: Dynastinae). *Bulletin of Entomological Research*, 113(1), 118–125. <https://doi.org/10.1017/S0007485322000384>
- Sullivan, G., Ozman-Sullivan, S., Jean-Pierre, L., Baxter, G., ZALUCKI, M., & Zeybekoğlu, Ü. (2016). Dung beetles (Coleoptera: Scarabaeidae) utilizing water buffalo dung on the Black Sea coast of Turkey. *TURKISH JOURNAL OF ZOOLOGY*, 40, 80–86. <https://doi.org/10.3906/zoo-1412-2>
- Wagner, P. M., Abagandura, G. O., Mamo, M., Weissling, T., Wingeyer, A., & Bradshaw, J. D. (2021). Abundance and Diversity of Dung Beetles (Coleoptera: Scarabaeoidea) as Affected by Grazing Management in the Nebraska Sandhills Ecosystem. *Environmental Entomology*, 50(1), 222–231. <https://doi.org/10.1093/ee/nvaa130>
- Yadav, M., Meena, P., Kumawat, N., Prajapat, R., Kumari, V., & Meena, S. (2024). Diversity and Seasonal Distribution of Scarab Beetles (Scarabaeidae; Coleoptera) in Jaipur Region, Rajasthan state of India. *Journal of Applied Bioscience*, 50(2), Article 2.

BIOLOGICAL MANAGEMENT OF CABBAGE BUTTERFLY (*Pieris brassicae nepalensis*) IN BAJURA, NEPAL

Mahesh Rokaya¹, Ritambar Ghimire¹ and Kailash Bhatta^{2*}

¹ School of Agriculture, Far Western University, Kailali, Nepal
² International Centre for Integrated Mountain Development, Kathmandu, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Bioassay, Biocontrol, Crucifers, Entomopathogenic fungi, Jholmal *Correspondence: kailash.bhatta07@gmail.com Tel: +977 - 9708513245	<i>Cabbage butterfly significantly impacts crucifer's production leading to average annual productivity losses of around 40-100%. To assess the efficacy of various biological management strategies for controlling the cabbage butterfly on cabbage, both the field and laboratory experiment were conducted in Randomized Complete Block Design (RCBD) and Completely Randomized Design (CRD) with 5 treatments (Metarhizium anisopliae, Beauveria bassiana, Neem oil, Jholmal – 3 and control) and 4 replications to enable a robust approach for validation of botanical efficacy under both controlled and natural growing environments. Larval mortality was recorded at 24, 48, and 72 hours after treatment. Neem oil showed the highest reduction of cabbage butterfly in both field (62.96%) and lab (79.17%) conditions, followed by Beauveria (45.26% and 59.17% lab), Metarhizium (37.03% and 55.06%), and Jholmal-3 (31.27% and 48.89%) respectively. Yield was significantly outperformed in plots treated with neem oil (31.62 MT/ha) and Jholmal-3 (30.21 MT/ha) compared to other treatments. Overall, neem oil proved to be the most effective solution for cabbage butterfly management. However, entomopathogenic fungi and Jholmal-3 also showed potential as alternative control measures. For further validation, future research should explore long-term impacts on natural enemies, soil health, and farmer adoption.</i>

1. INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata), a widely cultivated cruciferous vegetable, is an important crop grown globally, primarily during spring and fall in temperate zones and as a winter or early spring crop in warmer regions (Chiang et al., 1993; Cervenski et al., 2022). Originating from the Eastern Mediterranean region (Snogerup et al., 1990), cabbage is characterized by a short

stem supporting a compact head of overlapping leaves (Semuli, 2005). In Nepal, cabbage is cultivated across all agro-ecological zones, covering 29,638 ha with an annual production of 494,053 metric tons (MoALD, 2022). In Bajura, specifically, it is grown on 80 ha of land, yielding approximately 960 metric tons. The cabbage butterfly (*Pieris brassicae nepalensis*) is a major pest of cruciferous

crops, causing severe yield losses in Nepal, with damage reaching up to 100% in late-season cabbage cultivars (Joshi, 1994; Ali & Rizvi, 2007). Its infestation peaks in early spring and thrives in warm, dry conditions (Adhikari et al., 2023; Adhikari & Khadka, 2023). Commonly known as cabbage worm, big white butterfly, cabbage white, or cabbage moth, the cabbage butterfly gets its name from its snow-white wings and preference for cabbage as a primary food source (Ansari et al., 2012; Wilbur, 2011). The caterpillar stage is the most destructive, feeding all stages of crops with early instars scraping leaf surfaces and poking round holes (Youns et al., 2004) and later instars consuming entire leaves, causing 40-100% yield loss in crucifers often leaving only veins intact (Joshi 1994; Youns et al., 2004; Ali & Rizvi, 2007; Bhandari et al., 2009; Hopkins et al., 2009;). A single larva can consume up to 84 cm² of leaf area, significantly reducing both yield and quality. During the head formation stage, the late instars damage the head, reducing both the yield and quality of cabbage heads (Lal & Ram, 2004).

Effective management in pests requires an integrated approach combining cultural, biological, and chemical control methods. While synthetic pesticides remain a common control strategy, their excessive use leads to pesticide residues, pest resistance, environmental degradation, and several human health risks. Biopesticides have emerged as a sustainable alternative due to their biodegradability and minimal ecological impact. Entomopathogenic fungi, for instance, produce antifeedant and repellent compounds while enhancing plant growth, nutrient efficiency, and resistance (Poveda, 2021). Similarly, neem-based formulations disrupt pest growth and feeding, reducing reliance on synthetic chemicals (Lakshmanan, 2001). Jholmol-3 has also shown potential in reducing pest populations naturally, promoting eco-friendly and sustainable agriculture (Bhusal & Udas, 2020). Despite promising results from previous studies, limited research has been conducted on the efficacy of biological management strategies against cabbage

butterfly in Nepal's high-altitude regions like Bajura.

This study aims to evaluate the efficacy of biological management strategies against cabbage butterfly contributing to a transition from conventional chemical-based pest control to sustainable, environmentally friendly management practices.

2. MATERIALS AND METHODS

2.1 Description of study site

A series of both field and laboratory experiment were conducted in a farmer's field in Budhinanda municipality – 10, Dimmarpani, Bajura (high hill) during spring season (February – July) of 2024. is the study site was located at 29° 45' 92" N latitude and 81° 60' 39" E longitude, with an elevation of 2172.9 m asl. The study site has an arid, dry winter and cool summer climate (Paudel et al., 2012).

2.2 Climate description

We recorded the weekly micro-climatic data of the growing season with the help of agrometeorological devices. We measured weekly air temperature (minimum and maximum), cumulative precipitation and relative humidity with the help of thermometer, hygrometer and rain gauze. The data recorded during the study period are illustrated in Figure 1. During the study period, the minimum temperature ranged from -5.16°C in the first week of February to 14.07°C in the second week of July. The maximum air temperature reached 22.8°C in the third week of June and dropped to 5.62°C in the first week of February, indicating considerable diurnal variation. Precipitation was generally low and sparse throughout the season, with an average of 2.85 mm recorded throughout the cropping period with little or no rainfall during February – April 2024, and frequent rainfall during May – July 2024. The cropping season was characterized by cool and humid conditions with an average relative humidity of 56.63 % throughout the cropping season (range: 36.48 % – 84.26 %). These climatic conditions created a favorable environment for the infestation of cabbage butterflies, a major pest affecting cruciferous crops as described by Embaby and Lotfy (2015).

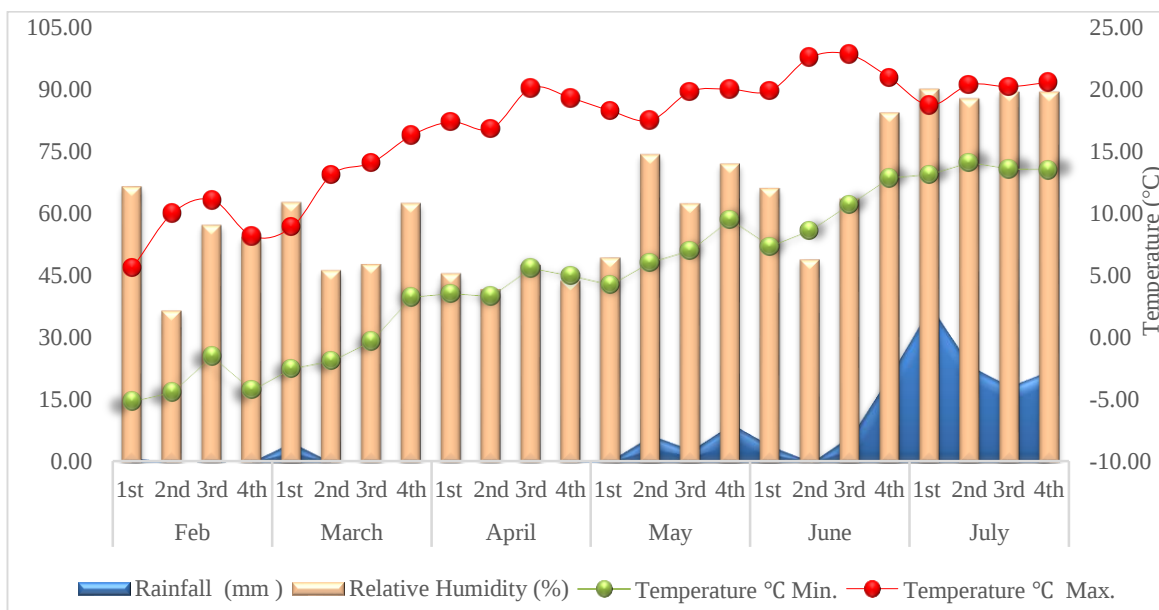


Figure 1. Weekly meteorological data of research site

2.3 Experimental design and treatments detail

The study was conducted in a Randomized Completely Block Design (RCBD) in the

field and a Completely Randomized Design (CRD) in the lab, with five treatments (Table 1) and four replications.

Table 1. Treatment details with dose and concentration of a.i of tested bio-control agents

Treatments	Doses	Type	Count
T ₁ <i>Metarhizium anisopliae</i> (Commercial)	2ml/ltr of Water	Entomopathogenic fungi	CFU @1 × 10 ⁹ spores/ml)
T ₂ <i>Beauveria bassiana</i> (Commercial)	2ml/ltr of Water	Entomopathogenic fungi	CFU @1 × 10 ⁹ spores/ml)
T ₃ Jholmal-3	1:5 (Jholmol-3: water)	Botanical Formulation	NA
T ₄ Neem oil (Multineem)	2ml/ltr of water	Botanical Insecticide	0.03 % E.C
T ₅ Control	Spray with plain water	Spray with plain water	

2.4. Preparation of treatments

A standard procedure for *Jholmol* preparation was followed. The formulation involved mixing chopped locally sourced insecticidal or insect-repellent plants with animal urine and water in a 1:5:5 ratio, allowing it to decompose for one month. After complete decomposition, the mixture was filtered through a cotton sieve and applied at a rate of 125 ml per liter of water (Bhusal and Udas, 2020). Additionally, commercially available formulations of neem oil, *Metarhizium*

anisopliae, and *Beauveria bassiana* were applied at the rate of 2 ml per liter of water.

2.5. Agronomic practices

All the standard agronomic practices were followed except insecticidal spray, including a recommended fertilizer application. Light irrigation was applied 2–3 days before field preparation, followed by four irrigations at 10-days intervals during the crop growing period. Two manual weddings were performed on the 25th and 50th days after showing to maintain optimal field conditions.

2.6. Laboratory experiment

Adult caterpillar of third instar with similar size and age were collected from cabbage growing field and were acclimatized for 8-10 hrs. Fresh leaves of similar stage were also collected, surface cleaned and dipped in solution containing individual treatment for 10 minutes. The treated leaves were kept under fan to evaporate water, cut to fit the size of the Petri dish and placed over Petri dish of 6.5 cm diameter.

The treated leaves were then placed on the moistened filter paper at the bottom of the petri dishes, and finally, 5 caterpillars were released in each Petri dish and number of alive caterpillars were counted after 24, 48, and 72 hours. The mortality percentage was calculated by Abbott's formula (Abbott, 1925):

$$\text{Mortality rate} = \frac{\text{Pre count} - \text{Post count}}{\text{Pre Count}} \times 100$$

2.7. Field experiment

Each plot measured 2.7 m² (1.5 m × 1.8 m) sown with Green Coronet variety maintained at 45 × 30 cm distance between each row and plant. Each individual plot and block were separated by a 50 cm buffer distance. From each plot, six plants were randomly selected and tagged for data collection.

When approximately 30% of the plant population was infested, the treatments were applied according to the instructions on the package label, as outlined in Table 1. The treatments were applied in the evening time using appropriate protective equipment. Each treatment was applied to different plots, ensuring that the plants in each plot were thoroughly wetted using a 5-liter pressure sprayer. Due to unfavorable climatic conditions, the application was performed only once.

A total of 6 sample plants were selected randomly from the plot. The population of cabbage butterflies were counted before 24 hours of application of treatments as pre-count and post-treatment counts were taken 24, 48, and 72 hours after the treatment as post-treatment counts.

The alive number of larvae after treatment was calculated by the following formula,

$$\text{Average Live Larvae per Plot (ALF)} = \frac{L}{N}$$

Where,

L= Number of live larvae counted after treating sample plants

N= Number of larvae before treating sample plants

Similarly, the percentage of reduction of population over control (PROC) was calculated by Henderson and Tilton (1955) formula

$$PROC = \left[1 - \frac{Ta \times Cb}{Tb \times Ca} \right] \times 100$$

Where,

Tb = Population in treatment before spray

Ta = Population in treatment after spray Cb =

Population in control before spray

Ca = Population in control after spray

The yield comparison between different treatments was done by using the increase in yield over control (Nyaupane et al., 2021).

$$\text{Increase in Yield Over Control (\%)} = \frac{T-C}{C} \times 100$$

Where,

T = yield from treatment plot, and

C = yield from the control plot

2.8 Statistical analysis

Data collected during the study were subjected to analysis of variance (ANOVA) to assess the significance of differences among the treatments using R-Studio (version 4.4.1). Mean comparisons were performed using the Duncan multiple range test (DMRT) at a 5% significance level, following the methods outlined by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Field assessment for biological treatments

The effectiveness of different biopesticides in managing cabbage butterfly larvae was assessed based on larval count reduction over time. On the first day after spray, the maximum larval count was recorded in the Jholmal-3 treatment (23.75), following the control (25.92), whereas the minimum count was observed in the neem oil treatment (15.13). By the third day, neem oil continued to demonstrate superior efficacy, reducing the larval count to 9.04, while Jholmal-3 exhibited the highest count (18.75) (Table 2). Statistical analysis revealed that neem oil exhibited the highest population reduction

over control (39.50%), followed by *Beauveria bassiana* (27.95%) and *Metarhizium anisopliae* (23.97%), though the latter two were not statistically different from each other. Data recorded on the second day after spray showed a trend similar to the first day, with neem oil proving most effective, followed by entomopathogenic fungi (*Beauveria* and *Metarhizium*) and Jholmal-3 (Table 2). By the third day post-treatment, neem oil demonstrated the highest efficacy (51.35%), followed by *Beauveria* (45.26%),

Metarhizium (35.86%), and Jholmal-3 (31.27%) in reducing the cabbage butterfly larvae population compared to the control. The superior performance of neem oil can be attributed to its active compound, azadirachtin, which exhibits antifeedant, repellent, and insect growth-regulating properties. Azadirachtin is known to induce sterility and ultimately cause larval mortality, as supported by previous studies (Erler & Ates, 2015; Negi & Kumar, 2020; Khanal et al., 2023) (Table 2).

Table 2. Effect of treatment on the live larvae and PROC % after application of treatments at field condition.

Treatment	Pre count	Post-Count					
		1 DAS	PROC%	2DAS	PROC%	3DAS	PROC%
<i>Metarhizium anisopliae</i>	27.70	20.63 ^{ab}	23.97 ^{bc}	18.08 ^b	33.74 ^b	17.58 ^b	35.86 ^{ab}
<i>Beauveria bassiana</i>	31.69	22.79 ^a	27.95 ^b	20.30 ^b	34.27 ^b	17.24 ^b	45.26 ^{ab}
Jholmal-3	27.42	23.75 ^a	13.95 ^c	20.13 ^b	23.58 ^c	18.75 ^{ab}	31.27 ^b
Neem oil	25.04	15.13 ^b	39.50 ^a	11.96 ^c	51.64 ^a	9.04 ^c	51.35 ^a
Control	26.04	25.92 ^a		25.42 ^a		24.60 ^a	
SEm (±)		2.03	3.40	1.61	2.32	2.14	5.90
LSD _{0.05}		6.26	10.49	4.97	7.17	6.59	18.19
CV		18.78	32.35	16.82	16.26	24.51	36.05
F-test		*	***	**	***	**	***
Grand Mean		21.64	21.07	19.18	28.65	17.44	32.75

SEm = Standard Error of Mean, LSD=Least significant difference at 0.05 level, CV= Coefficient of variation, DAS = Days after spray; Means followed by the same letter are not significantly different at $p < 0.05$; *** $p < 0.001$; ** $p < 0.01$; *Significant at $p < 0.05$;

3.2. Agro-morphological and yield analysis

The analysed data on yield and its associated attributes revealed that neem oil treatment resulted in the highest values across all parameters. Plants treated with neem oil exhibited maximum plant height (29.04 cm), head girth (16.12 cm), head weight (426.76 g), and yield (31.62 MT/ha). Notably, Jholmal-3 followed neem oil in efficacy, demonstrating significant plant height (27.23 cm), head girth (15.73 cm), and head weight (407.84 g), with a yield of 30.21 MT/ha. Both entomopathogenic fungi (*Beauveria* and *Metarhizium*) showed comparable effects, while the control treatment resulted in the lowest performance.

These findings align with the study by Bhatta et al., (2019) and Khanal et al. (2023), who also reported superior yield performance in neem oil-treated crops. The effectiveness of Jholmal-3 can be attributed to its composition, which includes cow urine, medicinal plants, and weeds that function as natural biopesticides. Additionally, cow dung and decayed plant materials present in Jholmal-3 serve as nutrient sources, promoting crop growth and development.

Table 3. Effect of treatment on the yield and its attributes

Treatment	Plant height (cm)	Head girth (cm)	Weight of head (g)	Yield (t/ha)
<i>Metarhizium anisopliae</i>	23.20 ^d	15.67 ^{ab}	378.82 ^{bc}	28.07 ^c
<i>Beauveria bassiana</i>	25.01 ^c	15.76 ^c	384.48 ^{bc}	28.95 ^{bc}
Jholmal-3	27.23 ^b	15.73 ^{bc}	407.84 ^{ab}	30.21 ^{ab}
Neem oil	29.04 ^a	16.12 ^a	426.763 ^a	31.62 ^a
Control	22.29 ^d	15.60 ^{bc}	357.13 ^c	24.57 ^d
SEm(±)	0.55	0.10	9.67	0.66
LSD _{0.05}	1.69	0.35	29.78	2.08
CV	4.32	1.45	4.94	4.57
F-test	***	*	**	***
Grand Mean	25.35	15.77	391.01	28.68

*Significant at $p < 0.05$; SEm = Standard Error of Mean, LSD=Least significant difference at 0.05 level, CV= Coefficient of variation; Means followed by the same letter are not significantly different at $p < 0.05$; *** $p < 0.001$; ** $p < 0.01$

3.3. Laboratory assessment of biological treatments

The effectiveness of different treatments on cabbage butterfly larval mortality under laboratory conditions is presented in Table 4. Result indicated that neem oil exhibited the highest mortality rate across all observation days, followed by entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*), Jholmal-3, and the control treatment.

On the first day after spray (1 DAS), neem oil recorded the highest mortality (73.33%), which was significantly higher than all other treatments ($p < 0.01$). *Beauveria* and *Metarhizium* showed comparable mortality rates of 47.50% and 45.00%, respectively, whereas Jholmal-3 (T3) recorded a lower mortality rate of 38.33%. The control treatment resulted in minimal mortality (8.33%).

By the second day (2 DAS), neem oil continued to show the highest efficacy with a mortality rate of 79.17%, followed by *Beauveria* (60.83%), *Metarhizium* (53.33%), and Jholmal-3 (48.33%). The control exhibited the lowest mortality (10.00%). Statistical analysis confirmed highly significant differences among treatments ($p < 0.001$).

On the third day (3 DAS), neem oil reached a maximum mortality of 85.00%, while

Beauveria (68.33%) and *Metarhizium* (59.17%) maintained a steady increase in mortality. Jholmal-3 (60.00%) also demonstrated a notable effect, although it remained less effective than the entomopathogenic fungi. The control (19.17%) continued to show minimal impact. Neem oil was the most effective treatment across all observation days, likely due to the presence of azadirachtin, which disrupts insect feeding and development, ultimately leading to higher mortality (Kilani-Morakchi et al., 2021). Furthermore, anti-fertility occurred causing barrier on metamorphosis, which plummeted the larval population (Jacobson, 1989; Bishwas, 2008; Akbar et al., 2010; Bishwas, 2013).

Azadirachtin is a broad-spectrum insecticide that acts as a feeding deterrent, insect growth disruptor (IGD), and sterilant and is used to control various agricultural pest species, including Coleoptera, Hemiptera, Diptera, Orthoptera, and Isoptera (Morgan, 2009). Besides these, the best limnoids compounds; Azadirachtin, Salannin, and Nimbin are highly embraced with the insecticidal property (Bhatta et al., 2019; Feinstein, 1952; Debashri and Tamal, 2012).

The effectiveness of *Beauveria* and *Metarhizium* can be attributed to their ability to infect and kill larvae through fungal colonization (Aw and Hue, 2017). Jholmal-3, which contains natural plant extracts and

microbial components, also demonstrated moderate efficacy but was less effective than neem oil and entomopathogenic fungi.

Table 4. Effects of treatment on mortality rate at lab condition

Treatment	Mortality		
	1 DAS	2 DAS	3 DAS
<i>Metarhizium anisopliae</i>	45.00 ^b	53.33 ^{bc}	59.17 ^b
<i>Beauveria bassiana</i>	47.50 ^b	60.83 ^b	68.33 ^b
Jholmal-3	38.33 ^b	48.33 ^c	60.00 ^b
Neem oil	73.33 ^a	79.17 ^a	85.00 ^a
Control	8.33 ^c	10.00 ^d	19.17 ^c
SEm(±)	4.03	3.71	4.70
LSD _{0.05}	12.15	11.20	14.18
CV	18.97	14.76	16.13
F-test	**	***	***
Grand Mean	42.5	50.33	58.33

SEm = Standard Error of Mean, LSD=Least significant difference at 0.05 level, CV= Coefficient of variation; Means followed by the same letter are not significantly different at $p < 0.05$; *** $p < 0.001$; ** $p < 0.01$

3.4. Correlation and regression analysis

A linear regression model was used to analyze the relationship between the number of alive larvae after spray and the resulting crop damage percentage. The regression analysis revealed a moderate coefficient of determination ($R^2 = 0.50$), indicating that the number of surviving larvae accounted for

50.09% of the variation in damage (Figure 2). Similarly, Figure 3 revealed a regression analysis for PROC % and yield with moderate coefficient of determination ($R^2 = 0.49$), indicating PROC % contributing 49% to the observed variation in yield of cabbage due to treatments.

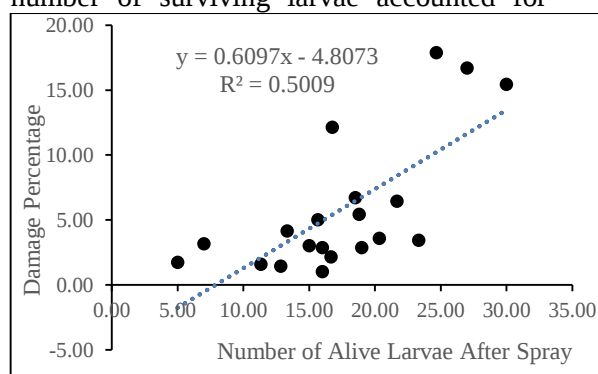


Figure 2. Regression analysis between the number of alive larvae after spray and damage percentage

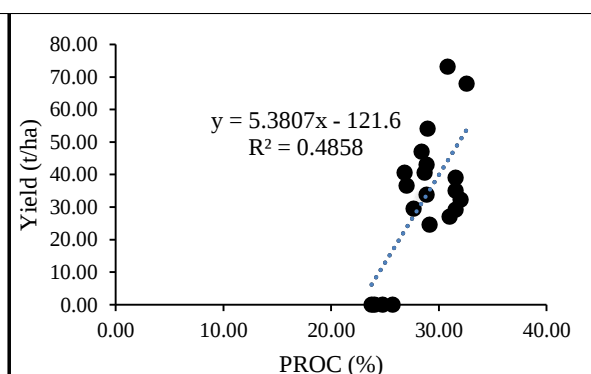


Figure 3. Regression analysis between PROC % and yield

4. CONCLUSION

The evaluation of various biological pesticides for the management of cabbage butterfly revealed that Neem oil was the most effective treatment, significantly reducing the larval population and achieving the highest population reduction over the control. This treatment also resulted in the highest yield and yield attributes, demonstrating both strong insecticidal efficacy and positive agronomic impact. While all treatments outperformed the control, *Beauveria bassiana* and *Metarhizium anisopliae* showed promising results, highlighting their potential as effective biological alternatives. Jholmal-3, despite being primarily recognized for its biostimulant properties, also exhibited notable efficacy in pest suppression. Given its effectiveness, Neem oil is recommended for farmers as a reliable solution for managing cabbage butterfly infestations and enhancing cabbage production. However, *Beauveria bassiana*,

Metarhizium anisopliae, and Jholmal-3 should also be promoted as viable options, particularly in integrated pest management (IPM) approaches. Further research is encouraged to explore optimal concentrations and formulations of these biopesticides to maximize their efficacy, cost-effectiveness, and sustainability in diverse agro-ecological conditions.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Green Resilient Agricultural Productive Systems (GRAPE) and Himalayan Resilience Enabling Action Programme (HI-REAP) project of International Centre for Integrated Mountain Development (ICIMOD) for technical and financial facilitation, and farmers from Budhinanda-10, Dimmarpani, Bajura for providing the research space and continuous support throughout the field work.

REFERENCES

- Abbott, W. S. (1925). A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, 18(1), 265–267.
- Adhikari, B., & Khadka, S. (2023). Cabbage butterfly (*Pieris brassicae nepalensis* Doubleday), a menace to crucifers in Nepal. *International Journal of Zoological and Entomological Letters*, 3(1). Retrieved from <https://www.zoologicaljournal.com/>
- Adhikari, B., Khadka, S., Khafle, S., Chaudhary, N., & Sapkota, S. (2023). Efficacy testing of ‘soft’ pesticides for the management of cabbage butterfly (*Pieris brassicae nepalensis* Doubleday) in Salyan, Nepal. *Russian Journal of Agricultural and Socio-Economic Sciences*, 144(12), 281–291. <https://doi.org/10.18551/rjoas.2023-12.32>
- Akbar, M. F., Haq, M. A., Parveen, F., Yasmin, N., & Khan, M. F. U. (2010). Comparative management of cabbage aphid (*Myzus persicae* Sulzer) (Aphididae: Hemiptera) through bio- and synthetic-insecticides. *Pakistan Entomologist*, 32(1), 12–17.
- Ali, A., & Rizvi, P. Q. (2007). Development and predatory performance of *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on different aphid species. *Journal of Biological Sciences*, 7(8), 1478–1483. <https://doi.org/10.3923/jbs.2007.1478.1483>
- Ansari, M., Hasan, F., & Ahmad. (2012). Influence of various host plants on the consumption and utilization of food by *Pieris brassicae*. *Bulletin of Entomological Research*, 102(2), 231–237.
- Aw, K. M. S., & Hue, S. M. (2017). Mode of infection of *Metarhizium* spp. fungus and their potential as biological control agents. *Journal of Fungi*, 3(2), 30.
- Bhandari, K., Sood, P., Mehta, P. K., Choudhary, A., & Prabhakar, C. S. (2009). Effect of botanical extracts on the biological activity of granulosis virus against *Pieris brassicae*. *Phytoparasitica*, 37(4), 317–322. <https://doi.org/10.1007/s12600-009-0047-2>
- Bhatta, K., Chaulagain, L., Kafle, K., & Shrestha, J. (2019). Bio-efficacy of plant extracts against mustard aphid (*Lipaphis erysimi* Kalt.) on rapeseed (*Brassica campestris* Linn.) under field and laboratory conditions. *Syrian Journal of Agricultural Research (SJAR)*, 6(4), 557–566.
- Biswas, G. C. (2008). Efficacy of some plant materials against the mustard aphid, *Lipaphis erysimi* (Kalt.). *Journal of the Asiatic Society of Bangladesh, Science*, 34(1), 79–82.
- Biswas, G. C. (2013). Comparative effectiveness of neem and synthetic organic insecticide against mustard aphid. *Bangladesh Journal of Agricultural Research*, 38(2), 181–187.
- Červenski, J., Vlajić, S., Ignjatov, M., Tamindžić, G., & Zec, S. (2022). Agroclimatic conditions for cabbage production. *Ratarstvo Journal*, 59(2), 43–50.
- Chiang, M., Chong, C., Landry, B., & Crete, R. (1993). Cabbage (*Brassica oleracea* subsp. *capitata* L.). In B. B. G. Kalloo (Ed.), *Genetic improvement of vegetable crops Elsevier*. (pp. 191–218). <https://doi.org/10.1016/B978-0-08-040826-2.50012-6>.
- Debashri, M., & Tamal, M. (2012). A review on efficacy of *Azadirachta indica* A. Juss-based biopesticides: An Indian perspective. *Research Journal of Recent Sciences*, 1(3), 94–99.
- Embaby, E. S. M., & Lotfy, D. E. S. (2015). Ecological studies on cabbage pests. *International Journal of Agricultural Technology*, 11(5), 1145–1160.
- Erler, F., & Ates, A. O. (2015). Potential of two entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) as biological control agents against the June beetle. *Journal of Insect Science*, 15(1), 1–6. <https://doi.org/10.1093/jisesa/iev029>
- Feinstein, L. (1952). *The year book of agriculture*. United States Department of Agriculture.
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons.

- Henderson, C. F., & Tilton, E. W. (1955). Tests with acaricides against the brown wheat mite. *Journal of economic entomology*, 48(2), 157-161.
- Hopkins, R. J., Van Dam, N. M., & Van Loon, J. J. A. (2009). Role of glucosinolates in insect-plant relationships and multitrophic interactions. *Annual Review of Entomology*, 54, 57–83. <https://doi.org/10.1146/annurev.ento.54.110807.090623>
- International Centre for Integrated Mountain Development (ICIMOD). (2020). *Jholmal: A nature-based solution for mountain farming systems*. Retrieved from https://www.icimod.org/wp-content/uploads/2021/01/Jholmal_English.pdf
- Jacobson, M. (1989). Botanicals pesticide: Past, present, and future. *ACS Symposium Series*. American Chemical Society.
- Joshi, S. (1994). *Harmful insect pests of vegetables in Nepal*. Vegetable Division, Khumaltar, 187.
- Khanal, D., Upadhyaya, N., Poudel, K., Adhikari, S., Maharjan, S., Pandey, P., & Joseph, M. N. (2023). Efficacy of entomopathogenic fungus and botanical pesticides against mustard aphid (*Lipaphis erysimi* Kalt.) under field conditions in Rupandehi, Nepal. *Journal of King Saud University - Science*, 35(8), 102849. <https://doi.org/10.1016/j.jksus.2023.102849>
- Kilani-Morakchi, S., Morakchi-Goudjil, H., & Sifi, K. (2021). Azadirachtin-based insecticide: Overview, risk assessments, and future directions. *Frontiers in Agronomy*, 3, 676208.
- Lakshmanan, K. K. (2001, March 1). Neem: A natural pesticide. *The Hindu*, 8.
- Lal, M. N., & B. R. (n.d.). *Cabbage butterfly, Pieris brassicae L., an emerging menace for Brassica oilseed crops in Northern India*. *Cruciferae Newsletter*, 27, 83.
- Ministry of Agriculture and Livestock Development (MoALD). (2022). *Statistical information on Nepalese agriculture 2021/22*. Government of Nepal, Agri-Business Promotion and Statistics Division.
- Morgan, E. D. (2009). Azadirachtin, a scientific goldmine. *Bioorganic & Medicinal Chemistry*, 17, 4096–4105. <https://doi.org/10.1016/j.bmc.2008.11.081>
- Negi, P., & Kumar, S. (2020). Study on the bio-efficacy of some biopesticide formulations against cabbage butterfly *Pieris brassicae* Linn. in mustard. *Journal of Pharmacognosy and Phytochemistry*, 9(5), 2694–2697.
- Nyaupane, S., Tiwari, S., Thapa, R. B., & Jaishi, S. (2021). Testing of bio-rational and synthetic pesticides to manage cabbage aphid (*Brevicoryne brassicae* L.) in cabbage fields at Rampur, Chitwan, Nepal. *Journal of Agriculture and Natural Resources*, 4(2), 29–39. <https://doi.org/10.3126/janr.v4i2.33652>
- Paudel, S. Jnawali, S. R., and Lamichhane, J. R. (2012). Use of geographic information system and direct survey methods to detect spatial distribution of wild olive (*Olea cuspidata* Wall.) from high mountain forests of northwestern Nepal. *Journal of sustainable forestry*. 31(7), 674-686. <https://doi.org/10.1080/10549811.2012.704769>
- Poveda, J. (2021). *Trichoderma* as a biocontrol agent against pests: New uses for a mycoparasite. *Biological Control*, 159, 104634. <https://doi.org/10.1016/j.biocontrol.2021.104634>
- Semuli, K. L. H. (2005). Nitrogen requirements for cabbage (*Brassica oleracea capitata*) transplants and crop response to spacing and nitrogen top-dressing. *International Journal of Horticulture*, 2(1), 121-123.
- Snogerup, S., Gustafsson, M., & von Bothmer, R. (1990). *Brassica* sect. *Brassica* (Brassicaceae): I. Taxonomy and variation. *Willdenowia*, 19, 271–36.
- Wilbur, N. (2011). Biological aspects of cabbage white butterfly species, *Pieris brassicae* (Linnaeus, 1758) in the environs of Taunggyi District. *Universities Research Journal*, 4(1), 10-15.
- Youns, M., Mohamad, N., Abdhur Raqib, & Masud, S. (2004). Population dynamics of cabbage butterfly (*Pieris brassicae*) and cabbage aphid (*Brevicoryne brassicae*) on five cauliflower cultivars at Peshawar. *Asian Journal of Plant Sciences*, 3(3), 391–393.

INSECT PESTS OF TOMATO AND THEIR MANAGEMENT PRACTICES
ADOPTED BY FARMERS IN CHANDRAGIRI AND KIRTIPUR
MUNICIPALITIES OF KATHMANDU DISTRICT

Janaki Pal^{1*}, Rajanish Mishra², Ramesh Bahadur Karki³, Lokmani Joshi⁴ and Naresh Joshi⁵

- ¹ Himalayan Collage of Agricultural Sciences and technology (HICAST), Kathmandu
- ² Ministry of Agriculture and Livestock Development (MOALD), Singhadurbar, Kathmandu
- ³ School of Agriculture, Far Western University, Tikapur, Kailali
- ⁴ Agriculture Officer, Chaukune RMP, Ministry of Land Management, Agriculture and Cooperatives, Karnali Province, Nepal
- ⁵ Institute of Agriculture and Animal Science (IAAS), Tribhuwan University, Kathmand

ARTICLE INFO	ABSTRACT
Keywords: Biological control, Chemical pesticides, Integrated Pest Management, Sampling *Correspondence: janakipal2055@gmail.com Tel: +977-9862425132	<i>This study aimed to identify insect pests of tomato and their management practices adopted by farmers in Chandragiri and Kirtipur Municipalities. Primary data was collected from 80 farmers between May and August 2024 using structured and semi-structured questionnaires. This research identified tomato leaf miners, whiteflies, tomato fruit borers, and aphids as the primary insect pests causing significant economic damage to tomato. Among the respondents, 33.75% relied solely on chemical pesticides, while others integrated cultural, mechanical, and botanical methods as management strategies. Crop rotation was the most common cultural practice, adopted by 51% of farmers. Botanical pesticides, used by 76% of respondents, were the dominant form of biological control, while mechanical methods, such as yellow sticky traps, were used by 51%. Agro-Vet stores were the main source of pesticides for 84% of respondents. Chemical pesticide application was frequent, with 30% spraying pesticides at 7–10 days interval, and 49% applying them in the morning. The study showed farmers heavily depended on chemical pesticides than other integrated non-chemical methods. From the study, it can be concluded that training programs on integrated pest management is essential, incorporating both chemical and non-chemical strategies.</i>

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables globally, which holds significant importance in both global agriculture and human nutrition (Padhmanabham, 2016). It is the third most commonly grown fresh vegetable crop in Nepal (MoALD, 2022). Well-known tomato cultivars in Nepal include Pesarubi, Roma, Manprekash, NCL 1, and Srijana (AITC, 2023). In particular, Kathmandu contributes 5,965 mt of tomato production in an area of

184 hectares, achieving a high yield of 32.42 metric tons per hectare (MoALD, 2022). Tomato is susceptible to different insect pests, and all parts of the plant, including leaves, stems, flowers, and fruits, could be subjected to attack. Tomato plants are infected by diseases and insect pests in the growth process, which lead to a reduction in tomato production and economic benefits for growers (Liu, 2020). Different pests of tomatoes being noticed worldwide are tomato leaf miner (*Tuta absoluta* Meyrick), tomato fruit borer (*Helicoverpa armigera* Hubner),

tobacco caterpillar (*Spodoptera litura* Fabricus), aphid species (*Aphis gosypii* Mordvilko, *Mizus persicae* Koch), white-fly species (*Bemisia tabaci* Gennadius, *Trialeurodes vaporariorum* William H. Haliday), etc. Among these pests the tomato leaf miner is a serious major problem throughout the world (Adhikari et al., 2019). Among all major insects, the South American tomato leaf miner was found to occur with about 89% as a major pest, then after that the whitefly (84%), which was followed by the *H. armigera* (41%) and the *S. litura* (39%), respectively (Gauli et al., 2020). In Nepal, since tomatoes grown commercially, pest management is a burning issue. Tomatoes are the most in-demand vegetables in the market. Among all the vegetables grown in Nepalese fields tomatoes are high-value vegetables that have a great contribution to farmers' livelihoods (Rajkarnikar, 2021). Due to high demand and good market value, the commercial growers are increasing day by day in Kathmandu. As the production increases, the insect pests also rationally increase in the commercial field. So, the management practices followed by the farmers directly represent in the fruit quality and quantity (Rijal et al., 2018). So, in these situations yield loss by insect pests' infestation has a negative impact on both individual national levels (Gurung, 2016). The aim of the study is to know the real scenario of insect pests of tomatoes in farms, management practices, and technical knowledge adopted by the farmers in the present condition.

2. METHODOLOGY

2.1 Site selection

For this study, the survey was conducted from May 10th, 2023, to August 10th, 2024, on the prominence site of tomato cultivation in the northern part of the Kathmandu district, specifically within ward numbers 2 and 3 of Chandragiri and ward numbers 4, 5, and 6 of Kirtipur Municipalities in the Kathmandu district covering an area of 50.7 sq km (Figure Figure 1). Those areas were chosen due to their fertile soils, favorable

climate for tomato farming, and the significant engagement of smallholder farmers in tomato production. Additionally, the proximity of these municipalities to major market centers within the Kathmandu Valley facilitates easy access to markets, making them representative study sites for analyzing tomato pest management practices and challenges. The geographic diversity within the selected areas also provides a comprehensive understanding of the region's agricultural practices. The district's fertile soil and favorable climate make it an ideal location for tomato cultivation, which is a significant agricultural activity in the region. Kathmandu is strategically positioned within the Kathmandu Valley, bordered by several municipalities. To the south, across the Bagmati River, lies Lalitpur Metropolitan City (Patan), forming a contiguous urban area with Kathmandu, both enclosed by a ring road. Kirtipur borders Kathmandu to the southwest, while Madhyapur Thimi is situated to the east. This geographic setting not only supports agricultural activities but also provides easy access to market centers within the valley, making Kathmandu an important hub for tomato production and trade.

2.2 Sample size and sampling techniques

The sampling for this study was conducted using a simple random sampling method among tomato-growing farmers in the Chandragiri and Kirtipur municipalities in the Kathmandu district. Simple random sampling is justified as an effective method because it ensures that each member of the population has an equal probability of being selected, which minimizes selection bias. This randomness is crucial in producing a sample that is representative of the entire population, allowing for more accurate and generalizable results. The total sample size consists of 80 households, which were selected randomly from the population of interest. The sample size for this study was 80 households; among them, 25 households were from Chandragiri municipality, and 55 households from Kirtipur municipality (Table 1)



Figure 1. Map showing study area

Table 1. Sample size distribution in the study area

SN	Name of study area	Sample size
1	Chandragiri municipality	25
2	Kirtipur municipality	55
	Total	80

The sample size was determined using Cochran Formula, which is given as, if the population size is unknown but a lot, the population proportion is known

$$n = \frac{P(1 - p)z^2}{e^2}$$

Where,

n = sample size

p = the population proportion ($p = 0.5$)

e = acceptable sampling error ($e = 0.1$)

z = z value at reliability level or significance level.

Reliability level 95% or significance level 0.05; $z = 1.96$

(Cochran, 1977)

2.3 Source of data

Primary data: Primary information was collected by using a structured and semi-structured questionnaire. The questionnaire was developed to gather all relevant information required to meet the objectives of study. A total of 80 respondents were chosen for the survey. The survey was carried out by interviewing the selected farmers with the help of a semi-structured questionnaire that covered questions regarding major insect pests of tomatoes,

their damage, and management practices adopted by farmers, etc.

Secondary data: Secondary information was collected from various published resources such as books, Articles, reports, research papers, journals like the Nepalese Journal of Agriculture Science and different concerned institutes like NARC, MoALD, HICAST library and from internet exploration.

2.4 Method and techniques of data analysis

The collected data was carefully edited for missing and incomplete answers. The entry, tabulation, cleaning, and processing of the data were then done in MS Excel. Then it was converted into standard units such as land in ropani, weight in kg, etc. Descriptive statistical tools mean, percentage were used for data analysis. The analyzed data was presented in tables, pie charts, line graphs, and bar graphs. In the study, descriptive statistics such as percentage age, frequency counts, and mean were used in analyzing the measures of respondents, socio-economic characteristics, and factors related to farming activities.

Index ranking of problems: Scaling method gives the way and attitude of the respondents towards propositions. The farmer opinion on the importance given to the different production and marketing constraints/problems was analyzed by using a 5-point scale of constraints/problems comprising the least serious, a little bit, moderate, serious, and the most serious by using 1,2,3,4, and 5, respectively. The index of importance was computed by using the following formula: (Miah, 1993)

$$I_{imp} = \frac{\sum Si fi}{N}$$

Where,

I_{imp} = Index of importance

Σ = Summation

Si = Scale value

fi = Frequency of importance given by the respondents

N = Total numbers of respondents

3. RESULTS AND DISCUSSION

3.1 Information and respondent's knowledge on insect/pest

Occurrence of pest incidences in the study area: During the study, about 86% of respondents mentioned that tomatoes were damaged by insects like tomato leaf miners, tomato fruit borers, whiteflies, and aphids, and the remaining 14 % mentioned the damage by diseases as shown in (Figure 2).

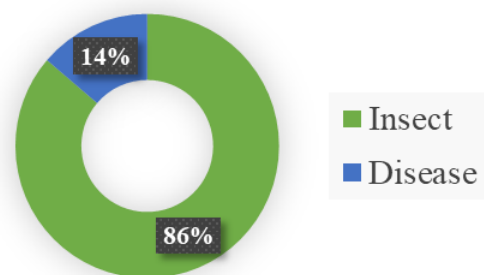


Figure 2. Percentage of pest incidences in tomato

Insect pest infestations were seen high when there was a lack of irrigation in the field. Insect pests were a major problem responsible for tomato loss due to several factors, including direct feeding by insects, rapid infestation and reproduction, difficulty in controlling them, confusion with disease symptoms, pesticide resistance, and climate changes as reported by the respondents.

Observation of insect pests of tomato:

Observations of insect pests in the tomato farming sector reveal significant challenges for local farmers. Pests such as fruit worms, aphids, whiteflies, beetles, and tomato leaf miners severely impact tomato production, leading to reduced yield and economic losses. The fruit worm (*H. armigera*), commonly known as "Gabaro," inflicts extensive damage by feeding on fruits, while aphids (*Aphis spp.*), known as "Lahi," weaken plants and spread diseases. The whitefly (*B. tabaci*), commonly known as "Seto Jhinga," spreads viral infections and

damages plants, and the tomato leaf miner (*T. absoluta*), commonly known as the "Leaf-eating insect," harms plant health through leaf-mining (

Table 2). These observations underscore the urgent need for effective pest management practices. Without proper education, training,

and resources, farmers struggle to manage these pests, highlighting the necessity for targeting training programs, improving access to pest management resources, and the implementation of integrated pest management (IPM) strategies to enhance tomato farming resilience in the region.

Table 2. Common insect pest of tomato

Local name	Common name	Scientific name
Gabaro	Tomato fruit borer	<i>Helicoverpa armigera</i> , Hubner
Lahi	Aphids	<i>Aphis spp</i> , Mizu Persicae
Seto Jhinga	White fly	<i>Bemisia tabaci</i> , Gennadius
Pat khane kira	Tomato leaf miner	<i>Tuta absoluta</i> , Meyrick

Damage level of insect pests: The study report shows that the tomato leaf miner is the most commonly reported pest, affecting 43% of respondents, followed by the whitefly at 34%. The tomato fruit borer is reported by 11% of respondents, while aphids and beetles are identified by 8% and 5% of respondents, respectively, as shown in (FigureFigure 3). The data indicates that the tomato leaf miner and whitefly are the most significant pests among the surveyed group. The high incidence of tomato leaf miner is likely due to its rapid reproduction rate, ability to

develop resistance to pesticides, and adaptability to various climatic conditions. Additionally, its capacity for significant crop damage through direct feeding on leaves, stems, and fruits makes it a major pest in tomato cultivation. Similar findings were reported by Joshi et al. (2018), Gauli et al. (2020), Panse et al. (2020), and Lamasal et al. (2022), who noted that the tomato leaf miner (*T. absoluta*), whitefly (*B. tabaci*), and fruit borer (*H. armigera*) were major infesting insects in the tomato crop.

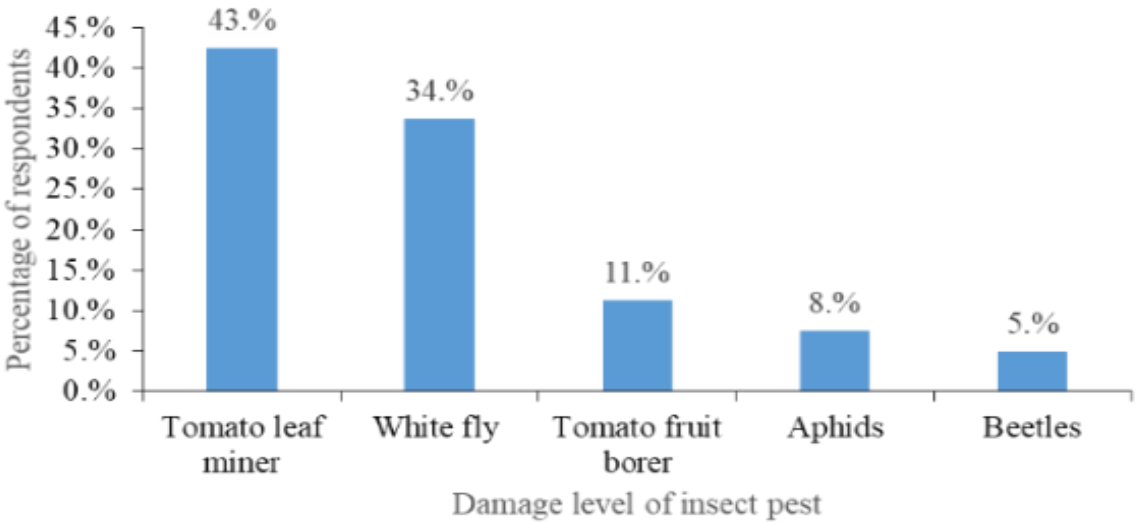


Figure 3. Percentage of damage level in tomato by insect pest

Stage of damages: During the study, most producers reported observing damage primarily during the fruiting stage (69%), followed by the vegetative stage (37%),

seedling stage (10%), and flowering stage 4%, as shown in (Figure Figure 4).

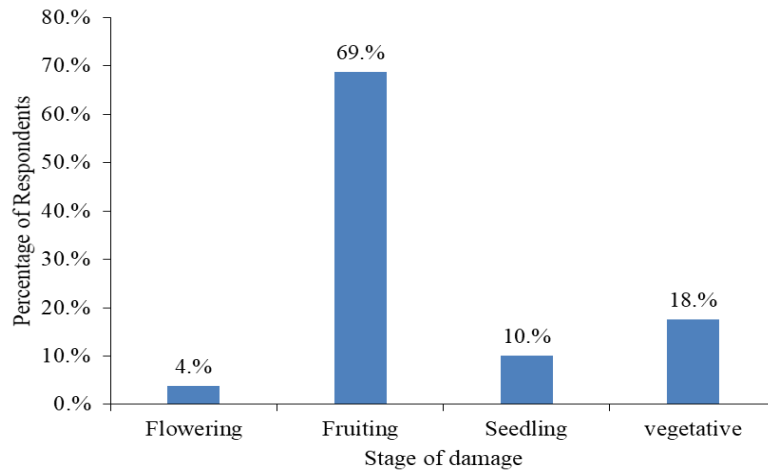


Figure 4. Stages of damages in tomato by insect pest

The highest percentage of insect damage occurred in the fruiting stage due to the high nutrient content of tomato fruits, which attracts borers, caterpillars, and aphids. Peak pest activity and favorable environmental conditions contributed to more damage during this stage than others. However, a report by Ghimire and Chhetri (2023) indicated that the flowering stage was highly susceptible (99.73%) in the research areas of Kathmandu, Bhaktapur, Kavre, and Pokhara, Nepal.

Trend of pest problem: In the survey area, 39% of respondents observed an increase in pest problems, while 35% reported a decrease, 14% noted no change, and 13% did not detect a trend (Figure Figure 5). The increasing and constant pest trends are linked to factors such as reliance on chemical pesticides, inadequate field sanitation, lack of crop rotation, and the development of pest resistance. Bhandari et al. (2021) noted that since 2003, the rise in diseases is attributed to excessive pesticide use, highlighting the complex interplay between pest management practices and crop health.

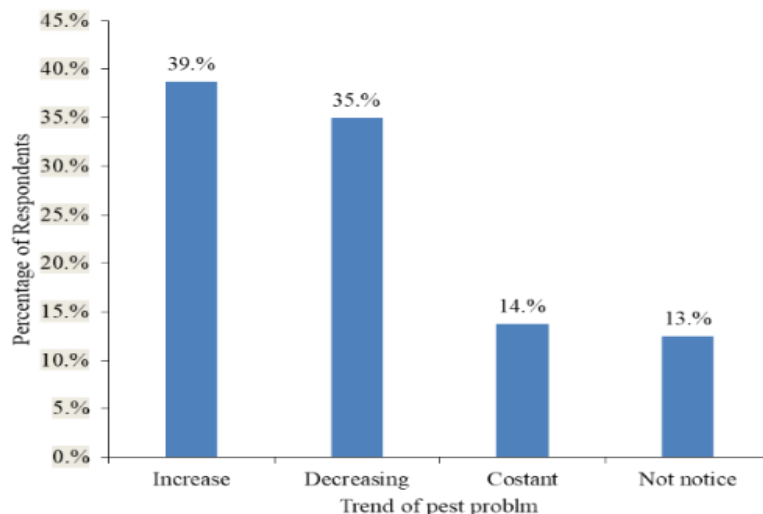


Figure 5. Trend of pest problem in tomato

3.2 Management practices

General pest management practice: The data shows that the majority of respondents, i.e. 33.75% prefer using chemical methods for pest management. Another 28.75% combine chemicals with cultural practices, while 26.25% use a mix of chemical and mechanical methods. The least common approach, used by 11.25% of respondents, combines botanical and mechanical practices as shown in (Table **Table 3**).

Botanical practices: Among biological methods employed, most of the respondents

practiced botanical pesticides, i.e., 76%, as shown in the below (FigureFigure **6**). The botanical practices adopted for insect pest control were the application of jholmol, neem-based pesticides like Azadirachtin and neem oil. These are natural, eco-friendly alternatives to synthetic pesticides. These methods are favored in organic farming because they reduce chemical residues in food, protect beneficial insects, and promote sustainable agriculture. (Lamsal et al., 2018) reported that 60% were using botanicals and bio-pesticides like neem and, *B. thuringiensis* in alternative ways.

Table 3. General pest management practice

SN	Management practices	Frequency	Percentages
1	Chemical only	27	33.75
2	Chemical + Cultural	23	28.75
3	Chemical + Mechanical	21	26.25
4	Botanical + Mechanical	9	11.25

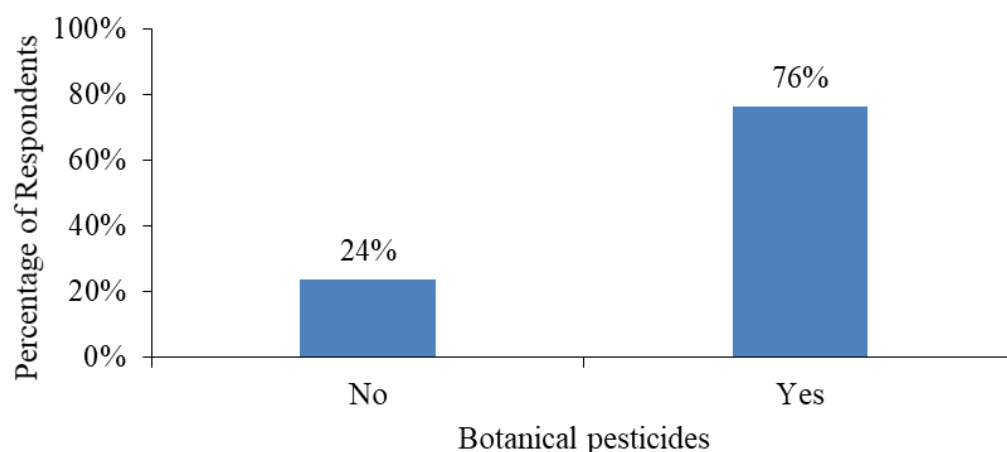


Figure 6. Botanical practices used in tomato pest control

Cultural methods: Among the cultural methods employed, most of them practiced crop rotation (51%), followed by intercropping (44%), and the remaining were practicing sanitation as a measure of pest management under cultural practice shown in (FigureFigure 7). These practices are commonly used because they are sustainable,

cost-effective, and reduce the need for chemical pesticides. According Adhikari *et al.* (2019), most effective, safe, economic, and practical method of *T. absoluta* control used by the farmers of the Kavre, Bhaktapur, and Lalitpur districts was pheromone traps, followed by cultural methods.

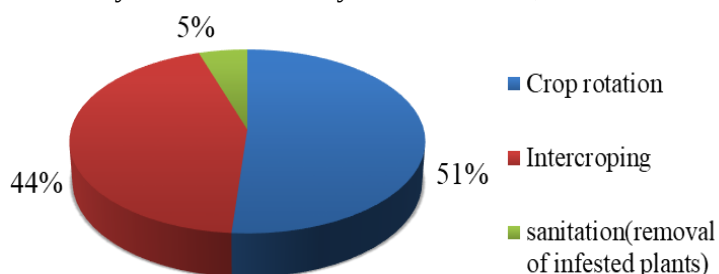


Figure 7. Practices of cultural method

Mechanical practices: Among the mechanical methods employed, most of them installed yellow sticky traps (51%), different lures (18%), and hand picking of larvae (31%) as shown in FigureFigure 8. Mechanical practices are non-chemical,

environmentally friendly, often simple, cost-effective, and can be employed without specialized knowledge. The use of TLM lure was found to be the best in terms of its effectiveness, safety, and practicability (Gautam and Joshi, 2017).

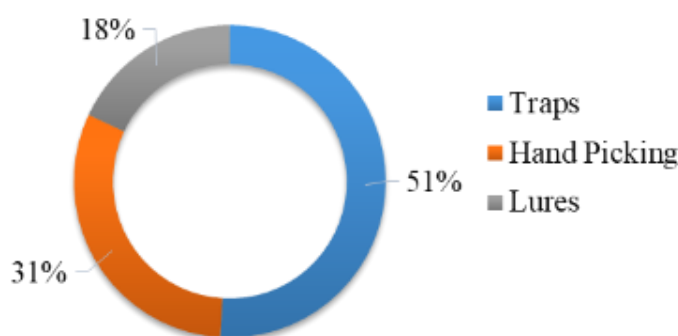


Figure 8. Percentage of mechanical practices

Chemical pesticides used in the survey area: According to the respondent, chemical pesticides were the foremost choice for management methods of pests. Different types of chemical pesticides were used by the farmers for the management of insect pests commonly seen in tomatoes (Table Table 4).

3.3 Pesticide use patterns

Time of pesticide application: The results indicate the distribution of pesticide usage among respondents across different times of the day: 49% of respondents used pesticides in the morning, 19% in the day, and the remaining 32% in the evening, as shown in (FigureFigure 9). The high preference for using pesticides in the morning likely stems from several practical reasons. Morning conditions are often cooler and less windy,

reducing the risk of pesticide drift and evaporation, which improves the effectiveness of the application. Additionally, pests are usually more active during the early hours, making it an optimal time to target them. Morning applications also allow the chemicals to dry and be absorbed before human activity increases, minimizing exposure risks. These practices aim to maximize the effectiveness of pesticides while minimizing environmental impact and health risks. But according to Thapa et al. (2020), the best time to use insecticide was in the evening because it was quite safe for beneficial insects like bees.

Table 4. Chemical pesticides used in survey area

SN	Targeted pest	Trade name	Composition	Dose
1.	<i>T. absoluta</i>	Deligate	Spinetoram 11.7% SC	0.5 gram./liter water
2.	White-fly	Ulala	50% Flonicamid WG	0.25-0.50gram/liter water
3.	Aphids	King rocket	Pyriproxyfen 10%+	40 ml/20 liter

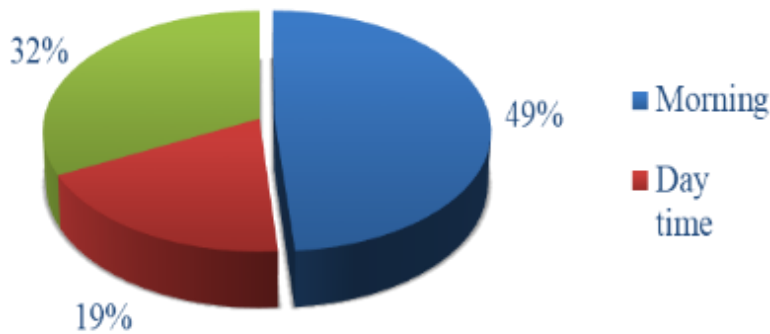


Figure 9. Time of pesticide application

Interval of application of pesticide: About 43% of the respondents used the chemical pesticides in a shorter interval, i.e., 7–10 days, while 30% of respondents were found (Table 5). A similar finding was reported in a case study of Chitwan: 62% use pesticides at the interval of 7-10 days (Rijal et al., 2018).

Dose of chemical pesticide: Most of the respondents (65%) were found to be using the recommended dose of chemical

to be making the interval of 10–15 days, only 7% for more than 20 days, 9% for 15–20 days, and so far less than 7 days as shown in (Table

pesticides, while 35% were using more than the recommended dose (Figure Figure 10). The majority received usage directions from agro-vets. The excessive use beyond recommendations might be due to the low impact of chemical pesticides or a lack of knowledge regarding the correct dosage

Table 5. Interval of application of pesticide

SN	Interval of application of pesticide	Percentage
1	<7 Days	11
2	7-10 Days	43
3	10-15 Days	30
4	15-20 Days	9
5	>20 Days	7

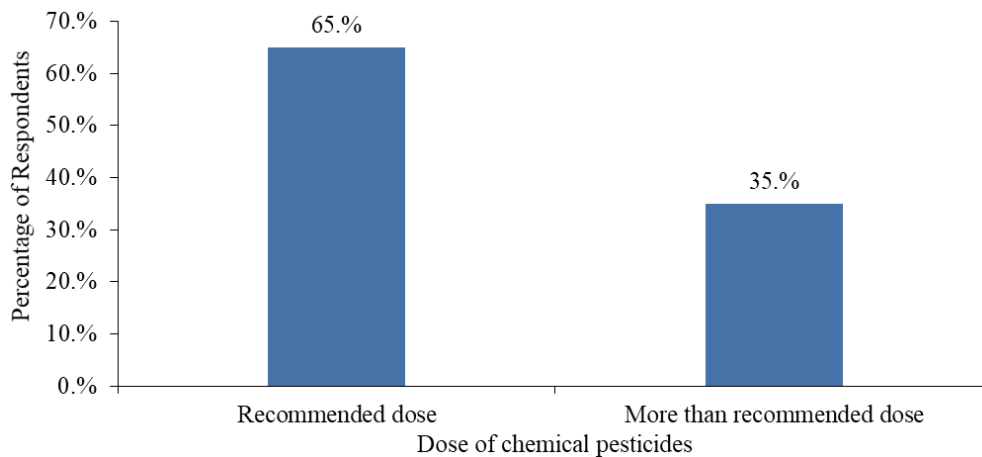


Figure 10. Dose of chemical pesticides in tomato

3.4 Knowledge on IPM

The study found that 70% of respondents were unaware of Integrated Pest Management (IPM) due to a lack of knowledge or awareness about IPM practices; 9% had a basic understanding, 7% had some idea, and

The remaining 14% were fully aware of IPM training, as shown in (Table Table 6). However, Rijal et al. (2018) reported that about 53% of farmers in the Nuwakot District had knowledge of IPM and were using IPM-based control measures.

Table 6. Knowledge on IPM

Idea on IPM	Respondent (No)	Percentage
Unknown	56	70
Just heard	7	9
Some idea	6	7
Well known	11	14

3.5 Barriers to adoption and potential incentives for farmers to adopt IPM

Farmers face several obstacles in adopting Integrated Pest Management (IPM), including a lack of awareness and knowledge about IPM practices, high initial costs, and limited access to necessary inputs. Resistance to change from traditional practices and inadequate extension services further hinders adoption. Market uncertainty, the time-consuming nature of IPM, and insufficient policy support also contribute to the slow uptake of these sustainable practices. Additionally, the difficulty in monitoring and evaluating IPM effectiveness adds to the challenges.

To encourage farmers to adopt IPM, various incentives could be implemented. These include offering training programs and

workshops to improve knowledge and awareness, providing financial subsidies or grants to offset high initial costs, and improving access to IPM materials and resources. Farmer-to-farmer knowledge exchange programs could foster peer learning, while crop insurance schemes could mitigate risks associated with IPM practices. Policy incentives and support would further encourage widespread adoption of IPM among farmers.

3.6 Major challenges to managing insect pests

In the research area, farmers encounter several significant challenges in managing insect pests in tomato cultivation (Table Table 7). The most critical issue is the high cost of pesticides, which ranks as the top challenge, with an index score of 0.81, as

identified by the majority of respondents, aligning with the findings of Rijal *et al.* (2018). The second major hurdle is the lack of knowledge about pest management practices, with an index score of 0.80. The unavailability of pesticides ranks third, with an index score of 0.62, highlighting the difficulties farmers face in accessing necessary pest control materials. Pest resistance to pesticides is also a notable concern, although it ranks fourth with a lower index score of 0.43. The environmental impact of pesticide use is considered the least challenging issue, with an index score of 0.33, suggesting that farmers prioritize economic and practical concerns over environmental ones. This data was collected from a field survey conducted in 2024

3.7 Respondent's suggestions to improve pest management

Respondents provided several key suggestions to improve pest management

practices (Table Table 8). The highest priority was placed on enhancing training and education, with an index score of 0.84, as respondents recognized the critical need for farmers to be better equipped with the knowledge necessary to manage pests effectively. Following this, the availability of pesticides was highlighted as the second most important factor, with an index score of 0.69, emphasizing the need for timely access to these essential inputs. Financial support and government subsidies ranked third (index score of 0.60), reflecting the concern over the high costs associated with pest control measures. Lastly, respondents suggested increasing access to biological control agents as a more sustainable and eco-friendlier alternative to chemical pesticides, although this was ranked as the lowest priority with an index score of 0.36. These suggestions align closely with the findings of Thapa *et al.* (2015).

Table 7. Major challenges to managing insect pests

Problem	Score					Index	Rank
	1	2	3	4	5		
High cost of pesticides	34	26	12	8	0	0.81	I
Unavailability of pesticides	4	30	21	13	12	0.62	III
Lack of knowledge	38	22	11	6	3	0.80	II
Pesticide resistance to pesticides	2	1	27	27	23	0.43	IV
Environment impact	2	1	9	26	42	0.33	V

Table 8. Respondent Suggestions to improve pest management

Suggestions	Score				Index	Rank
	1	2	3	4		
Training and education	41	29	8	2	0.84	I
Availability of pesticide	20	33	17	10	0.69	II
Financial support /subsidies	15	16	35	14	0.60	III
Access to biological control agents	4	2	20	54	0.36	IV

4. CONCLUSION

The study revealed significant challenges to producing tomatoes for farmers, with 86% reporting damage caused by pests like tomato leaf miners, fruit borers, whiteflies, and aphids. Damage was most severe during the fruiting stage (69%), making it the most vulnerable period. The tomato leaf miner (*T. absoluta*) was the most common pest, affecting 43% of farmers. Pest problems

were reported to have increased by 39%, primarily due to pesticide resistance, lack of crop rotation, and poor field sanitation. Most farmers (33.75%) relied on chemical pesticides, while others combined them with cultural, mechanical, or botanical methods, such as jholmol and neem-based pesticides. Awareness of Integrated Pest Management (IPM) was low, with 70% of farmers unaware of its practices, citing high costs, lack of inputs, and inadequate extension

services as barriers. Major challenges included the high cost of pesticides, limited knowledge, and pesticide resistance. Farmers suggested increasing training, improving pesticide availability, providing financial support, and sustainable pest management practices, better education, and resource access to enhance the resilience of tomato farming.

ACKNOWLEDGEMENTS

We would like to acknowledge the Warm Temperate Horticulture Centre, Kirtipur, Kathmandu. Special thanks go to all the farmers of Chandragiri and Kirtipur Municipality in the Kathmandu District, with whom we shared incredible moments during the survey, for their kind information, cooperation, and great participation in making my task reliable and meaningful.

REFERENCES

- Adhikari, D., Subedhi, R., Gautam, S., Pandit, D.P. & Sharma, D.R. (2019) 'Monitoring and management of tomato leaf miner, (*Tuta absoluta*, Meyrick) in Kavrepalanchowk, Nepal', *Journal of Agriculture and Environment*, vol. 20, pp. 1.
- AITC (2079) *Krishi Tatha Pasupanchi (Diary 2079)*. Hariharbhawan, Lalitpur, Nepal: AITC.
- Bhandari, B., Joshi, R. & Ghimire, K. (2020) 'Economic diversification and livelihood strategies of tomato farmers in Nepal', *Agricultural Economics Research Review*, vol. 33, no. 1, pp. 101-115.
- Cochran, W. G. (1977). *Sampling techniques*. 3rd Ed. New York: John Wiley & Sons.
- Gauli, K., Sah, L.P., Shrestha, J.B., Rajbhandari, B.P. & Ghimire, A.R. (2020) 'Major insect pests and pesticide use practices among tomato growers in Kathmandu and Bhaktapur districts', *Journal of the Plant Protection Society*, vol. 6, pp. 202-211.
- Gautam, M.R. & Joshi, P.K. (2018) 'Socio-economic factors influencing tomato cultivation in Nepal: A case study', *Journal of Agriculture and Environment*, vol. 19, pp. 63-75.
- Ghimire, S. & Chhetri, B.P. (2023) 'Menace of tomato leaf miner (*Tuta absoluta*) [Meyrick, 1917]): its impacts and control measures by Nepalese farmers', *AgroEnvironmental Sustainability*, vol. 1, no. 1, pp. 37-47.
- Gurung, T.B. and Shrestha, K., 2016. Integrated pest management in vegetable crops of Nepal: Status and future challenges. *Nepal Journal of Agricultural Research*, 1, pp.40-55.
- Joshi, A., Thapa, R.B. & Kalauni, D. (2018) 'Integrated management of South American tomato leaf miner [*Tuta absoluta* (Meyrick)]: a review', *Journal of the Plant Protection Society*, vol. 5, pp. 70-86.
- Lamsal, A., Sah, L.P., Giri, A.P., Devkota, M., Colavito, L.A., Norton, G., Rajotte, E.G. & Muniappan, R. (2018) 'Occurrence of South American Tomato Leaf Miner (*Tuta absoluta*) and current management practices adopted by farmers in Lalitpur district, Nepal', *Journal of the Plant Protection Society*, vol. 5, pp. 155-165.
- Liu, J. and Wang, X. (2020) 'Tomato Diseases and Pests Detection Based on Improved Yolo V3 Convolutional Neural Network', *Frontiers of Plant Science*, 11.
- Miah, A. (1993). *Applied statistics: A course handbook for human settlements planning*. Division of Human Settlements Development, Asian Institute of Technology, Thailand.
- MoALD. (2022). *Statistical information on Nepalese agriculture 2017/2018*. Ministry of Agricultural Development, Singha Durbar, Kathmandu, Nepal.
- Padhmanabham, P., Cheema, A., & Paliyath, G. (2016). Solanaceous fruits including tomato, eggplant, and peppers. In Y. H. Hui (Ed.), *Handbook of Fruit and Vegetable Flavors* (pp. 275–289).
- Panse, R.K., Bisen, S., Dongre, R., Kadam, D.M., Kuldeep, D.K. & Rajak, S.K. (2020) 'Pest population fluctuation in tomato (*Solanum lycopersicum* L.) crop and their correlation with weather parameters', in *Proceedings of Virtual National Conference on Strategic Reorientation for Climate Smart Agriculture (V-AGMET 2021)*, vol. 2, p. 209.
- Rajkarnikar, N. & Shrestha, D. (2021) Prospect and challenges of off seasonal tomato production: A case study of Pokhara, Kaski, Nepal, pp. 265-275.
- Rijal, J.P., Regmi, R., Ghimire, R., Puri, K.D., Gyawaly, S. & Poudel, S. (2018) Farmers' knowledge on pesticide safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal, Vol. 8(1), pp. 16
- Thapa, A., Tamrakar, A.S. & Subedi, I.P. (2015) 'Pesticide use practices among tomato growers in Kavre district, Nepal', *Nepalese Journal of Zoology*, 3(1), pp. 17-23.
- Thapa, R. and Poudel, P. (2020) 'Major pests of tomato and their management practices in Nepal', *Journal of Horticultural Sciences*, 25(1), pp. 95-110.

EFFECTS OF DIFFERENT METHOD OF SEED PRIMING ON SEED QUALITY PARAMETERS OF RAMPUR HYBRID-10 VARIETY OF MAIZE

Bipin Joshi^{1*}, Deepika Timsina¹, Prarthana Joshi¹, Dhanendra Adhikari¹ and Sapana Shrestha¹

¹ Agriculture and Forestry University, Rampur, Chitwan

ARTICLE INFO

Keywords:

Germination,
seed priming,
seed quality attributes,
vigour index

***Correspondence:**

bipeenjoshi2002@gmail.com
Tel: +977 9815697551

ABSTRACT

This study investigates the effects of different seed priming techniques on seed quality attributes of the seeds of Rampur Hybrid-10 maize variety at Rampur, Chitwan, Nepal. The objective was to evaluate the efficacy of various priming agents—including cow urine @50ml/L, salicylic acid @50mg/L, gibberellic acid (at 50 ppm and 75 ppm), hydropriming, and urea @0.1%—in enhancing germination and early seedling development under controlled laboratory conditions. A completely randomized design was employed, with seeds primed for 24 hours before being sown in washed sand. Key parameters such as germination percentage, mean germination time, root and shoot lengths, and seedling vigour index were recorded over a period of 15 days. The findings revealed that treatments using cow urine @50ml/L and gibberellic acid @ 75 ppm significantly improved germination rates and reduced the time to germination compared to the control and other treatments. Enhanced root and shoot development, along with a higher seedling vigour index, indicated that these priming techniques effectively promote the early growth. The results demonstrate that optimized seed priming can overcome initial seed emergence.

1. INTRODUCTION

Maize, often referred as the “queen of cereals,” plays an indispensable role in global food security and agricultural sustainability (Ikramullah et al., 2011), especially in developing countries like Nepal. This versatile crop is not only a primary source of calories for millions but also a critical component in animal feed and various industrial applications (Banerjee et al., 2020). In Nepal, maize stands as the second most important crop after rice, yet its full yield potential remains largely unrealized due to issues such as poor seed germination, delayed

emergence, and erratic seedling vigour (MOAD, 2017). These challenges, compounded by variable climatic conditions and limited access to modern agronomic practices, have sparked interest in innovative seed enhancement techniques. The urgency to improve crop establishment in maize underscores the need for scientifically validated interventions that can transform both yield outcomes and farming livelihoods.

Seed priming has emerged as one such promising technique, offering a practical approach to overcome inherent seed

dormancy and improve early seedling development. This method involves controlled hydration of seeds to initiate pre-germinative metabolic processes without allowing full radicle protrusion, thus reducing the mean germination time and enhancing uniformity in seedling emergence (Mousavi et al., 2012). Several studies have demonstrated that priming not only accelerates the initiation of vital enzymatic activities, such as α -amylase-mediated starch degradation, but also enhances nutrient mobilization, which in turn promotes robust seedling growth (Ajirloo et al., 2013; Amir et al., 2023). Moreover, both conventional treatments like hydropriming and chemical treatments involving hormonal agents such as gibberellic acid (GA_3) and salicylic acid have been extensively researched for their roles in enhancing seed vigour (Tian et al., 2014; Koirala et al., 2006). Notably, locally available organic priming agents such as cow urine, which is rich in essential nutrients and growth promoters, offer an economical alternative that could be particularly beneficial in resource-limited settings (Adhikari and Subedi, 2022).

Research in seed priming has demonstrated notable biochemical and physiological benefits for maize; however, comparative evaluations under controlled laboratory conditions remain scarce. Most studies have focused on either hormonal priming—such as treatments with GA_3 , which significantly enhance photosynthetic activity and stress tolerance (Tian et al., 2014). However, priming maize seeds with locally sourced organic agents like cow urine is studied little. Moreover, the effectiveness of these priming techniques in addressing inherent seed dormancy and inconsistent germination in

high-yielding varieties, such as Rampur Hybrid-10 in Chitwan, is under documented (Shrestha et al., 2019). Optimizing seed priming protocols under controlled lab conditions is critical, as it can lead to fast, uniform germination and improved seedling vigour, ultimately resulting in high yield of the crop.

In addition, the importance of conducting this research under controlled laboratory conditions cannot be overstated. Laboratory environments enable precise measurement of key parameters such as germination percentage, mean germination time, speed of germination, and seedling vigour by eliminating external environmental variability (Pegah et al., 2008). This controlled setup ensures that differences observed among various priming techniques are directly attributable to the treatments themselves. By adopting cost-effective and sustainable seed priming practices, farmers can reduce the need for repeated sowing, minimize wastage, and enhance overall farm efficiency, thereby contributing to food security and economic development (Banerjee et al., 2020). The primary aim of this study, therefore, is to systematically assess and compare these priming techniques under laboratory conditions, providing actionable recommendations for optimizing maize cultivation practices.

2. MATERIALS AND METHODS

The experiment was conducted under controlled laboratory conditions at the Agronomy Laboratory of Agriculture and Forestry University in Rampur, Chitwan, Nepal (Average annual Temperature is 23.2°C, annual rainfall 2407mm, 27.6506° N, 84.3503° E and at an elevation of 189 masl).

(Meng et al., 2022). Following key parameters were investigated:

2.1 Germination Percentage

The germination percentage of seeds for each treatment was computed using the formula adopted by (Timsina and Marahatta, 2024).

$$\text{Germination \%} = \frac{\text{Number of seed germinated}}{\text{Number of seeds sown}} \times 100 \%$$

2.2 Mean Germination Time

Mean Germination Time is the mean time taken by the overall seeds to complete the mechanism of germination and it is computed using the formula adopted by (Čanak et al., 2016).

$$\text{Mean Germination Time (MGT)} = \frac{\sum Dn}{\sum n}$$

Where, D= Number of days after the beginning of the experiment

n = Number of seeds germination on day D

2.3 Vigour Analysis

2.3.1 Root shoot length

Randomly selected 5 seedlings from each replication were used to record root and shoot length data. The data were collected on the 15th day as adopted by (Dhakal and Subedi, 2020)

2.3.2 Seedling Vigour Index I (SVI)

$$\text{SVI} = \frac{\text{SDW}}{\text{MGT}} \text{ (Ghassemi-Golezani et al., 2005)}$$

Where, SDW= Seedling dry weight

MGT= Mean Germination Time

2.3.3 Seedling dry weight

5 sample plants were removed from the tray after 14 days and weighed in weighing balance fresh weight was noted and then plant samples were subjected to oven drying for 24 hours at 105°C followed by dry weight noting. (Afzal et al., 2004).

All data were recorded systematically in structured datasheets and subsequently analysed using Microsoft Excel and R-Studio software. The experimental design was based on a completely randomized design (CRD) with four replications. Statistical analyses

were conducted using Analysis of Variance (ANOVA) to determine the significance of differences among the various priming treatments, and Duncan's Multiple Range Test (DMRT) was employed to compare the means at a 5% significance level (Gomez and Gomez, 1984).

3. RESULTS AND DISCUSSION

The experimental results obtained under controlled laboratory conditions provided the robust, quantitative evidence of the effects of various seed priming treatments on the performance of the Rampur Hybrid-10 maize variety. The study compared seven treatments: cow urine (50 ml/L), salicylic acid (50 mg/L), hydropriming (distilled water), GA₃ at 50 ppm, GA₃ at 75 ppm, urea (0.1%), and a control. The analysis focused on key parameters such as germination percentage, mean germination time (MGT), root and shoot lengths, Seedling Vigour Index I (SVI), and seedling dry weight.

3.1 Germination Percentage

In terms of germination percentage, the cow urine @50ml/L treatment achieved the highest value at 93.33%, indicating a substantial improvement over the control, which recorded a germination percentage of 85.00%. Likewise, GA₃ at 75 ppm also performed remarkably well with a germination percentage of 91.00%. In contrast, salicylic acid @50mg/L treatment observed a significantly lower germination percentage of 76.67%. However, the hydropriming, GA₃ at 50 ppm, and urea @0.1% treatments yielded intermediate values of 86.00%, 83.00%, and 86.33%, respectively. These differences suggest that nutrient-rich organic solutions, such as cow urine, and hormonal priming with a higher concentration of GA₃, effectively enhanced the physiological readiness of seeds to germinate. Previous research has demonstrated that organic priming agents can stimulate enzymatic activities and improve the nutrient mobilization, thereby enhancing seed viability (Heinonen-Tanski et al., 2019), and hormonal treatments like GA₃ are known to promote photosynthetic activity and stress tolerance in seedlings (Tian et al., 2014).

3.2 Mean Germination Time

Mean Germination Time (MGT) is a critical measure of the speed of germination. In this study, cow urine @50ml/L treatment resulted in the shortest MGT at 2 days. This rapid initiation of germination indicates that seeds primed with cow urine are metabolically more active. In contrast, the control exhibited a longer MGT of 4 days, and salicylic acid @50mg/L treatment resulted in the longest MGT of 4 days. Hydropriming, GA₃ at 50 ppm, GA₃ at 75 ppm, and urea @0.1% treatments showed intermediate MGT values of around 3 days, respectively. The reduction in MGT observed with cow urine @50ml/L and GA₃ at 75 ppm is indicative of an accelerated pre-germinative metabolic process, which is essential for rapid seedling establishment. This finding is consistent with the work of Mousavi et al. (2012), who reported that effective priming treatments can significantly reduce the lag phase before radicle emergence.

3.3 Shoot and Root Length

Root and shoot growth measurements further substantiate the effectiveness of the priming treatments. The cow urine @50ml/L treatment produced the longest root length 25.17 cm, while GA₃ at 75 ppm also resulted in a substantial root length of 24.53 cm. In contrast, the control recorded the shortest root length 16.60 cm. Salicylic acid @50mg/L, hydropriming, GA₃ at 50 ppm, and urea @0.1% resulted the intermediate root lengths of 20.06, 19.70, 20.53, and 24.60 cm, respectively. Shoot length followed a similar trend: GA₃ at 75 ppm led to the longest shoot length 29.33 cm, and cow urine 50ml/L treatment produced a shoot length of 27.58 cm. The control treatment, however, had a markedly lower shoot length of 23.92 cm, and the other treatments—salicylic acid @50mg/L, hydropriming, GA₃ at 50 ppm, and urea @0.1%—yielded shoot lengths of 26.26, 24.64, 27.79, and 27.28 cm,

respectively. The enhanced root development observed in the cow urine @50ml/L and GA₃ at 75 ppm treatments suggests an improved capacity for water and nutrient uptake, which is critical for subsequent plant growth. Similarly, the increased shoot lengths indicate a greater potential for light capture and photosynthetic efficiency. These observations align with the previous studies that have highlighted the role of hormonal stimulation in promoting cell elongation and division in maize (Ajirloo et al., 2013; Amir et al., 2023).

3.4 Seedling Vigour Index I

The Seedling Vigour Index I (SVI), which integrates both germination percentage and the sum of root and shoot lengths, provides an overall measure of seedling health and vigour. In this experiment, the cow urine @50ml/L treatment produced the highest SVI value 5693.05, a figure that is significantly higher than that observed with the salicylic acid @50mg/L treatment (3953.56) and hydropriming (4388.50). The GA₃ at 50 ppm and GA₃ at 75 ppm treatments resulted in SVI values of 5231.78 and 5050.65, respectively, while the urea @0.1% treatment and the control recorded values of 5322.25 and 5260.16. The higher SVI associated with cow urine @50ml/L treatment indicates not only a high germination percentage but also robust seedling growth in terms of root and shoot development. This composite index confirms that cow urine and, to a slightly lesser extent, GA₃ at higher concentrations, are more effective in enhancing early seedling vigour. These findings are consistent with previous research, which has shown that priming agents rich in nutrients and growth regulators can significantly improve the overall vigour of seedlings (Rane et al., 2020).

3.5 Seedling dry weight

Seedling dry weight, an indicator of biomass accumulation and metabolic efficiency, further supports the superiority of certain priming treatments. In this study, the GA₃ treatment at 75 ppm resulted the highest seedling dry weight (5.19 g), suggesting that this treatment substantially enhances the accumulation of dry matter in early growth stages. Hydropriming and cow urine @50ml/L treatments followed closely, yielding seedling dry weights of 5.07 g and 5.05 g, respectively. In contrast, the control treatment exhibited the lowest seedling dry weight (4.85 g). Salicylic acid 50mg/L, GA₃ at 50 ppm, and urea 0.1% treatments

produced intermediate values of 5.03 g, 4.97 g, and 4.90 g, respectively. Although the differences in seedling dry weight among some treatments were not statistically significant, the overall trend clearly indicates that priming treatments—particularly GA₃ at 75 ppm—enhance the biomass accumulation, likely due to improved enzymatic activity and nutrient utilization. This observation corroborates earlier studies that have linked effective priming to increased protein synthesis and overall biomass production in maize seedlings (Da et al., 2012).

Table 2. Mean Comparison of Germination and Vigor Traits of Maize

Treatments	Germination %	Mean germination time (days)	Root length (cm)	Shoot Length (cm)	Seedling Index I	Vigour	Seedling dry weight
1. T1	93.33 ^a	2.93 ^c	25.17 ^a	27.58	5693.05 ^a		5.05 ^a
2. T2	76.67 ^d	3.70 ^{bc}	20.06 ^{bc}	26.26	3953.55 ^c		5.03 ^a
3. T3	86.00 ^{bc}	3.02 ^{bc}	19.70 ^{bc}	24.64	4388.50 ^{bc}		5.07 ^a
4. T4	83.00 ^{cd}	3.21 ^{bc}	20.53 ^c	27.79	5231.78 ^a		4.97 ^a
5. T5	91.00 ^{ab}	3.03 ^{bc}	24.53 ^{ab}	29.33	5050.65 ^{ab}		5.19 ^a
6. T6	86.33 ^{bc}	3.15 ^{bc}	24.60 ^{ab}	27.28	5322.25 ^a		4.90 ^a
7. T7	85.00 ^{bc}	3.44 ^{ab}	16.60 ^c	23.92	5260.16 ^c		4.85 ^a
SEM (±)	2.12	0.079	0.88	0.83	146.39		0.067
LSD (α= 0.05)	6.45	0.41*	4.62	3.48	769.13		0.35
CV	4.28%	7.41%	0.0098**	0.189	8.80%		4.06%
F probability	0.0019**	0.0172*	12.23%	9.33%	0.015*		0.494
Grand Mean	85.904	3.21	21.6	26.69	4985.75		5.01

[(SEM (±) – Standard Error of the Mean, CV- Coefficient of Variation, LSD – Least Significant Difference (used to compare means), * significant at p=0.05, ** significant at p=0.01, *** significant at p=0.001 in a column is not significantly different based on LSD at p=0.05.)]

4. CONCLUSION

The experimental findings demonstrate that optimized seed priming markedly enhances the performance of the Rampur Hybrid-10 maize variety. Treatments using cow urine @50ml/L and GA₃ @75 achieved significantly higher germination percentages, reduced mean germination time, and improved root and shoot development compared to other treatments and the control. These results indicate that both nutrient-rich organic agents and hormonal treatments stimulate pre-germinative metabolic activities, leading to more uniform and vigorous growth.

The data strongly support the adoption of these cost-effective and sustainable priming techniques for maize cultivation, particularly in regions where crop productivity is limited by poor seed performance. Enhanced seedling vigour, as evidenced by higher seedling vigour Index I and increased biomass accumulation, confirms that these treatments facilitate efficient nutrient uptake and robust early growth. These scientific insights provide a solid basis for further field validation, paving the way for improved agronomic practices and enhanced food security in agro-climatic regions similar to Chitwan, Nepal.

REFERENCES

- Adhikari, S. B., & Subedi, R. (2022). Effect of seed priming agents (GA₃, PEG, hydropriming) in the early development of maize. *Russian Journal of Agricultural and Socio-Economic Sciences (RJOAS)*, 9(129), 113–633.
- Afzal, M., Nasim, S., & Ahmad, S. (2004). *Operational manual: Seed preservation laboratory and gene bank*. Plant Genetic Resources Institute (PGRI), NARC.
- Ajirloo, L., Mohammadi, R., & Safari, M. (2013). Effects of seed priming on germination and seedling vigour in maize. *Journal of Plant Physiology*, 170(3), 200–206.
- Amir, M., Prasad, D., Khan, F. A., Khan, A., Ahmad, B., & Astha. (2023). Seed priming: An overview of techniques, mechanisms, and applications. *Plant Science Today*.
- Armour, R. M., & Tomar, P. (2015). Seed priming: A review. *Journal of Agronomy and Crop Science*, 201(2), 123–131.
- Banerjee, S., Jana, K., Mondal, R., Mondal, K., & Mondal, A. (2020). Effect of seed priming on growth and yield of hybrid maize–lathyrus sequence under rainfed situation. *Current Journal of Applied Science and Technology*, 39(13), 126–136.
- Čanak, V., Pojskic, M., & Delina, A. (2016). A study on the effect of seed priming on germination and seedling growth in maize. *Seed Science Research*, 26(2), 85–91.
- Da, A., Pinto, S. R., Araujo de Freitas, G., Maciel Gonçalves, N. J., Flávio, H., Ramos, F., & Teodoro da Silva, I. (2012). Test germination of corn seeds in different environments. *Brazilian Journal of Applied Technology for Agricultural Science*, 5(3), 17–26.
- Ghassemi-Golezani, K., Reza, M., Ardekani, S., Rastilantie, M., Mir-Mahmoodi, T., Habibi, D., Paknezhad, F., & Ardekani, M. R. (2011). Effects of priming techniques on seed germination and seedling emergence of maize. *Journal of Food, Agriculture and Environment*, 9(2), 413–415.
- Heinonen-Tanski, H., Niemi, P., & Laine, T. J. (2019). Nutrient content of cow urine and its potential use in seed priming. *Journal of Sustainable Agriculture*, 33(4), 350–357.
- Ikramullah, I. H., Khalil, M. N., & MKN, S. (2011). Heterotic effects for yield and protein content in white quality protein maize. *Sarhad Journal of Agriculture*, 27(3), 403–409.
- Koirala, K. B., & Shrestha, P. (2006). Seed priming effects on germination performance of maize. *Journal of Maize Research*, 4(1), 35–42.
- Meng, A., Wen, D., & Zhang, C. (2022). Maize seed germination under low-temperature stress impacts seedling growth under normal temperature by modulating photosynthesis and antioxidant metabolism. *Frontiers in Plant Science*, 13, 843033.
- Ministry of Agriculture and Livestock Development. (2017). *Statistical information on Nepalese agriculture*. Government of Nepal.
- Mousavi, R., Mohammad, A. A., & Sepehri, A. (2012). The effects of on-farm seed priming and planting date on emergence characteristics, yield and yield components of a corn cultivar (S.C. 260) in Hamedan. *Annals of Biological Research*, 3(9), 4427–4434.
- Pegah, M., Jamali, F., & Saeid, H. (2008). Impact of seed priming on maize germination and seedling emergence. *Crop Science*, 48(2), 542–548.
- Rane, S., Deshmukh, R., & Singh, R. (2020). Comparative study of seed priming techniques in maize. *International Journal of Agronomy*, 10(2), 120–127.
- Shrestha, A., Pradhan, S., Shrestha, J., & Subedi, M. (2019). Role of seed priming in improving seed germination and seedling growth of maize (*Zea mays* L.) under rainfed condition. *Journal of Agriculture and Natural Resources*, 2(1), 265–273.
- Tian, X., Li, Y., & Zhang, W. (2014). Gibberellic acid enhances maize seed germination and stress tolerance. *Plant Physiology and Biochemistry*, 77, 65–72.
- Timsina, D., & Marahatta, S. (2024). Assessment of different seed priming agents on germination and biomass production of hybrid maize at Rampur, Nepal. *Cogent Food and Agriculture*, 10(1).

DETERMINANTS OF INSURANCE FOR BANANA IN CHITWAN, NEPAL

Ashma Dhakal^{1,*} and Udit Prakash Sigdel¹

¹ Agriculture and Forestry University, Chitwan, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Adoption, Banana farming Determinants of insurance Farmers' attitude, Insurance, Probit model *Correspondence: dhakalashma76@gmail.com Tel: +977 9843336828	Banana farming in Chitwan suffers from high risks and uncertainty. To safeguard farmers from potential losses, the availability of banana crop insurance becomes crucial. The study was conducted in Ratnanagar, Khairahani and Kalika municipalities of eastern Chitwan, with the objective of understanding farmers' attitude and the determinants of banana crop insurance adoption. A total of 140 farmers (70 insured and 70 non-insured) were randomly selected as respondents. Based on the sampling frame, an appropriate proportion of sample was considered from each municipality. Primary data were collected through household survey and key informant interviews, while secondary data were obtained from journals, publications, reports and other sources. The study results, using a Probit model, showed that knowledge, age, access to training, attitude, banana farming area, gender, and subsidies were significant factors affecting the adoption of insurance. The major constraints to insurance adoption were insufficient co-ordination between concerned authorities and farmers (0.837), small landholdings (0.836), lack of knowledge about the benefits of crop insurance (0.790), complex procedures (0.777), and lack of encouraging policies (0.733).The study emphasizes that enhancing crop insurance adoption requires increased awareness, training, improved coordination between stakeholders, simplified procedures, faster claim settlements, and customized products tailored for small-scale banana farmers.

1. INTRODUCTION

Nepalese agriculture is characterized by high risk and uncertainties. Therefore, managing risk has become increasingly important in agriculture due to inherently uncertain nature of this sector. Banana farming has become more popular in Nepal in recent years. It is one of Nepal's most vulnerable crops to

extreme environmental threats, particularly windstorms (Ghimire, Timsina, & Poudel, 2016). Every year, windstorms during and after the monsoon cause significant damage to banana farmers (Dulal & Kattel, 2020). The World Bank (2009) reported heavy losses of banana crops due to wind in Chitwan district of Nepal. Moreover, pest

infestations, diseases, and other natural calamities further exacerbate the vulnerability of banana farmers (Ghimire et al., 2016).

Other types of loss, such as those caused by insects, diseases can be managed, but dealing with loss caused by natural disasters is more challenging. The repeated occurrence of windstorms, diseases, and pests can create fear, demotivation, and reduced production among banana farmers. It becomes necessary to protect the farmers from natural calamities and ensure their sustainability in banana farming. In response to these challenges and to provide a safety net for farmers, insurance for banana crops is essential. To this end, the government of Nepal introduced a crop insurance scheme in 2013.

Chitwan has the largest number of banana farmers compared to other district (Ghimire et al., 2016). Banana farmers are more attracted to insurance than other crop farmers, however, coverage is still low (Ghimire & Timsina, 2020). According to data obtained from Shikhar Insurance company ltd, out of 549 registered banana farmers, only 211 had adopted insurance by December, 2022. A study conducted in 2022 to identify the factors affecting the adoption of insurance for banana in Chitwan district of Nepal found that only a small percentage of farmers had adopted insurance (Timilsina, Paudel, & Ghimire, 2022). Appropriate implementation of the scheme has not yet been practiced intensively (Thapa & Bam, 2020). Due to the low level of participation of farmers in the crop insurance, the future of this scheme remains uncertain (Thapa & Bam, 2020).

A previous study conducted by Dulal et al. (2022) in Chitwan district focused mainly on farmer's perceptions of banana loss at different stages, and their views on insurance as a risk minimizing tool for windstorm, However, it did not explore farmers perception of other aspects of insurance. Similarly, another study by Dulal and Kattel (2020) focused on the impact of insurance on banana production. Ghimire et al. (2016) examined factors affecting the adoption of insurance but did not considered role of risk

perception, attitude, and knowledge in adoption of insurance.

Attitude, knowledge and adoption may be interrelated, yet previous research on banana insurance has not explored this relationship. Abdullahi et al. (2021) stated that the attitude of the farmers toward the technology, their knowledge of how the technology works, and the constraints they face in their socio-cultural setting all influence the distribution and adoption of any agricultural technology. Despite the risks encountered in banana farming, there is relatively low rate of insurance uptake and information on farmers' attitude towards agricultural insurance as a tool for managing risk is limited. Therefore, this study attempts to fill the aforementioned gap through the following objectives.

- Assess socio-economic characteristics of banana farmers
- Determine the attitude and knowledge of farmers towards insurance for banana crops
- Identify the determinants of adoption of insurance among banana farmers

2. RESEARCH METHODOLOGY

2.1. Population, Sample Size and Sampling Technique

The study was conducted in eastern Chitwan. Three municipalities, namely Kalika, Ratnanagar and Khairahani Urban Municipality, were purposively, selected due to their significance as major banana growing areas in Eastern Chitwan. Moreover, these municipalities had already adopted the insurance scheme. To create the sampling frame, a comprehensive list of all commercial banana farmers in the three selected municipalities was compiled. From this, separate lists were prepared for farmers who had adopted the insurance scheme and those who had not. Based on the sampling frame, an appropriate proportion of sample was considered from each municipality resulting in a total of 70 insured and 70 non-insured farmers. A simple random sampling method was employed to select the samples from each of the three municipalities. (See Table

1).

Table 1. Sample size determination

Research site	Sampling frame	Sample size	
		Insured	Non-insured
Ratnanagar	206	29	29
Kalika	247	35	35
Khairahani	40	6	6
Total		70	70

Source: Banana Producers Association, Chitwan

2.2. Data collection

Primary data was collected using personal interview method through field survey. All selected respondents were personally contacted for data collection. A semi-structured interview schedule was used. In addition, key informant interview (KII) was conducted to obtain the primary data. A Checklist was prepared to conduct KII, and the questions in the checklist were open ended. To ascertain respondents' participation in agricultural insurance, they were asked to indicate whether their farm was under insurance cover. This was determined through a "yes" or "no" response.

Pretesting of instrument was done in Bharatpur metropolitan city with 7 sets of interview schedules for both insured and non-insured groups. Secondary data were collected from various publications, journals, research articles, bulletins, books, reports, proceedings published and presented by government, non-government and private institutions.

2.3. Data analysis

Both descriptive and inferential statistics were used for data analysis. Demographic and socio-economic characteristics of the respondents such as age, occupation, education, land size, income, knowledge, attitude, satisfaction, etc were analyzed using descriptive statistics like frequency, mean, percentage, standard deviation, and relative importance index (RII).

The formula for Relative important index (RII) is

$$I = \frac{\sum S_i F_i}{N * A}$$

where, I = Index value

Σ = Summation

S_i = Scale value

F_i = Frequency of importance given by the respondents

N = Total numbers of respondents

A = highest scale value

Under inferential statistics, an independent sample t-test was used for the continuous variables to compare means between different groups, and chi-square test was used to investigate relationships among categorical variables. Moreover, a Probit regression model was used to assess the determinants of insurance adoption among Banana farmers.

The model specification is given below

$$\Pr(Y=1) = f(b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11} + b_{12}X_{12} + b_{13}X_{13} + b_{14}X_{14} + b_{15}X_{15} + b_{16}X_{16} + b_{17}X_{17})$$

where,

$\Pr_{(Y=1)}$ = adoption of crop insurance (1= adoption, 0=otherwise)

X_1 = Age of household head (years)

X_2 = farming experience (years)

X_3 = area under banana (hectare)

X_4 = land ownership (1=leased land, 0=otherwise)

X_5 = membership of organization (1= involved in organization, 0= otherwise)

X_6 = training received (1= training received, 0= otherwise)

X_7 = Knowledge index (mean)

X₈= subsidy received (1= subsidy received, 0=otherwise)

X₉= education of household (years)

X₁₀= family size (number)

X₁₁= economically active member (number)

X₁₂= Gender (1=male, 0=otherwise)

X₁₃= access to loan (1= yes, 0=otherwise)

X₁₄= natural log of annual income from banana

X₁₅= Attitude score (mean)

X₁₆= Risk perception (mean)

X₁₇= information source (mean)

b₁, b₂,.....b₁₃= Probit coefficient

b₀= regression coefficient

2.4 Conceptual framework

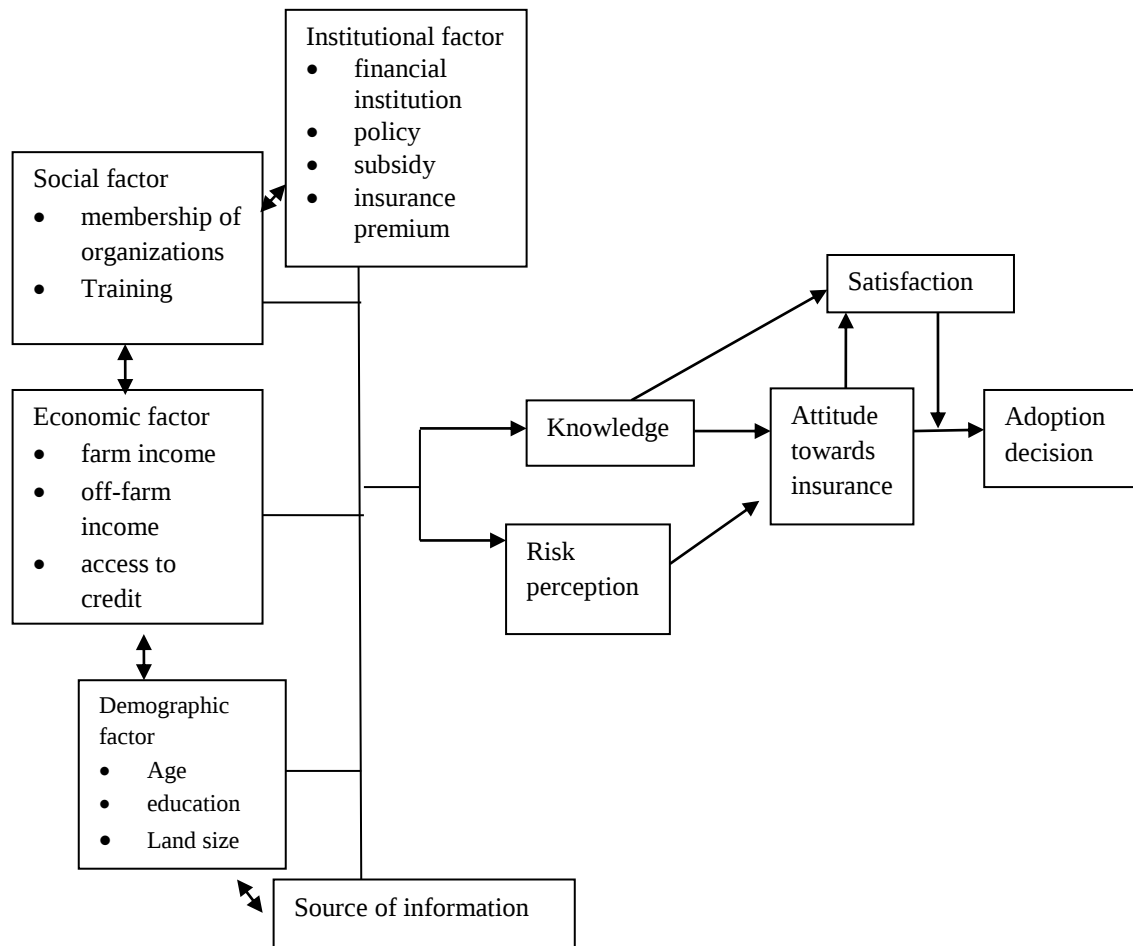


Figure 1. Conceptual framework of the study

(Source: Own illustration based on various literatures)

3. RESULTS AND DISCUSSIONS

3.1 Socio-demographic characteristic of the respondents

In the study area, a notable gender gap was observed, with most households led by males in both the insured and non-insured categories. These findings match up with national and provincial data i.e 69% and 69.5% respectively which show that most

households in Nepal are male headed (CBS, 2021).

Most of the insured farmers were Hindu, while non-insured farmers were mostly Buddhist. The study also identified the predominance of Brahmin/Chhetri respondents among both insured and non-insured farmers. The scenario is same with national context where major population is occupied by Bhramin/Chhetri (CBS, 2021).

Most insured farmers were literate compared to non-insured farmers. (See Table 2). Carrer et al. (2021) also indicated that producers with higher levels of education are better able to comprehend how the insurance market operates, the steps required to obtain insurance, and the importance of managing production risk.

Insured farmers had more farming experience, larger family sizes, more economically active members. Furthermore, the household heads of the non-insured group were found to be older, on average, than those of the insured groups (See Table 3). Insured farmers also had a average landholding compared to non-insured farmers. (See Table 4). Regarding land ownership, most non-insured farmers cultivated bananas on their own property, whereas most insured farmers farmed bananas on mixed land (i.e., on both their own property and rented land). (See Figure 2).

Table 2. Socio-demographic characteristic of the respondents for categorical variables

		Insurance Status		Total (N=140)	Chi-square
		Insured (n= 70)	Non-insured (n=70)		
Gender	Female	16 (22.8)	29 (41.4)	45 (32.14)	5.54** (p=0.019)
	Male	54 (77.2)	41 (58.6)	95 (67.86)	
Religion	Hindu	65 (93)	52 (74.3)	117 (83.6)	8.79*** (p=0.003)
	Buddhist	5 (7)	18 (25.7)	23 (16.4)	
Ethnicity	Bhramin/Chhetri	59 (84.3)	43 (61.4)	102 (72.9)	9.25*** (p=0.002)
	Janajati	11 (15.7)	27 (38.6)	38 (27.1)	
Occupation	Agriculture(except banana)	15 (21.4)	15 (21.4)	30 (21.4)	2.49 (p=0.64)
	Banana	53 (7.6)	49 (70)	102 (72.86)	
	Private service	1 (1.4)	3 (4.2)	4 (2.9)	
	Business	1 (1.4)	3 (4.2)	4 (2.9)	
Education	Illiterate	2 (2.86)	18 (25.7)	19 (13.6)	18.11*** (p= 0.001)
	Primary	17 (24.3)	20 (28.6)	36 (25.7)	
	Secondary	19 (27.1)	15 (21.4)	34 (24.3)	
	Higher secondary	21 (30)	11 (15.7)	32 (22.9)	
	Tertiary education	11(15.7)	6 (8.6)	17 (12.14)	

Note- ** and *** represents 5% and 1% level of significance respectively. Figures in parentheses indicate percentage. Source: Field Survey, 2023

Table 3. Socio-demographic characteristics of the respondents for continuous variables

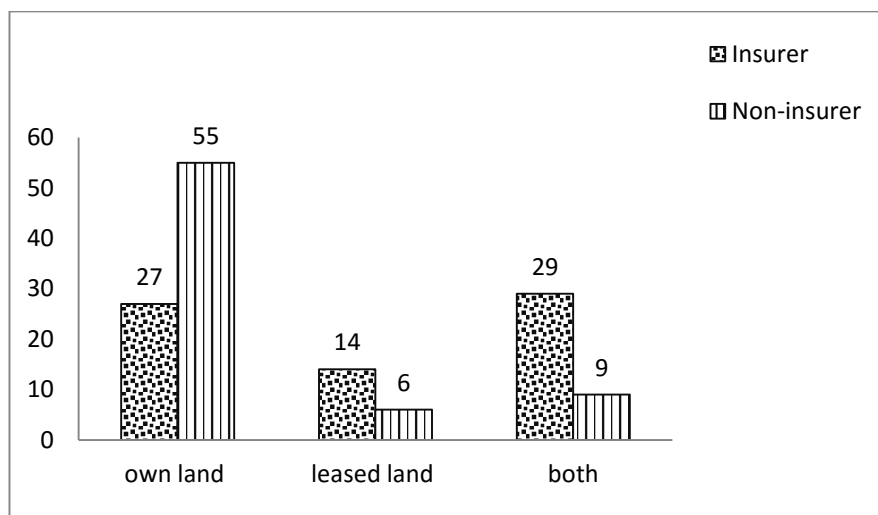
	Insurance status		Overall	t-value
	Insured	Non-Insured		
Economically active member (15-59 years)	3.67	3.30	3.48	1.89 (p= 0.89)
Farming experience	10.74	9.60	10.17	2.815** (p= 0.02)
Family size	5.43	5.16	5.29	1.074 (p=0.69)
Age (yrs)	50.44	52.34	51.39	-0.920 (p=0.19)

Note- ** represents 5% level of significance. Source: Field Survey, 2023

Table 4. Land Characteristics of insured and non-insured respondents

Land Characteristic	Insurance status		Overall (N=140)	t-value
	Insured	Non-Insured		
Total land (Ha)	2.035	1.095	1.57	6.45*** (p<0.01)
own land (Ha)	0.73	0.79	0.76	-0.57 (p=0.28)
Leased land (Ha)	1.30	0.30	0.8	5.58*** (p<0.01)
Area under Banana (Ha)	1.95	0.98	1.47	6.65*** (p<0.01)

Note- *** represents 1% level of significance. Source: Field Survey, 2023

**Figure 2.** Bar graph showing land ownership status of insured and non-insured respondents

Majority of both insured and non-insured farmers were involved in at least one organization, with farmers' cooperatives being the most common. However,

participation was higher among insured farmers (See Table 5). This result aligns with findings of Singh and Chandel (2019) who observed higher social participation among

farmers who had adopted livestock insurance. About 81% of insured farmers had participated in training related to banana farming, while only 23% of non-insured farmers had received similar training. Similar

finding was noted by Aditya et al. (2018) who revealed that adoption of insurance is higher for those who had some formal training in agriculture.

Table 5. Distribution of insured and non-insured respondents by social participation

S.N			Insurance status		Total	Chi-square
			Insured	Non-insured		
1.	Organizational involvement	Not involved	10 (14)	18 (26)	28 (20)	2.857* (p=0.091)
		Involved	60 (86)	52 (74)	112 (80)	
2.	Access to training	Not acquired	13 (19)	54 (77)	67 (48)	48.117*** (p<0.01)
		acquired	57 (81)	16 (23)	73 (52)	

Note- *** and * represents 1% and 10% level of significance, Figures in parentheses indicate percentage. Source: Field Survey, 2023

Findings on access to credit among insured and non-insured farmers revealed that a significant number of insured farmers had taken loan for banana farming, while very few non-insured farmers had done the same. The major source of loan for insured farmers was bank while micro-finance institutions were the least preferred. In contrast, micro finance institutions were the primary loan

source for non-insured farmers. It was found that 57% of insured farmers had acquired subsidy while only 19% non-insured farmers had access to it (See Table 6). Subsidy by here means any form of subsidy from government organizations, private institutions etc except subsidy on insurance premium.

Table 6. Distribution of insured and non-insured respondents by access to credit and subsidy.

Access to loan	Insurance status		Total (N=140)	Chi-square
	Insured (n=70)	Non-insured (n=70)		
Loan acquired	32 (45.7)	12 (17.1)	44 (31.4)	12.56*** (p<0.01)
Loan not acquired	38 (54.3)	58 (82.9)	96 (68.6)	
Subsidy acquired	40(57)	13(19)	53(37.7)	22.13*** p<0.01
Subsidy not acquired	30(43)	57(81)	87(62-1)	

Note: Figures in parentheses indicates percentage.*** represents 1% level of significance. Source: Field Survey, 2023

3.2 Sources of information for banana insurance

The major source of information for both insured and non-insured farmers was fellow farmers followed by Banana zone, Chitwan for insured and neighbours for non-insured farmers. The least used information was publications for both group (See Table 7).

However, radio and TV were not popular sources, possibly due to a decline in their popularity. A study in Nepal revealed decrease in level of engagement and reduction in the size of audience for radio (Sharecast, 2016).

Table 7. Sources of information for insurance.

Source of information		Insured		Non-insured	
		Mean Score	Rank	Mean Score	Rank
Mass media	Radio	0.36	XIII	0.37	XI
	Television	0.38	XII	0.40	X
	Social media	0.57	VII	0.53	V
	Publications	0.35	XIV	0.33	XIII
	Newspaper	0.39	XI	0.33	XIII
Personal cosmopolite	JT/JTA	0.44	IX	0.49	VI
	Insurance agent	0.42	X	0.34	XII
	Banana zone	0.66	II	0.55	IV
	Agriculture knowledge centre	0.64	III	0.49	VI
	Municipality	0.62	V	0.46	VIII
Personal localite	Progressive farmers	0.63	IV	0.41	IX
	Neighbour	0.61	VI	0.69	II
	Family members	0.49	VIII	0.62	III
	Other farmers	0.90	I	0.90	I
Average		0.53		0.49	

Source: Field Survey, 2023

3.3 Determinants of adoption of insurance

Probit model was used to identify the determinants of adoption of insurance for banana in study area. A pseudo-R-squared value obtained suggested that the model had

a relatively good fit. Similarly, likelihood chi-2 ratio and small p-value for the model revealed overall significance of the model. Similarly, the marginal effect was measured to evaluate the change in the probability of

the dependent variable being in a particular category due to a one-unit change in the independent variable, while other variables are kept constant. Among the seventeen variables used in the model seven variables were found significant at different levels. Knowledge of the HH had a significant positive effect on insurance adoption This suggests that individuals with higher levels of knowledge about insurance were more likely to adopt it.

There was an inverse correlation observed between age and the adoption of insurance This suggests that younger individuals were more inclined to obtain insurance compared to their older counterparts. This trend aligns with Rogers' theory of adoption, where as people age, they tend to fall into the "late majority" and "laggards" categories, which are less likely to adopt new innovations. Farmers' interest in purchasing agricultural insurance tends to diminish as they grow older (Birinci & Tumer, 2006).

Area under banana demonstrated a positive relationship with insurance adoption. This suggests that individuals with larger banana farming areas were more inclined to adopt insurance. This could be due to the fact that larger banana farming areas typically represent higher levels of investment and greater dependence on the crop for income generation. As a result, they may be more motivated to protect their investment by adopting insurance as a risk management

tool. Farming experience, family size and economically active status however, did not exhibit significant associations with insurance adoption.

Individuals who received training related to banana farming and those who received subsidies also displayed a positive and significant relationship with insurance adoption. A study conducted in determining the factors affecting adoption of insurance found positive and significant association between agriculture related training and adoption of insurance (Gautam et al., 2018). Another study conducted in Brazil found that individuals who received training related to banana farming showed a significant positive association with insurance adoption (Carrer et al., 2021).

The analysis revealed that individuals with more positive attitudes toward insurance were more likely to adopt insurance Moreover; risk perception did not show a statistically significant relationship with insurance adoption. Gender exhibited a positive association with insurance adoption. Additionally, the level of education did not appear to have a statistically significant effect on insurance adoption.

Several other variables, such as the type of land owned, income from banana farming, information sources, organization involvement did not demonstrate statistically significant relationships with insurance adoption.

Table 8. Probit regression model showing determinants of adoption of insurance for banana.

Variables	dy/dx	Coef.	Std. Err.	z	P>z
Knowledgeindex	0.43***	4.17	1.34	3.11	0.002
Age in years	-0.01***	-0.08	0.03	-2.64	0.01
Farming experience	0.02	0.21	0.13	1.62	0.11
Family size	0.01	0.12	0.25	0.5	0.62
Area under banana	0.01**	0.04	0.02	2.2	0.028
Involvement in organization	0.08	0.78	0.68	1.15	0.25

Training	0.20***	1.53	0.53	2.9	0.004
Subsidy	0.15*	1.34	0.74	1.82	0.07
Loan	0.06	0.59	0.64	0.91	0.36
Attitude	1.04***	10.10	3.31	3.05	0.002
Gender (Male)	0.14*	1.44	0.79	1.82	0.07
Education (years)	0.01	0.11	0.07	1.55	0.12
Economicallyactivemember	0.001	0.01	0.27	0.05	0.96
Land type (leased)	-0.07	-0.78	0.69	-1.11	0.26
Income from banana	-0.06	-0.57	0.38	-1.52	0.13
Risk perception	0.01	0.095	0.10	0.91	0.36
Information source	0.05	0.45	1.24	0.36	0.72
Log likelihood	-25.73				
LR chi2(17)	141.24				
Prob > chi2	<0.01				
Pseudo R2	0.73				

Note- *, **, *** represents significant at 10%, 5% and 1% respectively. Source: Field Survey, 2023

3.4 Constraints associated with the adoption of insurance for banana

Constraints associated with adoption of insurance here refer to various factors or barriers that hinder individuals or entities from obtaining insurance coverage or participating in insurance schemes. The findings revealed that major constraint associated with adoption of insurance was insufficient co-ordination and linkage between concerned authority and farmers.

Similarly, small land size was ranked second important constraint followed by lack of knowledge among producers regarding benefits of crop insurance and so on (See Table 9). The result is in line with Carrer et al. (2021) who similarly highlighted lack of understanding regarding the importance of insurance as a barrier to accessing it. Likewise, Kakri et al. (2019) identified the user and supplier confidence towards insurance product as the key challenges in adoption of agriculture insurance in Nepal.

Table 9. Constraints associated with the adoption of insurance for banana.

Statements	SA	A	N	D	SD	Index value	Rank
Lack of knowledge among producers regarding benefits of crop insurance	58	47	14	12	9	0.79	III
Lack of encouraging policy	28	66	22	19	5	0.73	V
Lack of confidence towards insurance market	11	60	21	37	11	0.63	VIII
Crop insurance is not priority for producer as compared to livestock insurance	5	37	36	48	14	0.56	XI
Low economic status of farmers	21	58	4	40	17	0.64	VII

Insufficient coordination and linkage among concerned authority and farmers	50	75	8	5	2	0.84	I
Complex procedure	39	70	12	14	5	0.78	IV
Less no of institution providing insurance	14	46	21	47	12	0.60	X
Excessive wastage of time during insurance	24	52	26	22	16	0.67	VI
Less coverage by insurance providers	16	45	32	40	7	0.63	IX
Small land holding	65	52	11	7	5	0.84	II

Source: Field Survey, 2023

4. CONCLUSION

Factors such as age, knowledge about insurance, attitude, access to training, banana farming area, and subsidies for banana farming and gender were significant factors associated with insurance adoption. The study concluded poor coordination between farmers and concerned authority, small land sizes, awareness gaps, complex procedures, and policy shortcomings as adoption barriers.

ACKNOWLEDGEMENTS

Directorate of Agriculture Development (DoAD), Ministry of Agriculture and Livestock Development, Bagmati Province for providing research fund.

Directorate of Research and Extension (DOREX), AFU

Member supervisor Mr. Tej Prasad Dawadi, Chief, Directorate of Agriculture Development (DoAD)

REFERENCES

- Abdullahi, K. A., Oladele, O. I., & Akinyemi, M. (2021). Attitude, Knowledge and Constraints Associated With The Use of Mobile Phone Applications By Farmers in North West Nigeria. *J. Agric. Food Res*, 6. <https://doi.org/10.1016/j.jafr.2021.100212>
- Aditya, K. S., Khan, T., & Kishore, A. (2018). Adoption of Crop Insurance and Impact: Insights From India. *Agric. Econ. Res. Rev*, 31(2), 163-174. <http://dx.doi.org/10.5958/0974-0279.2018.00034.4>
- Carrer, M. J., Silveira, R. L. F. D., Vinholis, M. D. M. B., & De Souza Filho, H. M. (2021). Determinants of Agricultural Insurance Adoption: Evidence from Farmers in the State of São Paulo, Brazil. *RAUSP Manag. J*, 55, 547-566. <https://doi.org/10.1108/RAUSP-09-2019-0201>
- CBS, (2021). National Population and Housing Census. Central Bureau of Statistics. <https://censusnepal.cbs.gov.np/Home/Index/EN>
- Devkota, D., Ghimire, Y. N., Timsina, K. P., Subedi, S., & Poudel, H. K. (2021). Determinants of Livestock Insurance Adoption in Nepal. *Cogent Food Agric*, 7(1), 1952012. <https://doi.org/10.1080/23311932.2021.1952012>
- Dulal, S., & Kattel, R. R. (2020). Resource Use Efficiency of Banana Production and Impact of Insurance Scheme Adoption on Banana Farming in Chitwan, Nepal. *Int. J. Appl. Sci. Biotechnol*, 8(2), 170-178. DOI: 10.3126/ijasbt.v8i2.29120
- Dulal, S., Khanal, S., & Khanal, A. P., (2022). Perception of Farmers Towards Insurance for Banana And Factors Affecting The Crop Insurance. *The Lumbini Agriculture Journal*, 1, 61-71. https://molmac.lumbini.gov.np/media/publications/Lumbini_Agriculture_Journal_Final.pdf
- Gautam, A., Shrestha, A., & Jaishi, M. (2018). Factors Affecting Adoption of Insurance for Banana in Kwasoti Municipality, Nepal. *Research and Reviews: Journal of Agricultural Science and Technology*, 7(2), 5-12. https://www.researchgate.net/publication/350212957_Factors_Affecting_Adoption_of_Banana_Insurance_in_Kwasoti_Municipality_Nepal
- Ghimire, R. (2013). Crops and Livestock Insurance Practices in Nepal. *Journal of Business and Social Sciences*, 1(1), 1-12. <https://dx.doi.org/10.2139/ssrn.2427605>
- Ghimire, R., Chapagain, R. K., Jagari, D. B., & Shahi, L. B. (2023). Farmers' Perception and Awareness Towards Agriculture Insurance As a Tool of Risk Management in Kaski and Chitwan Districts of Nepal. *The Lumbini Journal of Business and Economics*, 11(1), 191-212. DOI:10.3126/ljbe.v11i1.54326
- Ghimire, Y. N., Timsina, K., Kandel, G., Thapa Magar, D. B., Gautam, S., & Sharma, B. (2016). Agriculture insurance in Nepal: Case of banana and livestock insurance. *Socioeconomics and Agricultural Policy Research Division, Lalitpur, Nepal*, 1–12. <https://doi.org/10.13140/RG.2.1.4767.6403>
- Ghimire, Y. N., Timsina, K. P., & Gauchan, D. (2016). Risk Management in Agriculture: Global experiences and lessons for Nepal. Government of Nepal, Nepal Agricultural Research Council (NARC), *Socioeconomics and Agricultural Policy Research Division, Lalitpur, Nepal*. DOI:10.13140/RG.2.1.2670.4882
- Ghimire, Y. N., Timsina, K. P., Devkota, D., Kadel, G., Adhikari, S. P., & Poudel, H. K. (2020). Remodelling Agricultural Insurance System of Nepal. *Socioeconomics and Agricultural Policy Research Division, Nepal Agricultural Research Council*. DOI:10.13140/RG.2.2.14975.02729/1
- Kakri, R., Pandey, A., Timsina, K. P., & GC, A. (2019). Status of agriculture insurance service business in Nepal. *Nepalese Journal of Agricultural Sciences*, 21, 168-178. https://www.researchgate.net/profile/Arun-Gc/publication/354182847_Status_of_agriculture_insurance_service_business_in_Nepal/links/612a2d7a0360302a0061848d/Status-of-agriculture-insurance-service-business-in-Nepal.pdf
- Sapkota, B. (2021). *Farmers' Risk Perceptions, Attitudes and Management Strategies, and Willingness to Pay for Crop Insurance in Nepal*. [Doctoral thesis, The University of Western Australia, UWA School of Agriculture and Environment]. https://api.research-repository.uwa.edu.au/ws/portalfiles/portal/157906957/THESIS_DOCTOR_OF_PHILOSOPHY_SAPKOTA_Bibek_2021.pdf
- Sharecast Initiative Nepal, (2016). Nepal media and democracy survey-I Final Report. Lalitpur, Nepal. <https://sharecast.org.np/>

Singh, S. P., & Chandel, B. S. (2019). Factors Influencing In Adoption of Livestock Insurance With Special Reference To Haryana. *Indian Journal of Dairy Science*, 72(3), 336-341.

DOI:10.33785/IJDS.2019.v72i03.015

Thapa, L. K., & Bam, R. (2020). Prospects of Crop Insurance As A Risk Management Tool Among The Banana Farmers of Kanchanpur District, Nepal. *International Journal of Environment, Agriculture and Biotechnology*, 5(5), 1280-1287. https://ijeab.com/upload_document/issue_files/13IJEAB-109202024-Prospectsof.pdf

Timilsina, S., Khanal, M., Pradhan, R., Bhattarai, A., & Sapkota, M. (2022). Determinants Of Farmers' Participation In Insurance For Banana In Chitwan District, Nepal. *Journal of Agriculture and Environment*, 23, 1-13. <https://www.nepjol.info/index.php/AEJ/article/view/46844/34998>

The World Bank (2016) Agricultural Sector Risk Assessment : Methodological Guidance For Practitioners, Washington DC, World Bank Group.

<https://documents1.worldbank.org/curated/en/586561467994685817/pdf/100320-WP-P147595-Box394840B-PUBLIC-01132016.pdf>

FIELD EVALUATION OF BIOPESTICIDES AGAINST SPOTTED POD BORER ON YARDLONG BEAN AT JHUMKA, SUNSARI

Madhu Kumari Ray¹, Pratik Poudel¹, Kiran Acharya¹, Jharana Shrestha¹ and Saraswati Shrestha²

¹ Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan, Nepal

² Plant Protection Laboratory, Koshi Province, Ramdhuni-5, Jhumka, Sunsari

ARTICLE INFO	ABSTRACT
Keywords: Biopesticides, Integrated Pest Management, <i>Maruca vitrata</i>, Yardlong bean *Correspondence: Roymadhu429@gmail.com Tel: +9779819096718	A field study was carried out from March to July in Jhumka, Sunsari, Nepal to evaluate the comparative efficacy of selected bio-pesticides against the spotted pod borer (<i>Maruca vitrata</i>) on yardlong bean (<i>Vigna unguiculata</i> subsp. <i>sesquipedalis</i>). The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising five treatments and four replications. The treatments included Minchu + (<i>Bacillus thuringiensis</i> var. <i>kurstaki</i> and <i>Saccharopolyspora spinosa</i>), Biopower (<i>Beauveria bassiana</i>), Tracer (<i>Spinosad</i> 45% SC), Neem excel (<i>Azadirachtin</i> 1500ppm), and a control. Among the treatments, Minchu+ showed superior pest control efficacy, with the highest number of healthy pods (8.36) and the lowest number of infested pods (2.66). Tracer also demonstrated notable performance, with a mean yield of 0.990 kg/plot. Neem Excel and Biopower showed moderate efficacy, while the control had the lowest yield (0.517 kg/plot). The findings suggest that Minchu+ and Tracer are promising biopesticides for integrated pest management (IPM) strategies against <i>Maruca vitrata</i> in yardlong bean cultivation.
1. INTRODUCTION Yardlong bean (<i>Vigna unguiculata</i> subsp. <i>sesquipedalis</i>) is a vital leguminous crop widely cultivated in tropical and subtropical regions, including Nepal. It is valued for its nutritional content, including vitamins, minerals, and protein, and its ability to fix atmospheric nitrogen, enhancing soil fertility (Jiang et al., 2020). The plant is characterized by its long, slender pods, which can grow up to 1 meter in length, and its vigorous climbing habit. Yardlong beans thrive in warm climates and require well-drained soil with plenty of sunlight. They can be grown vertically on trellises, which helps maximize space and improve air circulation. The plants are sensitive to frost and are usually grown as annuals in temperate regions. Yardlong bean is not only valued for its unique appearance but also for its nutritional benefits. The pods are a rich source of vitamins A, C, and several B vitamins, as well as minerals such as iron and calcium (Tey et al., 2019). These	nutritional properties make yardlong bean an important vegetable in many local diets, contributing to food security and health. The increasing interest in yardlong beans can also be attributed to their health benefits, which include antioxidant properties and potential anti-inflammatory effects (Baskaran, 2018). In addition to its culinary uses, yardlong bean plays a significant role in sustainable agricultural practices. As a legume, it has ability to fix atmospheric nitrogen, thereby improving soil fertility and reducing the need for synthetic fertilizers (Nguyen et al., 2021). Yardlong bean is one of the fresh vegetables grown commercially in Nepal. Its annual production is increasing due to their commercial value and higher yield. It is grown on 4563 hectares, with a total production of 49757 mt and a productivity of 10.90 mt/ha in Nepal (MoALD, 2022). The area, production and productivity for Yardlong bean is 28 ha, 182 mt, and 6.57 mt/ha, respectively in Sunsari district. (MoALD, 2022). However, the farmers are

unable to fully harness their production potential due to damage caused by the pest. The spotted pod borer (*Maruca vitrata*) is a significant pest affecting yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*) cultivation, leading to considerable economic losses for farmers (Shrinivasan et al., 2012). Conventional pesticide use has been the primary method of control, but concerns over environmental impact, pesticide resistance, and consumer health have led to a growing demand for alternatives (Aktar et al., 2009). However, like many crops, its cultivation is often threatened by pests, notably the spotted pod borer (*Maruca vitrata*). This pest is particularly damaging to leguminous crops, feeding on the pods and flowers, which can lead to significant yield losses if not managed effectively (Pande et al., 2021). The larvae of the spotted pod borer cause direct damage by burrowing into the pods, making them unmarketable and reducing the overall quality of the harvest.

Biopesticides offer an environmentally friendly alternative for managing the spotted pod borer (*Maruca vitrata*), a key pest affecting yardlong bean. Derived from natural materials such as plants, microorganisms, or minerals, bio pesticides can effectively reduce pest populations while minimizing harm to beneficial organisms. For instance, formulations containing *Bacillus thuringiensis* (Bt), a soil bacterium known for its insecticidal properties, have been shown to effectively target lepidopteran larvae, including those of the spotted pod borer (Mandal et al., 2021). Field studies indicate that applying Bt can significantly reduce larval infestations and improve pod

quality compared to untreated controls (Suresh et al., 2020). Additionally, Neem oil, extracted from the seeds of the neem tree (*Azadirachta indica*), exhibits insecticidal and growth-regulating properties, making it another effective biopesticide against spotted pod borer (Khan et al., 2019). Spinosad, a natural insecticide derived from the fermentation of the bacterium (*Saccharopolyspora spinosa*), and the entomopathogenic fungus (*Beauveria bassiana*) are effective bio control agents for managing the spotted pod borer on yardlong bean. Utilizing bio pesticides as part of an Integrated Pest Management (IPM) approach not only enhances crop protection but also contributes to sustainable agricultural practices by reducing reliance on synthetic chemicals. This study aims to evaluate the efficacy of different bio pesticides in managing *Maruca vitrata* on yardlong bean under field conditions.

2. MATERIALS AND METHODS

2.1 Research Site and Duration

The research was conducted in Ramdhuni-5, Jhumka, Sunsari, Nepal, from March to July 2024. The site is located at 26°39'48.2"N latitude and 87°11'40.3"E longitude, with an altitude of 85 meters above sea level.

2.2 Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments and four replications. Five different treatments viz. Minchu+, Bio power, Tracer, Neem excel and control plot.

Table 1. Different treatments and their composition/components

Treatment	Trade Name	Symbol	Treatment Composition/Components	Dose
1	Minchu+	T1	(<i>Bacillus thuringiensis</i> var. <i>kurstaki</i> and <i>Saccharopolyspora spinosa</i>) 15% SC	4ml/l
2	Bio power	T2	(<i>Beauveria bassiana</i>)	5g/l
3	Tracer	T3	Spinosad 45% SC (<i>Saccharopolyspora spinosa</i>)	4ml/l
4	Neem excel	T4	Azadirachtin 1500ppm	4ml/l
5	Control	T5		Water spray

2.3 Data Collection and data analysis

Data on the number of healthy and infested pods, plant height, and yield were collected weekly after treatment application. Statistical analysis was performed using R-Studio version 4.3.1, with ANOVA and Duncan's Multiple Range Test (DMRT) for mean separation.

3. RESULTS AND DISCUSSION

3.1 Effect on Healthy Pods

The effect of different bio pesticides against spotted pod borer on yardlong beans, measured by the number of healthy pods per plot is shown in table 2. A healthy pod is one that is intact, undamaged, and free from *Maruca vitrata* larval feeding, boreholes, or webbing, which are typical symptoms of infestation. Healthy pod count is commonly used to assess crop protection efficacy in pest management trials (Sharma, 2001). Among the treatments, Minchu+ showed the highest efficacy, with a mean of 8.36 healthy pods across the sprays, significantly outperforming other treatments. This aligns with the findings of Patil et al., (2021), who

demonstrated the superior bio efficacy of Minchu+ in managing pod borers in leguminous crops. Tracer, with a grand mean of 8.08 pods, exhibited comparable performance to Minchu+. Spinosad, the active ingredient of tracer, has been widely recognized for its rapid action against pod-borer pests. Bio power and Neem excel offered moderate benefits, with grand means of 7.36 pods and 7.31 pods, respectively. Although less effective than Minchu+ or Tracer, these treatments still showed significant improvements over the control, corroborating the growing interest in bio pesticides as sustainable alternatives (Mishra et al., 2021). In contrast, the control group exhibited the lowest performance, with an average of 4.84 healthy pods, suggesting the critical role of bio pesticides in maintaining pod health. The statistical analysis revealed significant differences between treatments, particularly after the second spray. The field evidence indicates that Minchu+ is the most effective treatment for controlling spotted pod borer on yardlong beans and improving pod health.

Table 2. Effect of bio pesticides used against spotted pod borer on yardlong bean based on number of healthy pods per plot at Jhumka, Sunsari, 2024

Treatments	No. of healthy pods per plot					Mean no. of healthy pods
	Before spray	7 days after 1 st spray	7 days after 2 nd spray	7 days after 3 rd spray	7 days after 4 th spray	
Minchu+	2.13 ^a	7.81 ^a	8.25 ^a	8.56 ^a	8.81 ^a	8.36 ^a
Bio power	1.56 ^a	6.94 ^{ab}	7.38 ^c	7.38 ^b	7.75 ^b	7.36 ^b
Tracer	1.69 ^a	7.38 ^a	8.13 ^{ab}	8.25 ^a	8.56 ^a	8.08 ^a
Neem excel	2.00 ^a	7.31 ^a	7.44 ^{bc}	7.25 ^b	7.25 ^b	7.31 ^b
control	1.94 ^a	6.19 ^b	5.31 ^d	4.50 ^c	3.38 ^c	4.84 ^c
LSD (0.05)	0.76	0.95	0.73	0.67	0.56	0.62
SEM (+-)	0.11	0.14	0.11	0.10	0.08	0.09
F-probability	ns	*	***	***	***	***
CV (%)	26.48	8.68	6.46	6.06	5.07	5.58
Grand mean	1.86	7.13	7.3	7.19	7.15	7.20

Note: ns: no statistically significant; CV: Coefficient of variation; LSD: least significant difference; SEM (±): Standard error of mean; Letters a, b, c represent the ranking of treatments according to DMRT at 0.05 level of significance; * and *** denote significance at p=0.05 and p=0.001 respectively.

3.2 Effect on Infested Pods

The effect of bio pesticides used against the spotted pod borer on yardlong beans, based on the number of infested pods per plot before and after various sprays is shown in table 3. Before any treatment, the mean number of infested pods per plot across treatments ranged from 2.44 to 2.75.

After the first spray, there were noticeable reductions in infestation, with Minchu+ showing the lowest mean infected pods(1.50) compared to the control (5.13). As application of treatments progressed, the number of infested pods generally continued to decrease, especially in plots treated with Minchu+ and Tracer (Spinosad 45% SC) which aligns with the findings of Prasad et al., (2023) which demonstrated Tracer, containing Spinosad as the active ingredient, is highly effective against lepidopteron pests, which often damage pods. By the fourth

spray, Minchu+ exhibited the greatest efficacy, reducing the infestation of spotted pod borer's larva to 1.50 pods per plot on average, whereas the control plot showed a significant increase in infestation to 7.94 pods. Bio power and Neem excel treated plots performed moderately well, with mean number of infested pods and respectively.

Similar results were reported by Kumar et al., (2021) which demonstrated combining bio power and neem excel reduce reliance on chemical pesticides, mitigate the risk of resistance development and ensure long-term pest management. Infestation levels rose steadily in control plots to 7.94 pods after the fourth spray, with a mean of 6.59.

In terms of overall performance, Minchu+ (2.66), followed by Tracer (2.78), achieved the lowest mean number of infested pods across all spray intervals.

Table 3. Effect of bio pesticides used against spotted pod borer on yardlong bean based on number of infested pods per plot at Jhumka, Sunsari, 2024

Treatments	No. of infested pods per plot					Mean no. of infested pods
	Before spray	7 days after 1 st spray	7 days after 2 nd spray	7 days after 3 rd spray	7days after 4 th spray	
Minchu+	2.44 ^a	3.56 ^b	3.06 ^b	2.50 ^c	1.50 ^d	2.66 ^c
Bio power	2.56 ^a	4.44 ^{ab}	3.88 ^b	3.13 ^{bc}	2.69 ^c	3.53 ^b
Tracer	3.25 ^a	3.81 ^b	3.00 ^b	2.56 ^c	1.75 ^d	2.78 ^c
Neem excel	2.63 ^a	3.88 ^b	3.69 ^b	3.61 ^b	3.56 ^b	3.69 ^b
control	2.75 ^a	5.31 ^a	6.13 ^a	7.00 ^a	7.94 ^a	6.59 ^a
LSD (0.05)	1.24	0.92	1.00	0.77	0.65	0.71
SEM (+-)	0.18	0.13	0.15	0.11	0.09	0.10
F-probability	ns	**	***	***	***	***
CV (%)	29.62	15.17	16.49	13.26	12.16	11.91
Grand mean	2.72	4.2	3.95	3.76	3.50	3.85

Note: ns: no statistically significant; CV: Coefficient of variation; LSD: least significant difference; SEM (±): Standard error of mean; Letters a, b, c represent the ranking of treatments according to DMRT at 0.05 level of significance; * and *** denote significance at p=0.05 and p=0.001 respectively.

3.3 Effect on Yield

To minimize yield variation arising from field fertility heterogeneity, a uniform

fertilizer dose was applied to all experimental plots. This approach ensured that any observed yield differences could be

attributed primarily to the bio pesticide treatments rather than underlying soil nutrient variability. The fertilizer dose—12 kg FYM, 44 g urea, 92.46 g DAP, and 30.80 g MOP per plot—was determined based on the recommended rates . This standardized application helped maintain consistent fertility across the field and reduced the likelihood of treatment bias (MoALD, 2023).

The efficacy of selected bio pesticides against the spotted pod borer (*Maruca vitrata*) on yardlong bean, evaluated based on the yield of healthy pods (kg/plot) is shown in table. The mean yield (ton/ha) of the yardlong bean pod was significantly influenced by the application of selected bio pesticides, with highest mean yield observed in Minchu+ (1.001 kg/plot) treated plot. Minchu+ emerged as the most effective treatment, with results corroborating prior studies by Patil et al. (2021), which

highlighted its superior bio-efficacy against pod borers in legumes. Minchu+ was followed by Tracer with mean yield of 0.990 kg/plot and Neem excel with mean yield of 0.814 kg/plot. The Bio power treated plots showed a lower yield of 0.779 kg/plot of healthy pod, while the control plot had the lowest yield at 0.517 kg/plot. Bio Power and Neem Excel, while eco-friendly, demonstrated moderate performance, aligning with Mishra et al. (2019), who noted the potential of bio-pesticides when used in integrated pest management (IPM).

The efficacy rank of the selected bio pesticides based on mean yield of healthy pod per plot over control was as follows- Minchu+ (*Bacillus thuringiensis* var. *kurstaki* and *Saccharopolyspora spinosa* 15% SC)> Tracer (Spinosad 50% SC) > Neem excel (Azadirachtin 1500ppm)> Bio power (*Beauveria bassiana*).

Table 4. Effect of bio-pesticides used against spotted pod borer on yardlong bean based on the yield of healthy pods per plot at Jhumka, Sunsari, 2024

Treatments	Mean yield of healthy pods(kg/plot)
Minchu+	1.001 ^a
Bio power	0.779 ^b
Tracer	0.990 ^a
Neem excel	0.814 ^b
Control	0.517 ^c
LSD (0.05)	0.05
SEM (+-)	0.007
F- probability	***
CV (%)	3.81
Grand Mean	0.82

Note: ns: no statistically significant; CV: Coefficient of variation; LSD: least significant difference; SEM (±): Standard error of mean; Letters a, b, c represent the ranking of treatments according to DMRT at 0.05 level of significance; * and *** denote significance at p=0.05 and p=0.001 respectively.

4. CONCLUSION

The study found that Minchu+ and Tracer (Spinosad 45% SC) significantly reduced *Maruca vitrata* infestation and increased pod yield in yardlong beans, making them the most effective treatments tested. In the Nepalese context, it is recommended that government agencies promote their use through national IPM programs, researchers

conduct further large-scale trials for local adaptation, extension agents disseminate knowledge and practical training, and farmers adopt these options for environmentally friendly and effective pest management. Their wider adoption could support sustainable agriculture and improve productivity in Nepal.

REFERENCES

- Aktar, M. W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: Their benefits and hazards. *Interdisciplinary Toxicology*, 2(1), 1–12.
- Baskaran, V. (2018). Nutritional and health benefits of yardlong beans (*Vigna unguiculata* subsp. *sesquipedalis*). *Journal of Food Science and Technology*, 55(7), 2680-2690.
- Jiang, H., Zhang, J., & Chen, Y. (2020). Nutritional and functional properties of yardlong bean (*Vigna unguiculata* subsp. *sesquipedalis*): A review. *Journal of Food Science and Technology*, 57(4), 1393-1402.
- Khan, M. I., Kahn, A. A., & Ullah, F. (2019). Efficacy of neem oil against *Maruca vitrata* in yardlong bean. *Journal of Plant Protection Research*, 59(3), 215-221.
- Kumar, A., & Reddy, K. R. (2019). Biopesticides in the management of *Maruca vitrata*: Current status and future prospects. *Biological Control*, 135, 77-85.
- Mandal, K., Das, S., & Bhowmik, D. (2021). Efficacy of *Bacillus thuringiensis* in the control of *Maruca vitrata* in legumes. *International Journal of Pest Management*, 67(4), 345-352.
- Mishra, R., Sharma, V., & Singh, P. (2021). Advances in bio-pesticides: Sustainable alternatives for pest control. *Agricultural Science Journal*, 45(3), 120–135.
- MOALD, (2022). Ministry of Agriculture and Livestock Development. MOALD, from [https:// www.moald.gov.np/publication/ Agriculture Statistics](https://www.moald.gov.np/publication/Agriculture%20Statistics).
- Ministry of Agriculture and Livestock Development (MoALD). (2023). *Krishi Diary 2080*. Government of Nepal, Agriculture Information and Training Centre.
- Nguyen, T. H., Trinh, T. D., & Le, H. T. (2021). The role of legumes in sustainable agriculture: A focus on yardlong bean. *Sustainability*, 13(10), 5505.
- Pande, S., Kaur, S., & Srivastava, R. (2021). Insect pests of yardlong bean: Identification and management strategies. *Journal of Entomology and Zoology Studies*, 9(2), 1450-1456.
- Patil, A. B., Kumar, S., & Reddy, M. N. (2021). Efficacy of Minchu+ in managing pod borers in leguminous crops. *Journal of Crop Protection*, 15(3), 200-210.
- Prasad, R., & Kachhawa, N. (2023). Monitoring strategies for effective management of *Maruca vitrata*. *Agricultural and Forest Entomology*, 25(2), 123-130. <https://doi.org/10.1111/afe.12501>
- Sharma, H. C. (2001). *Tropical legumes: Biology, production, and use* (pp. 367–400). CABI Publishing. <https://doi.org/10.1079/9780851994482.0367>
- Srinivasan, R., Prasad, J., & Kaur, S. (2012). Management of legume pod borer, *Maruca vitrata* (Geyer) in yardlong beans. *International Journal of Vegetable Science*, 18(3), 248-258.
- Suresh, K., Kumar, A., & Ranjan, S. (2020). Biopesticides for sustainable management of spotted pod borer in yardlong bean: Field efficacy studies. *Journal of Agricultural Science*, 12(5), 102-109.
- Tey, Y. S., Aizat, A., & Ong, K. L. (2019). Nutritional composition and health benefits of yardlong bean. *Food Chemistry*, 295, 355-363. DOI: <https://doi.org/10.1016/j.foodchem.2019.05.069>.

SOIL FERTILITY STATUS OF NEPAL: ANALYSIS FROM 2011-2025

Santosh Shrestha^{1*}, Saroj Koirala², Sudip Poudel³, Deekshya Adhikari⁴, Nirmal Mani Dahal⁵ and Janma Jaya Gairhe⁶

- ¹ Agricultural Technology Center Pvt. Ltd., Lalitpur, Nepal
- ² University of Jyväskylä, Seminaarinkatu 15, 40014, Finland
- ³ Himalayan College of Agricultural Sciences and Technology (HICAST), Purbanchal University, Kathmandu, Nepal
- ⁴ Campus of Life Sciences, Tribhuvan University, Dang, Nepal, ORCID
- ⁵ Hong Kong Polytechnic University, Hung Hom, Hong Kong
- ⁶ Institute of Agricultural and Animal Science, Tribhuvan University, Kathmandu, Nepal, ORCID

ARTICLE INFO	ABSTRACT
Keywords: Food security, nutrient management, soil fertility, sustainable agriculture *Correspondence: santoshshrestha.soil@gmail.com Tel: +977 9840012016	Soil fertility governs agricultural productivity by regulating nutrient availability for crop growth. This study reviews soil fertility trends in Nepal from 2011/12 to 2024/2025, analyzing total nitrogen (N), available phosphorus (P), available potassium (K), soil organic matter (OM), and pH as information provided from governmental laboratories and digital soil map of Nepal. Time-series regression analyses reveal marginal increases in nutrient indices (N: +0.02, $r^2 = 0.11$; P: +0.07, $r^2 = 0.28$; K: +0.08, $r^2 = 0.23$), with a shift from low to medium and high nutrient status. Conversely, the pH index declined slightly (-0.006, $r^2 = 0.04$), indicating increasing soil acidity. Declines in organic amendments, imbalanced fertilizer application, and inadequate soil management practices drive these trends, threatening long-term soil health and food security. These findings underscore the need for evidence-based interventions to optimize nutrient management and mitigate acidification, ensuring sustainable agricultural systems in Nepal.

1. INTRODUCTION

Soil fertility is critical for sustaining agricultural productivity by providing essential nutrients for crop growth. In Nepal, intensive cultivation with high-yielding varieties and chemical fertilizers has diminished reliance on organic amendments, such as farmyard manure (FYM) and compost, leading to soil degradation (Pandey et al., 2017). Such poor soil management tactics along with erosion has summed up for lower yield (Pimentel & Burgess, 2013). Nepal is dominated by cereals-based farming system (Shrestha et al., 2006) where plant nutrient loss is estimated to be 310kg/ha annually (Kharal et al., 2018) while nutrient added is only 67 kg/ha (MOALD, 2017). Use of organic amendment and farm size has been reduced due to shortage of labor and land fragmentation (Paudel & Thapa, 2001).

Many authors report to reduced soil fertility due to erosion, reduced amendments, increased soil acidity and unbalanced chemical fertilizers, etc. (Neupane & Thapa, 2001; Pilbeam et al., 2005). These challenges threaten long-term agricultural sustainability and food security, particularly in Nepal’s mid-hills, where fragile geomorphology amplifies degradation.

This research aimed to review and quantify the change in the fertility status, trends of soils fertility in Nepal over time (2011-2025). It identifies the potential drivers for such changes in fertility and proposes a evidence based strategies for sustainable soil management. Results offer a foundation for region-specific interventions to enhance soil fertility and support agricultural productivity.

2. MATERIALS AND METHODS

Several secondary source of information such as books, annual reports, research papers, proceedings were used to collect data related to soil fertility status from 2011/2012 to 2024/2025. Annual reports published from provincial laboratory and digital soil map of Nepal are the major source of information

for this study. Time series analysis and regression analysis was performed and visuals were also prepared in the same. Nutrient index was calculated by using formula given by Ramamurthy & Bajaj (1969) (Equation 1). For this calculation the number of low or medium or high ranges samples were provided in the annual reports.

Nutrient Index = $\frac{nL+2nM+3nH}{n_t}$

Equation 1: Formula for nutrient index

Where, nL = number of low ranged samples
nM = number of medium ranged samples
nH = number of high ranged samples
n_t = nL + nM + nH = total number of samples

Table 1. Rating of Nutrient index

Nutrient index value	Nutrient index	Index value for studied soil parameters	
		Soil pH Index	Soil Nitrogen/ Phosphorus/ Potassium/ Organic Matter
<1.67	Low	Acidic	Low
1.67-2.33	Medium	Neutral	Medium
>2.33	High	Alkaline	High

3. RESULTS AND DISCUSSION

3.1 Status of soil nitrogen

Throughout these years (2011-2025), the percentage of samples classified as low nitrogen consistently exceeded 50%. In contrast, high nitrogen samples were significantly less prevalent than those in the medium range. Data derived from the Digital Soil Map (DSM) indicated that the proportion of samples with low nitrogen content was approximately 34%, while those in the medium range was 65.2%.

Regression analysis conducted between the number of samples and fiscal years revealed a gradual incline in low nitrogen samples (r² = 0.35), with a decrease of 3.41 units

observed from 2011/2012 to 2024/2025 (Figure 1). Conversely, samples exhibiting higher nitrogen levels also showed a decrease (r² = 0.62), but at a lesser rate of 1.6 units. Notably, medium-range nitrogen samples demonstrated an increase at a higher rate of 5.02 units (r² = 0.46). The data suggest that the number of medium-range nitrogen samples is rising more rapidly compared to both higher and lower nitrogen samples.

In the overall nutrient index calculation from 2011/2012 to 2024/2025, there was a notable increase in the nitrogen nutrient index, with a correlation coefficient (r²= 0.16), indicating a rise of 0.02 units (Figure 2). This suggests that the status of soil nitrogen is improving, though at a relatively slow rate.

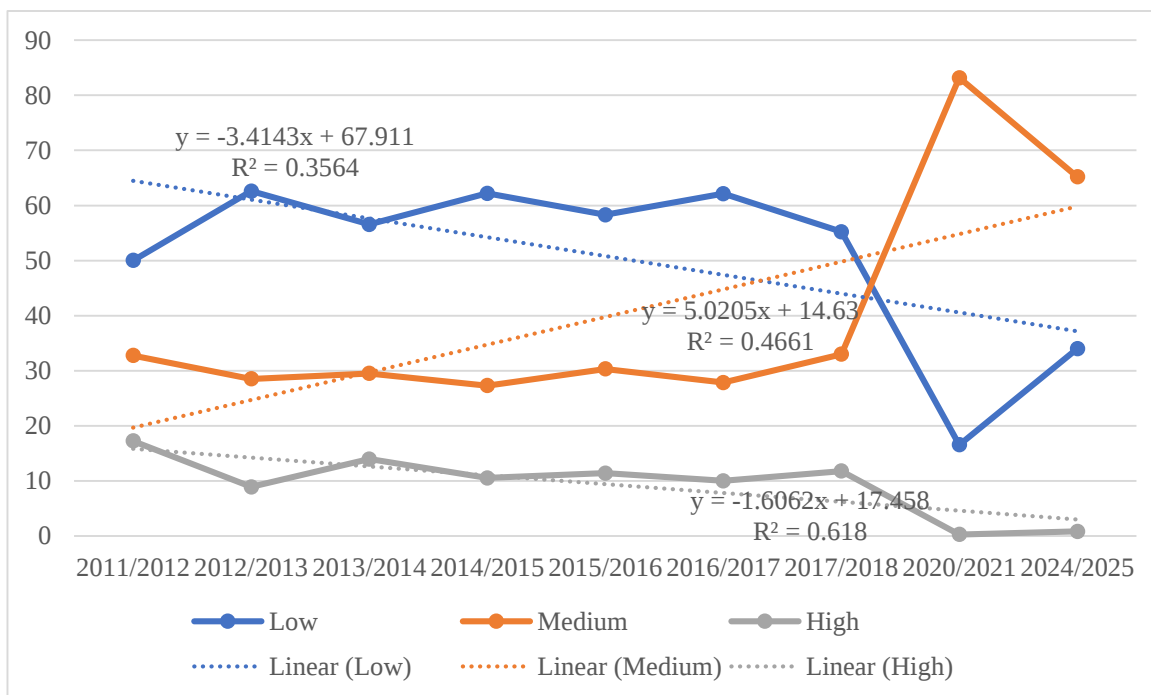


Figure 1. Status of soil nitrogen from FY 2011/2012 to 2024/2025

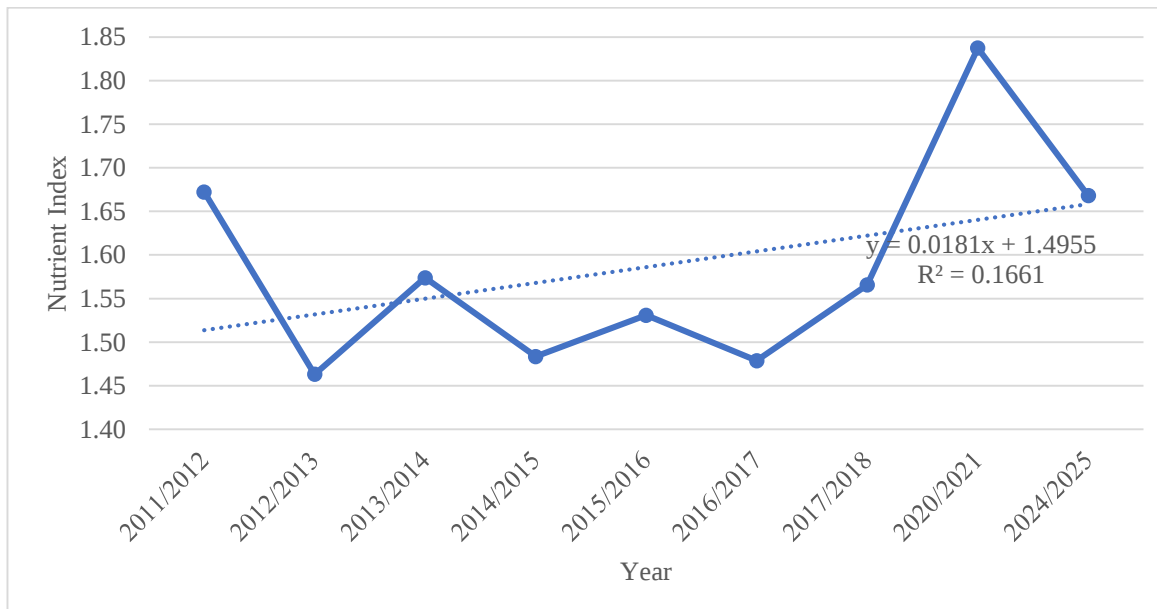


Figure 2. Status of nitrogen nutrient index from FY 2011/2012 to 2024/2025

Steep slopes at higher elevation cause nutrients to leach downward and accumulate resulting in higher soil nutrients at lower elevations. The decreasing trend of C-isotope and N-isotope at the higher altitude might be attributed to the lower mineralization rate

and net nitrification rates (P Sah & Brumme, 2018). The reduction in N loss can be estimated due to decrease in organic matter addition, tillage practices and lower rate of crop residue incorporation (Wang et al., 2001). In soil, factors like time, dose, source

of application and their interaction plays important role in determining efficiency of fertilizer applied (Thapa, 2010). Besides tremendous supply of urea from 2013/14 (MOALD, 2020). Baral et al. (Baral et al., 2019) shows lower rate and imbalanced dose of urea application than recommended dose in paddy cultivation. Intensive crop system practices such as paddy-wheat, paddy-wheat-vegetables or polyhouse cultivation highly reates variation in the nutrient content (N,P,K) as revealed by Koirala et al., (2021) where nutrients were more concentrated in polyhouse than widely adapted paddy-wheat rotation in Nepal.

3.2 Status of soil phosphorus

Throughout these years (2011-2025), the percentage of samples with low phosphorus levels consistently exceeded 40%, while medium and high phosphorus samples accounted for over 25% and 20%, respectively. Notably, post-2020/21, the

proportion of high phosphorus samples increased significantly, exceeding 82% and declined to 60% on 2024/2025. Regression analysis indicated a decrease in the number of samples with low phosphorus ($r^2 = 0.42$), declining by 4.02 units. Similarly, medium phosphorus samples also showed a decrease ($r^2 = 0.31$), with a reduction of 1.13 units. In contrast, high phosphorus samples exhibited an increase ($r^2 = 0.44$), rising by 5.15 units (Figure 3). The rate of increase in high phosphorus samples was equivalent to the rate of decrease observed in both low and medium phosphorus samples.

The nutrient index for soil phosphorus ($r^2 = 0.43$) demonstrated an increase of 0.09 units from the fiscal years 2011/2012 to 2024/2025 (Figure 4). This trend indicates a decline in the number of low phosphorus samples, suggesting an overall improvement in soil phosphorus status during this period.

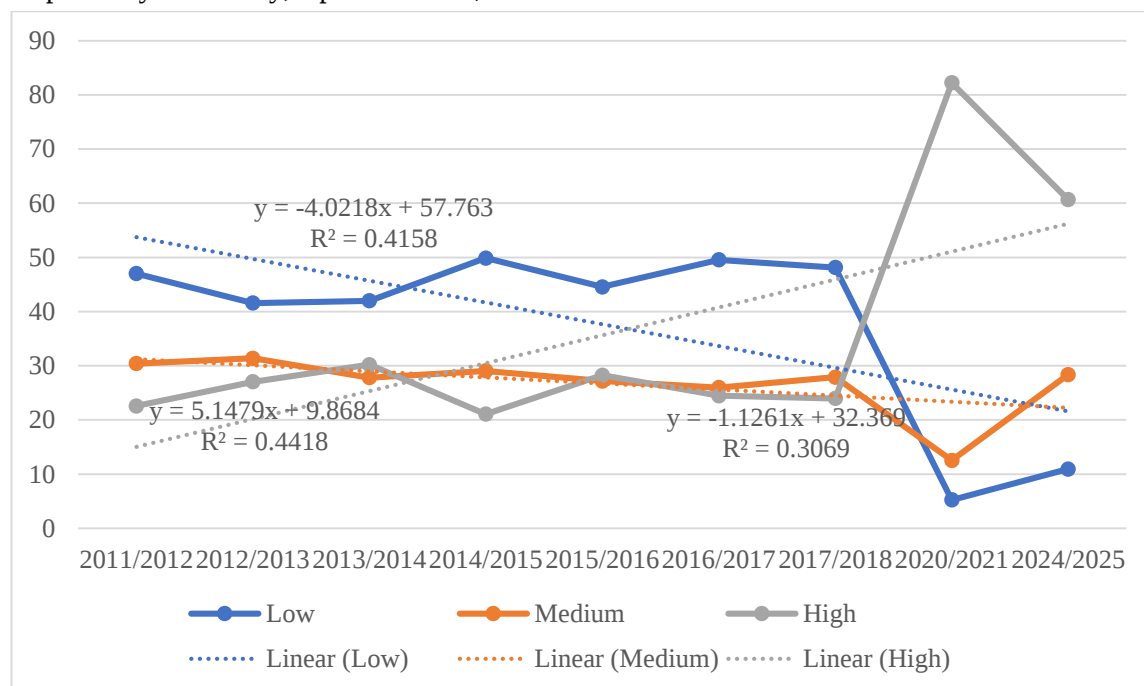


Figure 3. Status of phosphorus of Nepal for FY 2011/2012 to 2024/2025

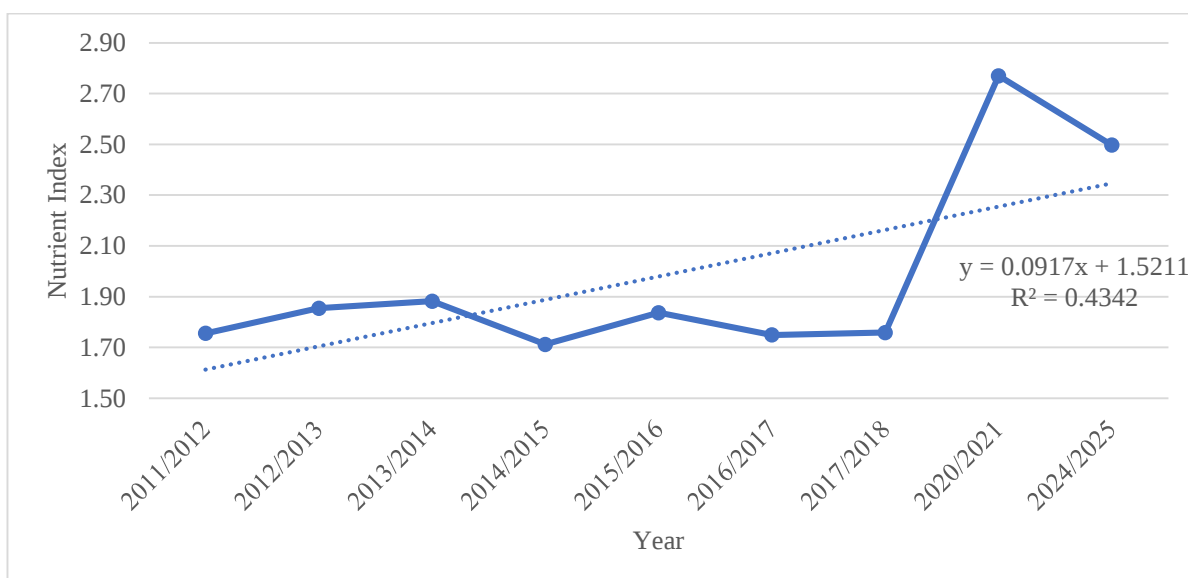


Figure 4. Status of phosphorus nutrient index from FY 2011/2012 to 2024/2025

Soil P is highly correlated with soil pH (Koirala et al., 2021; von Tucher et al., 2018). Since soils of Nepal are predominantly acidic in nature low availability of phosphorus might be evident. Phosphorus containing fertilizer (Diammonium phosphate) supply has drastically been improved since 2009/2010 (MOALD, 2020). Schreier et al. (1999) in his study claims that along with P fertilizer high rate of organic matter is also perquisite to improve phosphorus dynamics in soil.

3.3 Status of soil potassium

Throughout this period (2011-2025), samples containing low potassium consistently exceeded 40%, while medium potassium samples were above 25% and high potassium samples were approximately over 15%. Following the fiscal year 2020/21, the proportion of high potassium samples

dramatically increased to 73% and towards 43% on 2024/2025.

Regression analysis indicated a decrease in the number of low potassium samples ($r^2 = 0.38$), with a reduction of 5.19 units. In contrast, medium potassium samples showed a minimal decline ($r^2 = 0.15$), decreasing by 1.35 units, whereas high potassium content samples exhibited a significant increase ($r^2 = 0.31$), rising by 3.84 units (Figure 5). This trend suggests that the rate of increase in high potassium samples corresponds with the decrease in both low and medium potassium samples.

Similarly, the nutrient index for potassium ($r^2 = 0.36$) showed an increase of 0.09 units (Figure 6). This upward trend indicates a rise in the proportion of high potassium samples, reflecting an overall improvement in soil potassium status during the observed period.

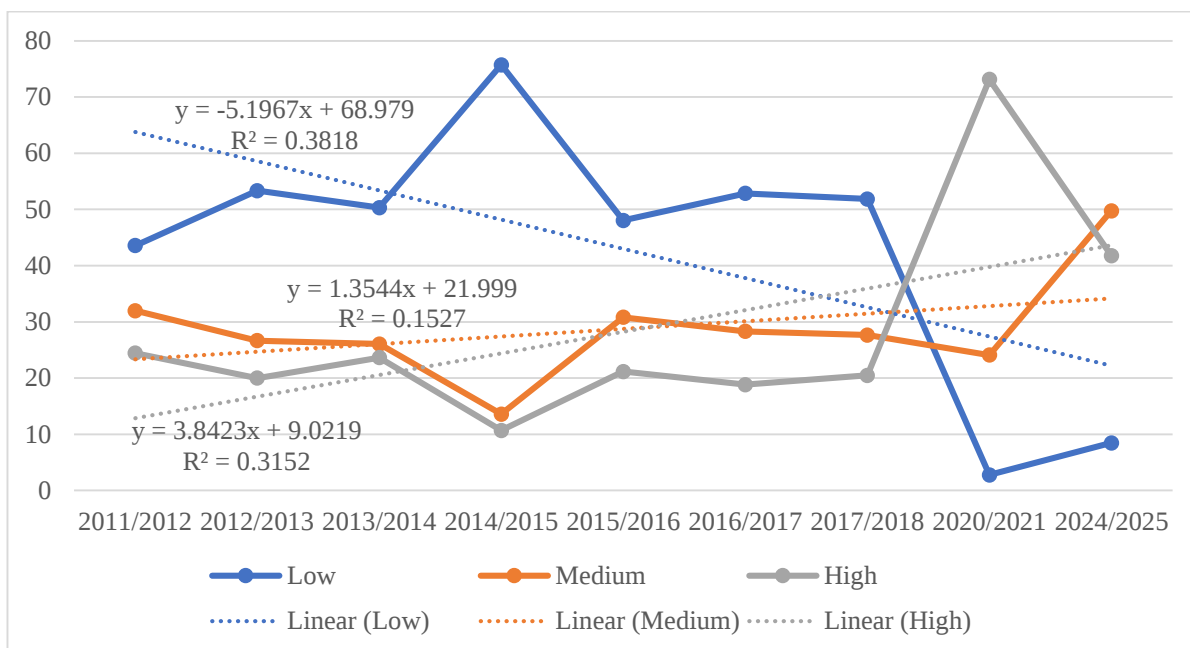


Figure 5. Status of potassium of Nepal for FY 2011/2012 to 2024/2025

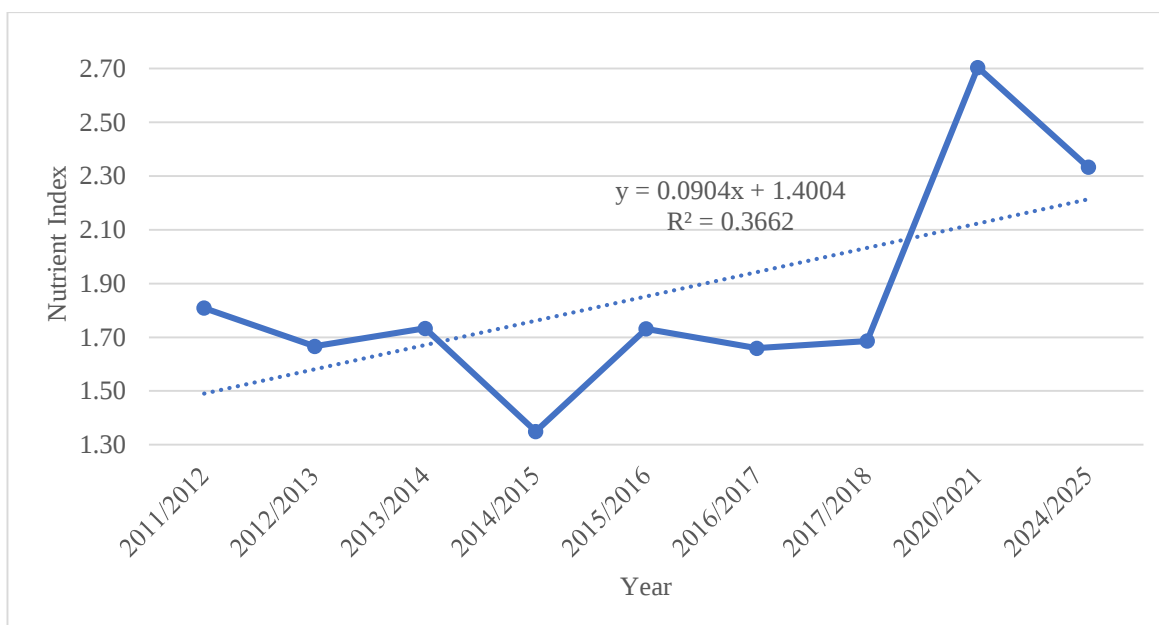


Figure 6. Status of potassium nutrient index from FY 2011/2012 to 2024/2025

Mica dominated bed rocks subsequently makes Nepal rich in potassium (Ojha et al., 2021; Schreier et al., 1999). This was at par with our result that soil with medium and higher status of K was continuously increasing in quantity. Adequate potassium fertilizer supply and application rate is though lower than compared to phosphorus

and nitrogenous fertilizer (MOALD, 2020) is relevant in context of Nepal.

3.4 Status of soil pH

The acidic samples consistently dominated, comprising more than 50% of the total each year, while neutral pH samples accounted for over 24% (CAL, 2017; Dawadi & Thapa, 2015; SMD, 2011, 2012, 2014, 2015).

Following the launch of the Digital Soil Map (DSM), data from 2020/21 indicated that acidic samples reached 53% and reached to 61% on 2025. Alkaline samples remained relatively stable, constituting approximately 10% each year. Regression analysis revealed a decrease in the number of acidic soil samples ($r^2 = 0.04$), with a reduction of 0.28 units. Conversely,

neutral pH samples exhibited an increase ($r^2 = 0.28$), rising by 0.93 units (Figure 7). Additionally, alkaline soil samples showed a decline ($r^2 = 0.33$), decreasing by 1.22 units. These trends suggest a shift in soil pH distribution, with a gradual increase in neutral pH samples at the expense of acidic and alkaline samples.

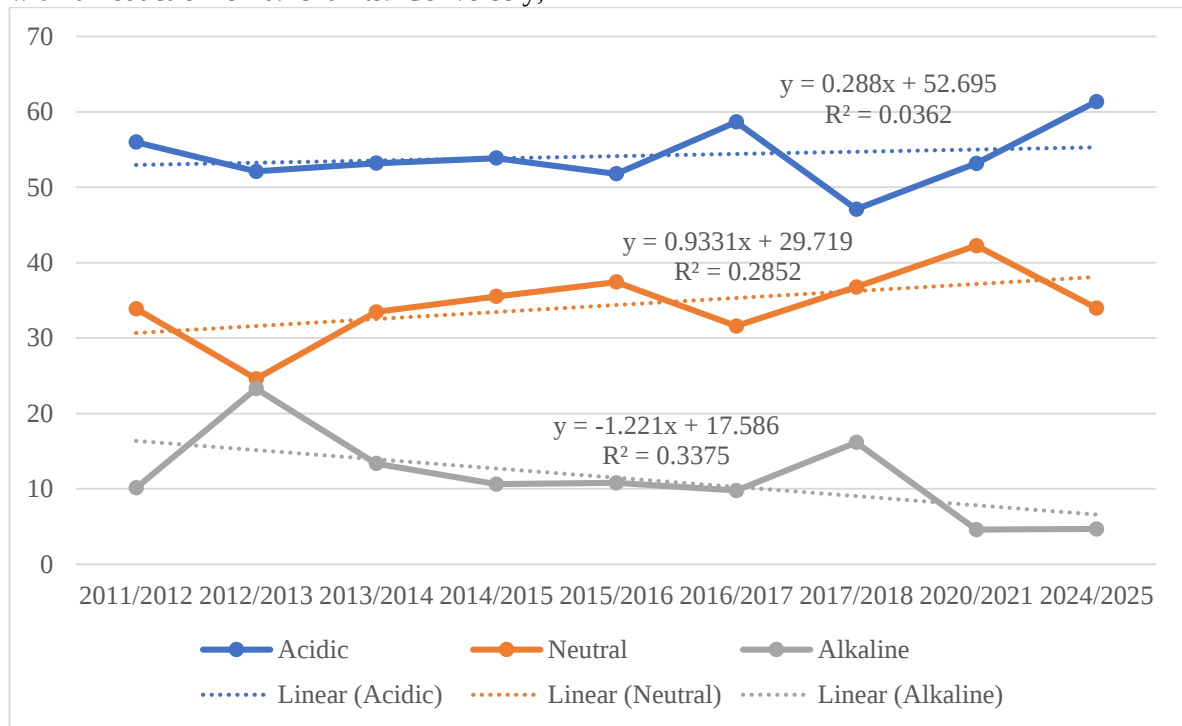


Figure 7. Status of soil pH of Nepal for FY 2011/2012 to 2024/2025

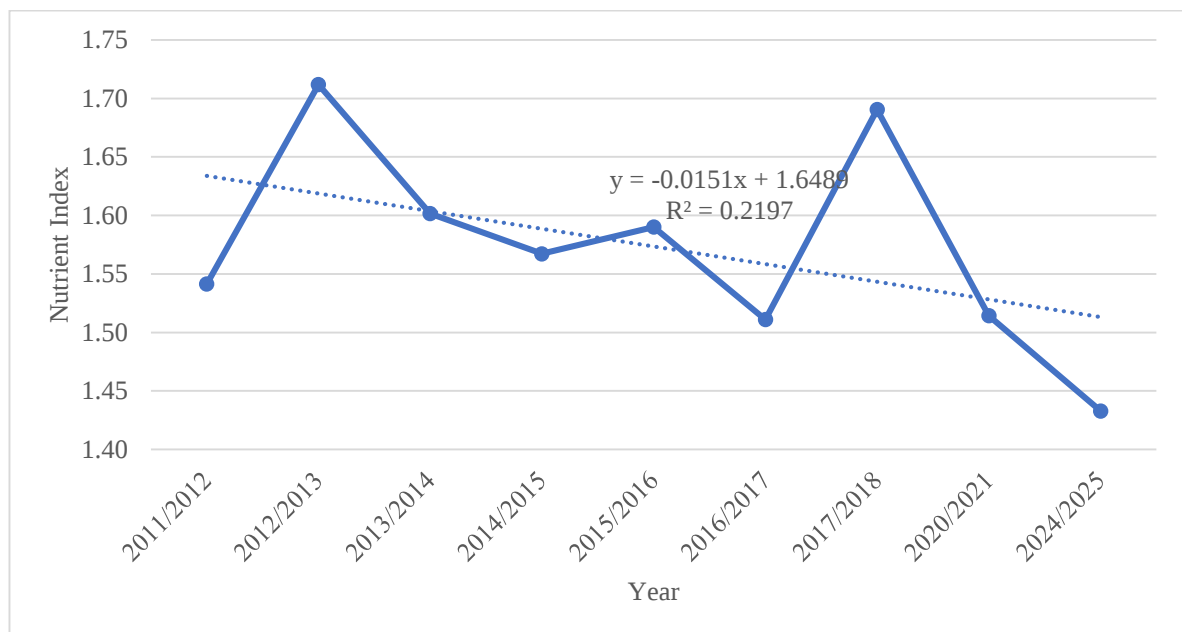


Figure 8. Status of soil pH nutrient index from FY 2011/2012 to 2024/2025

Literature shows that Nepal has acidic parent material such as sandstone, siltstone, quartzite and shale which are capable to make soil acidic naturally but higher aluminum concentration and loss of major cations by rainfall are also responsible for the acidic condition (Ghimire & Bista, 2016). But different from our result, acidic share is though highest but share of acidic and alkaline soil is decreasing with year while neutral samples are increasing in numbers. Though literatures conveyed higher acidic shares of soils of Nepal (Ojha & Panday, 2021), this increment in neutral soils might be due to increased awareness from farmers level trainings on soil management, increased soil testing facility and soil test-based recommendation of lime, organic manures, and other amendments that are actively started by department of agriculture during fiscal year 2011/2012 to 2024/2025 (Pandey et al., 2018).

3.5 Status of soil organic matter

Samples exhibited low organic matter status, with the exception of FY 2013/14 (CAL, 2017; Dawadi & Thapa, 2015; SMD, 2011, 2012, 2014, 2015). Medium organic matter (OM) was present in more than 22% of samples, while high OM was found in approximately 4%. Following FY 2020/21, there was a significant increase in medium-range samples, exceeding 50%. In the fiscal year (2024/2025), low organic matter was identified in only 47.81% of samples, while high organic matter constituted a minimal percentage of 1.68%.

Statistical analysis revealed that the number of samples with low organic matter ($r^2 = 0.1$) decreased by 1.73 units. In contrast, medium organic matter samples ($r^2 = 0.23$) increased by 1.93 units, and high organic matter samples ($r^2 = 0.01$) rose by 0.19 units (Figure 9). Overall, the organic matter index ($r^2 = 0.05$) showed a slight decline of 0.01 units (Figure 10), indicating a gradual shift in soil organic matter status despite the increase in medium and high ranges.

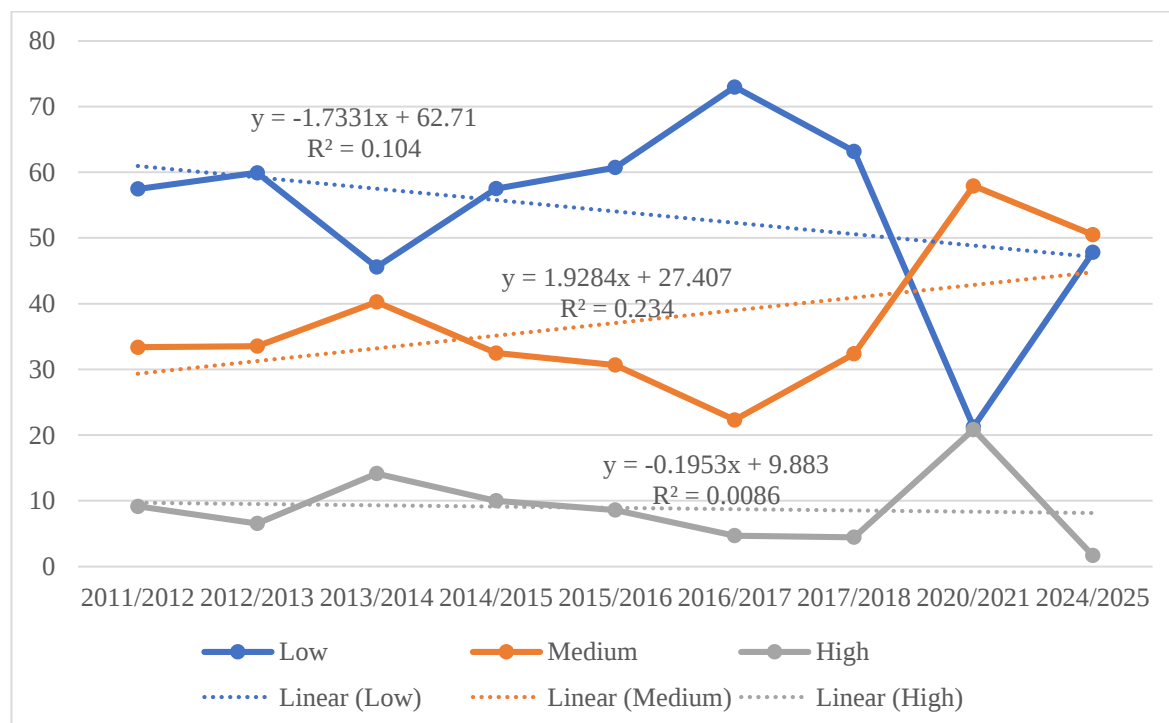


Figure 9. Status of soil organic matter of Nepal for FY 2011/2012 to 2024/2025

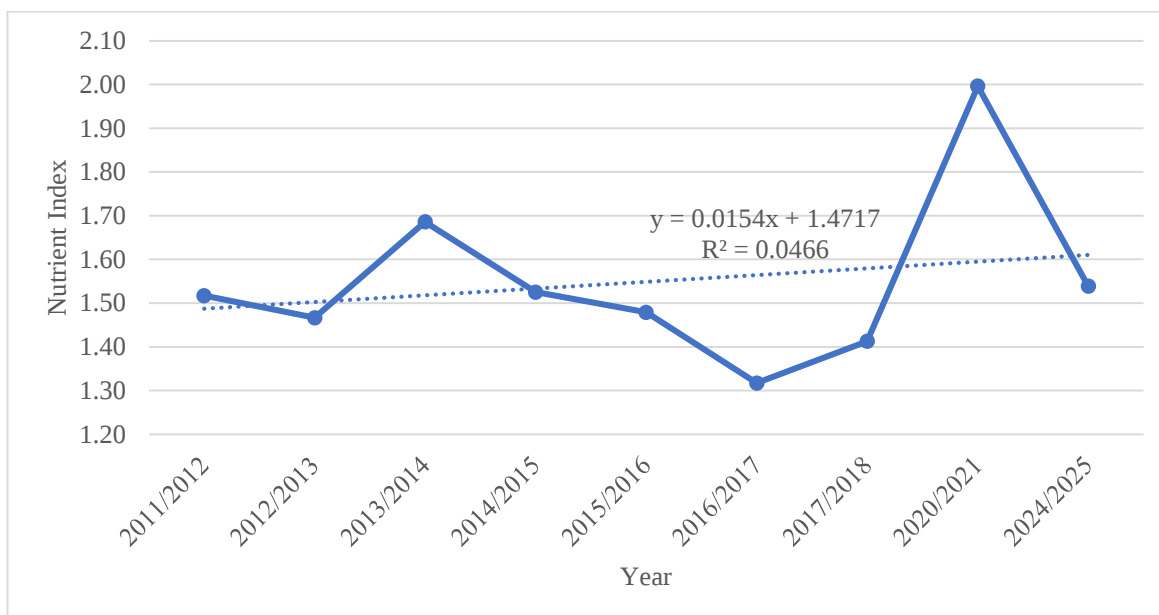


Figure 10. Status of soil organic matter nutrient index from FY 2011/2012 to 2024/2025

Deforestation has a greater negative impact on soil organic carbon (SOC) in the upper soil layer (Ghimire & Bista, 2016; Ojha & Panday, 2021). Gairhe et al., (2021) also found that soil organic matter content with lower OM content was increasing by 0.046 units from FY 2014/15 to 2017/18. They also concluded to decreasing number of medium and high ranged samples of OM. This difference in rate of change of samples is due to long time series analysis. This increase in lower range of soil organic matter is due to dependency in chemical fertilizer rather than use of organic amendments like FYM, compost (Pandey et al., 2017). This declining trend of OM and increase in low organic matter content is due to less use of organic matter source like Farm yard manure (FYM) as livestock numbers are reducing, shifting to conventional agriculture practices with heavy mechanization followed by monoculture with less use of organic manures (Ojha & Panday, 2021).

3.6 Implications of the study

In Nepal, very less chronological studies have been done and very less detailed information on soil nutrient status and also systematic investigation of soil fertility is lacking. From production point of view, the fertility status of soils as reflected by a combined measure of the macro-nutrient and selected micro-nutrient status could be

useful. Soil fertility decline has been one of the main reasons for poor agricultural growth in Nepal in recent decades. A number of factors are responsible for the decline in soil fertility, where the three major factors are accelerated soil erosion, increased use of acidifying fertilizers and reduced organic matter input into the soils. Soil erosion rate is triggered by change in land-use and land cover (Brady et al., 2008; Davidson & Janssens, 2006). Declining soil fertility in Nepal poses severe threats to food security, biodiversity, and socio-economic stability. With over 40% of soils exhibiting low nitrogen, phosphorus, and potassium levels, and 55% showing low organic matter (CAL, 2017; SMD, 2015), crop yields are significantly reduced, jeopardizing agricultural productivity critical for feeding Nepal's growing population (Pimentel & Burgess, 2013; Kharal et al., 2018). This nutrient depletion, coupled with a pH index decrease of 0.006 units ($r^2 = 0.04$), indicating increasing soil acidity, restricts nutrient bioavailability, further exacerbating yield losses for staple crops like rice and wheat, which underpin national food systems (Ghimire & Bista, 2016). Such declines threaten food security by increasing reliance on imports and driving up food prices, disproportionately affecting rural and low-income communities dependent on subsistence agriculture (MOALD, 2017).

Beyond agriculture, soil degradation disrupts soil microbial communities, reducing biodiversity and impairing ecosystem services such as nutrient cycling and carbon sequestration, which are vital for ecological resilience (Uddin et al., 2018). This loss of biodiversity weakens soil's capacity to support diverse agroecosystems, increasing vulnerability to pests, diseases, and climate variability.

Soil erosion, contributing approximately 50% to soil degradation, exacerbates these issues by removing nutrient-rich topsoil, further diminishing fertility and agricultural potential (Uddin et al., 2018). The socio-economic ramifications are profound, as declining yields reduce farmers' incomes, perpetuate poverty cycles, and drive rural-to-urban migration, straining urban infrastructure. To mitigate these threats, a suite of sustainable soil management strategies is essential. Promoting organic amendments, such as farmyard manure (FYM), compost, and biochar, can replenish organic matter, enhance nutrient retention, and improve soil structure (Pandey et al., 2017). Balanced fertilizer application, informed by routine soil testing, can address nutrient imbalances, optimize inputs while minimize environmental impacts like eutrophication (Pandey et al., 2018). Conservation tillage and cover cropping can reduce erosion by stabilizing soil and increasing ground cover, preserving fertility and reducing sediment runoff into water bodies (Uddin et al., 2018). Agroforestry systems, integrating trees with crops, can enhance soil organic matter and provide additional income sources, supporting both ecological and economic resilience (Neupane & Thapa, 2001). Scaling up mobile soil-testing services and farmer training programs can empower local communities to adopt precision agriculture, tailoring interventions to site-specific needs (Pandey et al., 2018). Updating national fertilizer recommendations to reflect current soil data and promoting subsidies for organic inputs can incentivize sustainable practices. These strategies, implemented through coordinated policy efforts, can restore soil health, safeguard food security, protect biodiversity,

and ensure long-term agricultural sustainability in Nepal.

4. CONCLUSION

Soil fertility is crucial for supplying essential nutrients for the productive growth and development of plants. Effective monitoring and enhancement of soil fertility are essential to guide agricultural production. A decline in soil fertility can lead to significant reductions in crop yields, with increasing evidence linking yield reductions directly to soil fertility loss. Current studies indicate that the nutrient indices for nitrogen (N), phosphorus (P), potassium (K), and organic matter (OM) are increasing, at a minimal rate. However, this slight upward trend is insufficient to meet the demands of a growing population, as the rate of population increase far outpaces improvements in soil fertility.

An intriguing finding from the pH index analysis suggests that, under current management practices, soil pH could shift entirely into the acidic range (unity index) within the next 43 years. Various factors contribute to this degradation, including reduced use of organic amendments, imbalanced application of chemical fertilizers, inadequate sustainable soil management practices, outdated national fertilizer recommendations, and ineffective government extension services. It is imperative that researchers, policymakers, and high-level authorities recognize this degradation as a serious threat to food security in the near future. Immediate action is required to develop and implement amelioration strategies to ensure sustainable agricultural practices. This study utilized time series data from 2011/12 to 2020/21; however, no official publications have emerged since 2017/18. Additionally, due to federal divisions within the country, state-specific soil test data is lacking. The launch of the Digital Soil Map (DSM) in 2020/21 provided valuable soil nutrient data for this analysis. While the regression analysis indicates a minimal determination power, it serves as a tool for extracting patterns regarding soil status. Long-term time series analyses are recommended for more accurate projections and evaluations of real-time soil fertility status.

REFERENCES

- Abedi, M., Bartelheimer, M., & Poschlod, P. (2013). Aluminium toxic effects on seedling root survival affect plant composition along soil reaction gradients—a case study in dry sandy grasslands. *Journal of Vegetation Science*, 24(6), 1074–1085.
- Baral, B., Pande, K., Gaihr, Y., Baral, K., Sah, S., & Thapa, Y. (2019). Farmers' Fertilizer Application Gap In Ricebased Cropping System: A Case Study of Nepal. *SAARC Journal of Agriculture*, 17(2), 267–277. <https://doi.org/10.3329/sja.v17i2.45311>
- Benedict, R. H. (1949). Methods and costs of terrace construction under Iowa conditions.
- Bhandari, J., & Zhang, Y. (2019). Effect of altitude and soil properties on biomass and plant richness in the grasslands of Tibet, China, and Manang District, Nepal. *Ecosphere*, 10(11). <https://doi.org/10.1002/ecs2.2915>
- Brady, N. C., Weil, R. R., & Weil, R. R. (2008). *The nature and properties of soils* (Vol. 13). Prentice Hall Upper Saddle River, NJ.
- CAL. (2017). Annual Report of Soil Management Program 2017/2018. <http://centralaglab.gov.np/pages/publication-2020-02-16-112011>
- Davidson, E. A., & Janssens, I. A. (2006). Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature*, 440(7081), 165–173.
- Dawadi, D. P., & Thapa, M. (2015). Soil fertility status of Nepal: report from laboratory analysis of soil samples of five developmental regions. *Proceedings of the Second National Soil Fertility Research Workshop*, 24–25 March, 2015, March, 42–51.
- Diamond, D. D., & Smeins, F. E. (1985). Composition, classification and species response patterns of remnant tallgrass prairies in Texas. *American Midland Naturalist*, 294–308.
- Fornara, D. A., & Tilman, D. (2009). Ecological mechanisms associated with the positive diversity–productivity relationship in an N-limited grassland. *Ecology*, 90(2), 408–418.
- Gairhe, J. J., Khanal, S., & Thapa, S. (2021). Soil organic matter (SOM): status, target and challenges in Nepal. *Malaysian Journal of Sustainable Agriculture*, 5(2), 90–94. <https://doi.org/10.26480/mjsa.02.2021>.
- Ghimire, R., & Bista, P. (2016). Crop Diversification Improves pH in Acidic Soils. *Journal of Crop Improvement*, 30(6), 657–667. <https://doi.org/10.1080/15427528.2016.1219894>
- Hormann, K. (1974). Die Terrassen an der Seti Khola—Ein Beitrag zur quartären Morphogenese in Zentralnepal (Terraces on the Seti Khola—A Contribution to Quaternary Morphogenesis in Central Nepal). *Erdkunde*, 161–176.
- Jež, J., & Komac, M. (2020). *Landslide susceptibility assessment method*. 3(May), 11–21.
- Ji, C.-J., Yang, Y.-H., Han, W.-X., He, Y.-F., Smith, J., Smith, P., & others. (2014). Climatic and edaphic controls on soil pH in alpine grasslands on the Tibetan Plateau, China: a quantitative analysis. *Pedosphere*, 24(1), 39–44.
- Kharal, S., Khanal, B. R., & Panday, D. (2018). Assessment of soil fertility under different land-use systems in Dhading District of Nepal. *Soil Systems*, 2(4), 1–8. <https://doi.org/10.3390/soilsystems2040057>
- Koirala, S., Shrestha, S., Raut, P., Pandey, B., & Timalisina, A. (2021). Effect of Mid term Cropping Sytem Adoption on Soil Chemical Properties at Changunaryan Municipality, Bhaktapur, Nepal. *Current Research in Agricultural Sciences*, 8(2), 80–89. <https://doi.org/10.18488/journal.68.2021.82.80.89>
- Måren, I. E., Karki, S., Prajapati, C., Yadav, R. K., & Shrestha, B. B. (2015). Facing north or south: Does slope aspect impact forest stand characteristics and soil properties in a semiarid trans-Himalayan valley? *Journal of Arid Environments*, 121, 112–123.
- MOALD. (2017). Statistical information on Nepalese agriculture 2016/2017. Ministry of Agriculture and Livestock Development.
- MOALD. (2020). Statistical information on Nepalese agriculture 2018/2019. In Ministry of Agriculture and Livestock Development. <https://nepalindata.com/resource/statistical-information-nepalese-agriculture-207374-201617/>
- Neupane, R. P., & Thapa, G. B. (2001). Impact of agroforestry intervention on soil fertility and farm income under the subsistence farming system of the middle hills, Nepal. *Agriculture, Ecosystems & Environment*, 84(2), 157–167. [https://doi.org/10.1016/S0167-8809\(00\)00203-6](https://doi.org/10.1016/S0167-8809(00)00203-6)
- Ojha, R. B., & Panday, D. (2021). The soils of Nepal. Springer Nature. <https://doi.org/https://doi.org/10.1007/978-3-030-80999-7>
- Ojha, R. B., Shrestha, S., Khadka, Y. G., & Panday, D. (2021). Potassium nutrient response in the rice-wheat cropping system in different agro-ecozones of Nepal. *PLoS ONE*, 16(3 March), e0248837. <https://doi.org/10.1371/journal.pone.0248837>
- P Sah, S., & Brumme, R. (2018). Altitudinal gradients of natural abundance of stable isotopes of nitrogen and carbon in the needles and soil of a pine forest in Nepal. *Journal of Forest Science*, 49(No. 1), 19–26. <https://doi.org/10.17221/4673-jfs>
- Palpurina, S., Wagner, V., von Wehrden, H., Hájek, M., Horsák, M., Brinkert, A., Hölzel, N., Wesche, K., Kamp, J., Hájková, P., & others. (2017). The relationship between plant species richness and soil pH vanishes with increasing aridity across Eurasian dry grasslands. *Global Ecology and Biogeography*, 26(4), 425–434.
- Pandey, G., Khanal, S., Pant, D., Chhetri, A., & Basnet, S. (2017). *An overview of fertilizer distributionscenario in Nepal: a time series analysis*.
- Pandey, S., Bhatta, N. P., Paudel, P., Pariyar, R., Maskey, K. H., Khadka, J., Thapa, T. B., Rijal, B., & Panday, D. (2018). Improving fertilizer recommendations for Nepalese farmers with the help of soil-testing mobile van. *Journal of Crop Improvement*, 32(1), 19–32. <https://doi.org/10.1080/15427528.2017.1387837>

- Paudel, G., & Thapa, G. (2001). Changing farmers land management practices in the hills of Nepa. *Environmental Management*, 286, 789–803.
- Pilbeam, C. J., Mathema, S. B., Gregory, P. J., & Shakya, P. B. (2005). Soil fertility management in the mid-hills of Nepal: Practices and perceptions. *Agriculture and Human Values*, 22(2), 243–258. <https://doi.org/10.1007/s10460-004-8284-y>
- Pimentel, D., & Burgess, M. (2013). Soil erosion threatens food production. *Agriculture*, 3(3), 443–463. <https://doi.org/10.3390/agriculture3030443>
- Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R., & others. (1995). Environmental and economic costs of soil erosion and conservation benefits. *Science*, 267(5201), 1117–1123.
- Ramamurthy, B., & Bajaj, J. . (1969). Available nitrogen, phosphorus and potassium status of Indian soils. *Fertilizer News*, 14, 25–36.
- Schreier, H., Brown, S., Lavkulich, L., & Shah, P. (1999). Phosphorus dynamics and soil P fertility constraints in Nepal. *Soil Science*, 164(5), 341–350.
- Shrestha, R. K., Ladha, J. K., & Gami, S. K. (2006). Total and organic soil carbon in cropping systems of Nepal. *Nutrient Cycling in Agroecosystems*, 75(1–3), 257–269. <https://doi.org/10.1007/s10705-006-9032-z>
- SMD. (2011). Annual Report of Soil Management Program 2011/2012.
- SMD. (2012). Annual Report of Soil Management Program 2012/13.
- SMD. (2014). Annual Report of Soil Management Program 2014/2015.
- SMD. (2015). Annual Report of Soil Management Program 2015/2016.
- Thapa, M. (2010). Factors affecting fertilizer use efficiency in dry season paddy production in Makawanpur district, mid hill, Nepal. *Agronomy Journal of Nepal*, 1, 123–133. <https://doi.org/10.3126/ajn.v1i0.7552>
- Uddin, K., Matin, M. A., & Maharjan, S. (2018). Assessment of land cover change and its impact on changes in soil erosion risk in Nepal. *Sustainability (Switzerland)*, 10(12). <https://doi.org/10.3390/su10124715>
- von Tucher, S., Hörndl, D., & Schmidhalter, U. (2018). Interaction of soil pH and phosphorus efficacy: Long-term effects of P fertilizer and lime applications on wheat, barley, and sugar beet. *Ambio*, 47(Suppl 1), 41–49. <https://doi.org/10.1007/s13280-017-0970-2>
- Wang, J., Fu, B., Qiu, Y., & Chen, L. (2001). Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. *Journal of Arid Environments*, 48(4), 537–550. <https://doi.org/10.1006/jare.2000.0763>

ECOFRIENDLY MANAGEMENT OF STRIPED FLEA BEETLE (*Phyllotreta striolata*) BY USING DIFFERENT BIOPESTICIDES ON RADISH AT JHUMKA, SUNSARI

Jharana Shrestha^{1*}, Kiran Acharya¹, Madhu Kumari Ray¹ and Saraswati Shrestha²

¹ Agriculture and Forestry University, Chitwan, Nepal

² Plant Protection Laboratory, Koshi Province, Jhumka, Sunsari

ARTICLE INFO

Keywords:
Biopesticides,
Radish,
Striped flea beetle

*Correspondence:
Jharanashrestha30@gmail.com
9822533957

ABSTRACT

The study was conducted at Jhumka, Sunsari, Nepal, from April to May 2024 to assess the effectiveness of different biopesticides in managing striped flea beetles (SFB) on radish (*Raphanus sativus* L.). A randomized complete block design (RCBD) was used, with five treatments: Eko-Trump (*Bacillus thuringiensis*, T1), Minchu+ (*B. thuringiensis* var. *kurstaki* & *Saccharopolyspora spinosa* – 15%, T2), Biocatch (*Verticillium lecanii*, T3), Neem Excel (Azadirachtin 1500 ppm, T4), and a control (water, T5), replicated four times over 20 plots. Treatments were applied for three times which were applied at five-days intervals, with data collected before and after each application. Minchu+ was the most effective treatment, reducing SFB infestation by 46.28% after the first spray, 53% after the second, and 61.6% after the third. Neem Excel also showed increasing efficacy, achieving 57.15% reduction after the final spray. Biocatch and Eko-Trump were comparatively less effective, compared to the control. Minchu+ also recorded the highest plant height (27.56 cm), root weight (158.75 g), and yield (39.69 ton/ha), followed by Neem Excel with 27.36 cm, 151.25 g, and 37.81 ton/ha respectively. Thus, Minchu+ proved to be the most effective and eco-friendly biopesticide for controlling SFB and improving radish growth and yield.

1. INTRODUCTION

The Brassicaceae family includes the radish (*Raphanus sativus* L.), a type of root vegetable. for radish growth. One of Nepal's most widely consumed root vegetables, radish may be produced all year round in the country's hills and during the winter months in the Terai. The

popularity of radish cultivation may be attributed to its greater versatility, low production costs, short crop duration, and ease of maintenance for growing in nearly any type of soil. In addition, radish has fewer pest and disease issues than other vegetable crops (Shrestha and Shakya, 2004). A pH of 5.5 to 6.8 is ideal for soil. Radish is high in B, C, and A vitamins (Arya, 2002). Crops called radishes are grown for their swelling tap roots,

which can have a cylindrical, tapered, or globular shape. Its tips can be used as a leafy vegetable, and the entire plant is edible. Radish is a winter root vegetable crop that is grown in Nepal's Terai region from September to January (NARC, 2017). Since radish is a crop that grows quickly, root formation and growth should continue unhindered. The best nutrition for this should come from sources of organic, inorganic, and biofertilizer. Chemical fertilizers are costly and, if applied frequently, can lead to poor soil and water quality. Therefore, alternative low-cost organic nutrient sources must be employed (Kumar et al., 2014). In Nepal the total area, production and yield of radish was 292,812 hectare ,15.57 metric ton and yield 1,579 ton/ha respectively (MOALD (2022/23).

The rising demand for food safety and quality in recent decades is shown in the strict limits on the amount of pesticide residues on commodities and the strict safety controls on product imports (Kumar, M et al.,2019). One of the most widely used microbial biopesticides is *Bacillus thuringiensis*, popularly known as Bt. Potential benefits of the use of biopesticides to agriculture and public health programmes are considerable (Suresh kumar and Archana singh,2015). More than 225 microbial biopesticides are manufactured in 30 OECD their release, emphasis has been given towards utilizing entomopathogens which are the potential bio-pesticides (Megaladevi, P and Manjunatha, M, 2019) .Along with the commercialization and knockdown effects, usages of chemicals have increased dramatically in recent decades. According to Bretthour and Weersink (2001), the extensive use of pesticides in agriculture has greatly enhanced output, making it a dominant force in the production system and a possible contributor to agro-environmental deterioration. Pesticides present a number of threats to the environment, non-target agricultural ecosystems, and human health (Travis et al., 2006). Biopesticides such as neem oil and Azadirachtin-based products effectively repel and inhibit the growth of flea

beetles, significantly reducing pest populations and limiting crop damage (Saxena, 2003). This promotes sustained yield improvement in radish cultivation (Glare et al., 2012). Effective flea beetle control ensures undamaged radish leaves and roots, leading to higher yields and better-quality produce. Biopesticides also align with organic farming standards, enhancing marketability (Marrone, 2019). By keeping flea beetles from feeding on radish leaves, biopesticides assist promote the best possible root development and lessen overall plant stress. This makes it possible to focus more energy on root growth. Consequently, biopesticide-treated plants typically develop larger roots, which is crucial for crop quality and yield (Mohan et al., 2013).

2. MATERIALS AND METHODS

2.1 Research site and time of research

The research was conducted at Jhumka, Municipality, Ramdhuni-5, Sunsari, Nepal which was commanded by Plant Protection Laboratory, Koshi Province. Geographically the Research location was located at 26°39'48.2"N latitude to 87°11'40.3"E longitude 85m(278.8714feet) altitude. The research was carried out from April to May, 2024 until the harvest of radish.

2.2 Experiment details

The study was conducted using a Randomized Complete Block Design (RCBD) with five treatments and four replications, resulting in a total of 20 experimental plots. Each plot measured 0.8 × 0.8 m, with 20 cm spacing maintained both row-to-row and plant-to-plant. The first bio pesticide treatment was applied in 15 days after sowing (DAS), 2nd in 20 DAS and 3rd in 25 DAS.

2.3 Treatment details

Table 1. Different treatments their symbols and doses

Treatment	Trade Name	Symbol	Treatment Composition or component	Dose
1	Eko-trump	T1	<i>Bacillus thuringiensis</i>	3g/ltr
2	(Minchu+)	T2	<i>Bacillus thuringiensis</i> <i>kurstaki</i> & <i>Saccharopolyspora spinosa</i> – 15%SC	2.5ml/ltr
3	Bio-catch	T3	<i>Verticillium lecani</i>	10gm/ltr
4	Neem excel	T4	Azadirachtin (1500ppm)	5ml/ltr
5	Control (Water spray)	T5		0

2.4 Data collection

Insect population data were recorded one day before the first spray (pretreatment) and for five days after applying each of the three treatment. Four randomly selected plants per plot were inspected, and the number of striped flea beetles per plant was recorded. Data of plant height root weight and yield were also recorded on the day of harvesting.

2.5 Efficacy calculation

The efficacy of various biopesticides was evaluated against major insect pests of radish, focusing on the striped flea beetle (*Phyllotreta striolata*). The experiment involved three consecutive foliar applications at five-days intervals. Pretreatment populations were recorded one day prior to the first spray, and observations of beetle populations were taken before and five days after each spray. Insect counts were conducted by randomly selecting four plants per plot and recording the number of striped flea beetles present. Efficacy was calculated using Abbott's formula.

$$\text{Percent efficacy} = \left(\frac{C - T}{C} \times 100 \right)$$

Where,

C = Mean pest population in the control plot
T = Mean pest population in the treated plot

2.6 Statistical analysis

Statistical analysis was performed using R-Studio version 4.3.1, with ANOVA and Duncan's Multiple Range Test (DMRT) for mean separation.

3. RESULTS AND DISCUSSION

3.1 Efficacy of different biopesticides on radish for controlling striped flea beetle after first, treatments application at Jhumka, Sunsari, 2024

The efficacy of various biopesticides was evaluated against major insect pests of radish, focusing on striped flea beetle (*Phyllotreta striolata*). The study involved three consecutive sprays at five-day intervals, with pretreatment populations recorded one day before the first treatment application. Flea beetle populations were observed before and after the first, second, and third sprays. The results revealed that the pretreatment striped flea beetle population ranged from 1–18 beetles per plant and showed no significant differences among treatments.

After the first spray, Minchu+ was the most effective, achieving a (46.8%) reduction in the flea beetle population, followed by *Verticillium lecanii* (40.31%), *Bacillus thuringiensis* (31%), and neem (22.8%) compared to the control.

Table 2. Effect of different biopesticides in controlling striped flea beetle after 1st treatment application on radish at Jhumka Sunsari,2024.

Treatments	Before application	Days of treatment application					Mean	Reduction Over Control (%)
		Day1	Day2	Day3	Day4	Day5		
T1	5.75 ^a	5.50 ^a	9.00 ^a	5.75 ^{bc}	6.25 ^{bc}	8.50 ^{bc}	6.5	31
T2	4.50 ^{ab}	4.50 ^a	5.25 ^b	4.75 ^c	5.50 ^c	5.25 ^c	5.025	46.68
T3	3.50 ^b	4.25 ^a	6.25 ^b	4.50 ^c	7.25 ^{bc}	9.75 ^b	5.625	40.31
T4	5.00 ^{ab}	5.50 ^a	6.75 ^b	8.00 ^{ab}	8.25 ^b	10.50 ^b	7.325	22.8
Control	4.75 ^{ab}	5.75 ^a	8.75 ^a	10.25 ^a	11.50 ^a	18.00 ^a	9.425	
Grand mean	4.7	4.9	7.2	6.65	7.75	10.4		
CV (%)	26.70	25.75	17.52	29.12	22.99	26.14		
LSD (0.05%)	1.93	1.94	1.94	2.98	2.74	4.19		
SEM ($\pm$)	0.63	0.63	1.11	0.96	0.89	1.36		
F		*	.	**	**	***		

Note: CV, Coefficient of variation; LSD, Least significant difference; SEM ($\pm$), Standard error of mean; F-probability; f-value, Letters "a", "b" " c" represent range of treatments according to DMRT at 0.05 level of significance; (*, **, ***) denote significance at $p=0.1$, $p=0.05$, $p=0.01$, $p=0.001$ respectively.

3.2 Efficacy of different biopesticides on radish for controlling striped flea beetle after second, treatments application on at Jhumka, Sunsari, 2024

After the second spray, Minchu+ again showed the highest effect with a (53%)

reduction over control, followed by neem (33.66%), *V. lecanii* (28.75%), and *B. thuringiensis* (26.29%).

Table 3. Effect of different biopesticides in controlling striped flea beetle after 2nd treatment application on radish at Jhumka, Sunsari, 2024

Treatments	Days of treatment application					Mean	Reduction Over Control (%)
	Day 1	Day2	Day3	Day4	Day5		
T1	11.0 ^a	8.25 ^a	7.50 ^{ab}	5.75 ^{ab}	5.00 ^c	7.5	26.29
T2	5.00 ^b	5.50 ^d	5.00 ^c	4.50 ^b	4.50 ^c	4.88	53
T3	8.25 ^{ab}	8.75 ^b	7.75 ^{ab}	6.00 ^{ab}	5.50 ^{bc}	7.25	28.75
T4	8.00 ^{ab}	6.25 ^{cd}	7.25 ^b	5.75 ^{ab}	6.500 ^b	6.75	33.66
T5	12.50 ^a	13.25 ^a	9.50 ^a	7.75 ^a	7.875 ^a	10.18	
Grand mean	8.95	8.4	7.4	5.95	5.86		
CV (%)	31.67	16.41	16.87	6.35	15.10		
LSD (0.05%)	4.36	2.35	1.92	2.41	1.37		
SEM (±)	1.42	0.69	0.62	8.78	0.44		
F-Probability	*	***	**	.	**		

Note: CV, Coefficient of variation; LSD, Least significant difference; SEM (±), Standard error of mean; F-probability; f-value, Letters "a", "b" " c" represent ranking of treatments according to DMRT at 0.05 level of significance; (*, **, ***) denote significance at p=0.1, p=0.05, p=0.01, p=0.001 respectively.

3.3 Efficacy of different biopesticides on radish for controlling striped flea beetle after third treatments application at Jhumka, Sunsari, 2024

After the third spray, the trend remained consistent: Minchu+ led with a 53% reduction, neem achieved 33.66%, *V. lecanii* 28.75%, and *B. thuringiensis* 26.29%.

These results highlight Minchu+ and neem oil as the most effective biopesticide in controlling striped flea beetle populations on radish crops. The finding was similar to the

Uma and Manjuthana (2020) who highlighted that maximum number of flea beetle is controlled by NSKE 5%(Neem Seed Kernel Extract). The group of alkaloids (tetranorterprenoids) found in neem seeds may be the cause of the lower beetle population in NSKE 5% treated plots. The terpenoids (azadirachtin) found in neem fruits are primarily responsible for the antifeedant, repulsive, and growth-modifying effects of neem on insects, as demonstrated by numerous studies.

Table 4. Effect of different biopesticides in controlling striped flea beetle after 3rd treatment application on radish at Jhumka Sunsari, 2024

Treatment	Days of treatment application					Mean	Reduction Over Control (%)
	Day 1	Day2	Day3	Day4	Day5		
T1	3.75 ^{bc}	3.75 ^b	3.75 ^b	3.5 ^b	2.75 ^b	3.2	42.86
T2	2.50 ^c	3.00 ^b	3.00 ^b	1.50 ^c	1.00 ^c	2.15	61.6
T3	3.75 ^b	3.50 ^b	3.50 ^b	2.0 ^c	2.25 ^b	3.05	45.54
T4	2.50 ^{bc}	2.75 ^b	2.50 ^b	2.25 ^c	2.0 ^b	2.4	57.15
T5	8.75 ^a	6.50 ^a	5.50 ^a	4.75 ^a	5.25 ^a	5.6	
Grand mean	4.2	3.9	3.65	2.8	2.65		
CV (%)	35.04	31	30.84	24.17	18.55		
LSD (0.05%)	2.27	1.9	1.73	1.04	0.75		
SEM (±)	0.52	0.69	0.56	0.34	0.25		
F-Probability	*	***	**	.	**		

Note: CV, Coefficient of variation; LSD, Least significant difference; SEM (±), Standard error of mean; F-probability; f-value, Letters "a", "b" "c" represent ranking of treatments according to DMRT at 0.05 level of significance; (*, **, ***) denote significance at p=0.1, p=0.05, p=0.01, p=0.001 respectively.

3.4 Quantitative characteristics like plant height, root weight and yield of radish after treatment application on radish at Jhumka, Sunsari, 2024

3.4.1 Plant height

The maximum plant height was obtained from Minchu+ (27.56cm) and neem (27.80cm) followed by *verticillium lecani* (26.25cm) and *Bt* (26.06cm). The findings were similar to Capinera, (2001), who showed that neem-treated radish plants exhibit a noticeable increase in height compared to untreated control plants.

3.4.2 Root weight

The data collected from various treatments indicated that the highest root weight was observed in the plots treated with Minchu+ (158.75gm), followed by neem oil (151.25gm), *Verticillium lecani* (142.50 gm), and *Bacillus thuringiensis* (127.50gm), compared to the

control. These findings were consistent with the work of Marrone (2019), who emphasized that neem oil enhances radish plant health, leading to improved root development and increased root weight. This can be attributed to the plant's ability to allocate more energy to root growth rather than defending against pest damage.

3.4.3 Yield

The data recorded in different treatments revealed that the maximum-weight was obtained in the plots treated with Minchu+, (39.69 ton/ha) followed by neem oil (37.81ton/ha), *Verticillium lecani* (35.63ton/ha) and *Bt* (31.88ton/ha) as compared to control. The findings were aligned with the findings of Rai (2020), in which she tested different chemical pesticides and biopesticides to control striped flea beetle in radish and among the biopesticides neem

oil gave the highest yield. The findings were like Uma and Manjuthana (2020) in which root yield was obtained highest from the Neem Seed Kernel Extract 5% which is like

our findings. The greater efficiency may be due to antifeedant and repellent properties of neem product.

Table 5. Quantitative characteristics of radish after treatment application on radish at Jhumka, Sunsari,2024

Treatment	Plant height (cm)	Root weight (gm)	Yield ton/ha
T1	26.06 ^a	127.50 ^c	31.88 ^b
T2	27.56 ^a	158.75 ^a	39.69 ^a
T3	26.25 ^a	142.50 ^{ab}	35.63 ^{ab}
T4	27.38 ^a	151.25 ^{ab}	37.81 ^{ab}
Control	25.44 ^a	122.50 ^c	30.62 ^b
mean	26.54	140.5	35.13
CV (%)	6.59	12.81	12.81
LSD (0.05%)	2.69	27.73	6.93
SEM (±)	0.87	4.49	1.12
F-Probability.	.	.	**

Note: CV, Coefficient of variation; LSD, Least significant difference; SEM (±), Standard error of mean; F-probability; f-value, Letters "a", "b" " c" represent ranking of treatments according to DMRT at 0.05 level of significance; (*, **, ***) denote significance at p=0.1, p=0.05, p=0.01, p=0.001 respectively.

4. CONCLUSIONS

The research was conducted on the eco-friendly management of striped flea beetles (*Phyllotreta striolata*) in radish using biopesticides demonstrated their potential as sustainable alternatives to chemical pesticides. Among the treatments, Minchu+(*Bacillus thuringiensis* kurstaki & *Saccharopolyspora spinosa* – 15%SC) was the most effective, resulting in the lowest flea beetle population, maximum height, the highest marketable yield, and the greatest root weight, followed by neem excel (Azadiirectin 1500ppm), Biocatch (*Verticillium lecanii*), and Eko-trump (*Bacillus thuringiensis*) as compared to untreated control plots.

Biopesticides were effective in reducing flea beetle populations significantly over the course of three consecutive sprays, at five days of interval. Although their impact was slower compared to synthetic pesticides. They

provided long-term benefits by promoting sustainability, reducing the likelihood of pest resistance, and preserving soil fertility and beneficial insects.

The findings highlight that, biopesticides can effectively manage striped flea beetles in radish crops, leading to improved productivity. This approach aligns with sustainable agricultural practices, offering an eco-friendly solution for pest management while ensuring minimal impact on human health and the environment. Further research and training for farmers on the use of biopesticides are recommended to enhance adoption and effectiveness.

This study was limited to a single location and season, which may not fully represent the variability in striped flea beetle populations or environmental conditions across different

regions. Additionally, only short-term effects of biopesticides were evaluated, without

assessing their long-term impact or residual effects on the crop and ecosystem.

REFERENCES

- Alamalakala, L., Parimi, S., Dangat, S., & Char, B. R. (2015). Non-Bt soil microbe-derived insecticidal proteins. In *Biocontrol of Lepidopteran Pests: Use of Soil Microbes and Their Metabolites* (pp. 89–121). Springer.
- Budhathoki, P., Gnawali, P., Baral, D., & Gyawali, A. (2020). Pesticidal potential of ethnobotanically important plants in Nepal: A review. *Acta Scientifica Malaysia*, 4(2), 45–50.
- Capinera, J. L. (2001). *Handbook of vegetable pests*. Academic Press.
- Chandrasekaran, M., & Thavaprakasam, S. (2017). Efficacy of neem oil as a fungicide for controlling plant diseases. *Biocontrol Science and Technology*, 27(10), 1265–1273.
- Chapagain, T. R., Piya, S., Dangal, N. K., Mandal, J. L., & Chaudhary, B. P. (2010). Comparison of commercial and local varieties of radish at different levels of manures and fertilizers. *Nepal Journal of Science and Technology*, 11, 51–56.
- Dahal, K. M., Bhattarai, D. R., Sharma, M. D., & Poudel, B. (2021). Evaluation of radish (*Raphanus sativus* L.) varieties under shade-net condition for yield and quality. *Nepalese Horticulture*, 15, 16–23.
- David, I. (2024). Analysis of physiological and biochemical parameters in the radish (*Raphanus sativus* L.) obtained in different cultivation systems.
- Edo, G. I., Ndudi, W., Makia, R. S., Jikah, A. N., Yousif, E., Gaaz, T. S., ... & Umar, H. (2024). Nutritional immunological effects and mechanisms of chemical constituents from the homology of medicine and food. *Phytochemistry Reviews*, 1–35.
- Gamba, M., Asllanaj, E., Raguindin, P. F., Glisic, M., Franco, O. H., Minder, B., ... & Muka, T. (2021). Nutritional and phytochemical characterization of radish (*Raphanus sativus*): A systematic review. *Trends in Food Science & Technology*, 113, 205–218.
- Government of Nepal, Ministry of Agriculture and Livestock Development. (n.d.). Singhadurbar, Kathmandu, Nepal.
- Grišakova, M., Metspalu, L., Jogar, K., Hiiesaar, K., Kuusik, A., & Poldma, P. (2006). Effects of biopesticide Neem EC on the large white butterfly, *Pieris brassicae* L. (Lepidoptera, Pieridae). *Agronomy Research*, 4, 181–186.
- ISAAA. Cloyd, R. A. (2008). Efficacy of Spinosad against pests of greenhouse plants. *Journal of Economic Entomology*, 101(1), 127–133.
- Isman, M. B. (2006). Neem and other botanical insecticides: Barriers to commercialization. *Phytoparasitica*, 34(1), 35–40.
- James, C. (2017). Global status of commercialized biotech/GM crops: 2017 (ISAAA Briefs No. 53).
- Jaronski, S. T. (2010). Ecological considerations for the use of *Verticillium lecanii* as a biocontrol agent. *Bio Control*, 55(2), 193–201. <https://doi.org/10.1007/s10526-009-9259-x>
- Jayathilaka, R. M. M. S., Debarawatta, R. D. N., & Jayasekara, S. J. B. A. (2016). Effect of neem extract in controlling flea beetle (*Phyllotreta cruciferae*) in radish (*Raphanus sativus*) and other major pests of horticultural crops.
- Jha, R. K. (2008). An assessment of farm-level use of biopesticides in Nepal: A case study based on IPM farmers' field schools of Bhaktapur District. In *Third Annual Meeting of Plant Protection Society of Nepal*; Kathmandu, Nepal.
- Karar, H., Hassan, Z., Ijaz, M., Khan, A. A., & Abbas, S. K. (2020). Eco-friendly management of aphids on radish seed crop (*Raphanus sativus*), saving pollinators and predators.
- Khatri, K. B., Ojha, R. B., & Pande, K. R. (n.d.). Nutrient risk management using organic manures in radish production at Rampur, Chitwan, Nepal.
- Kumar, M., Kumar, S., & Kumar, K. (2019). Role of bio-pesticide in vegetable pest management: A review. *Journal of Pharmacognosy and Phytochemistry*, 8(2), 1757–1763.

- Kumar, S., & Singh, A. (2015). Biopesticides: Present status and future prospects. *Journal of Fertilizers and Pesticides*, 6(2), 1–2.
- Mandi, R., Pramanik, A., & Baskey, S. (2016). Efficacy of eco-friendly pesticides on the management of cabbage aphid (*Myzus persicae* Sulzer) on cabbage. *The Bioscan*, 11(2), 1223–1226.
- Marrone, P. G. (2019). Pesticidal natural products—Status and future potential. *Pest Management Science*, 75(9), 2325–2340. <https://doi.org/10.1002/ps.5433>
- Mazid, S., Kalita, J. C., & Rajkhowa, R. C. (2011). A review on the use of biopesticides in insect pest management. *International Journal of Scientific Advances and Technical Research*, 1(7), 169–178.
- Megaladevi, P., & Manjunatha, M. (2019). Management of *Lipaphis erysimi* (Kalt.) Using newer insecticides and biopesticides in radish. *Innovative Farming*, 4(4), 196–200.
- Nath, G., & Singh, K. (2012). Combination of vermiwash and biopesticides against aphid (*Lipaphis erysimi*) infestation and their effect on growth and yield of mustard (*Brassica campestris*). *Dynamic Soil, Dynamic Plant*, 6(1), 96–102.
- Nepal Agricultural Research Council (NARC). (2017). *Annual report 2016/2017: Horticulture Research Division*. Lalitpur, Nepal: Nepal Agricultural Research Council.
- Noosidum, A., Mangtab, S., & Lewis, E. E. (2021). Biological control potential of entomopathogenic nematodes against the striped flea beetle, *Phyllotreta sinuata* Stephens (Coleoptera: Chrysomelidae). *Crop Protection*, 141, 105448.
- Parajuli, S., Shrestha, J., Subedi, S., & Pandey, M. (2022). Biopesticides: A sustainable approach for pest management. *SAARC Journal of Agriculture*, 20(1), 1–13.
- Poudel, K., Karki, S., Sah, M. K., & Mandal, J. L. (2018). Evaluation of radish (*Raphanus sativus* L.) Genotypes in Eastern mid-hills condition of Nepal. *World News of Natural Sciences*, 19.
- Raghavendra, K. V., Rekha, B., Ramesh, K. B., Felix, K. T., & Chander, S. (2023). Integrated pest management strategy for striped flea beetle, *Phyllotreta striolata*, infesting radish (*Raphanus sativus*). *The Indian Journal of Agricultural Sciences*, 93(12), 1308–1313.
- Rai, S. (2023). Insect pest complex of radish and eco-friendly management of major insect pests in Meghalaya (Doctoral dissertation, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Imphal).
- Ramsdale, M., et al. (2001). Control of whiteflies using *Verticillium lecanii* in greenhouse environments. *Pest Management Science*, 57(6), 531–539. <https://doi.org/10.1002/ps.266>.
- Saxena, R. C. (2003). Neem in pest management: Status and prospects. *Journal of Agricultural Research*, 41(4), 501–509.
- Sharma, S., Pathak, R., & Kandel, R. (2024). Effect of different organic manures on the growth and yield of radish (*Raphanus sativus* L.) in Parbat District. *Journal of Wastes and Biomass Management*, 6(2), 37–40.
- Shelton, A. M., Zhao, J. Z., & Roush, R. T. (2002). Economic, ecological, food safety, and social consequences of the deployment of BT transgenic plants. *Annual Review of Entomology*, 47(1), 845–881.
- Singh, S. R. (2006). Response of biofertilizers and pesticides on yield and quality of cabbage, radish, and brinjal in vegetable-based rotation system. *Applied Biological Research*, 8(1&2), 33–36.
- Singh, S. R., & Singh, A. K. (2001). Effect of organic farming technology on yield and quality of radish (*Raphanus sativus* L.) under mid-hills of Himachal Pradesh. *Agricultural Science Digest*, 21(2), 115–117.
- Thomas, S. E., et al. (2007). The mode of action of *Verticillium lecanii* on insect pests. *Pest Management Science*, 63(11), 1142–1147.
- Thuy, L. T., Young, I. S., Farooq, M., & Lee, D. J. (2020). Productivity and nutritional quality of radish under different planting geometry. *Journal of Applied Horticulture*, 22(2), 164–168.
- Uma, G. S., & Manjunatha, M. (2020). Evaluation of selected botanical insecticides against radish flea beetles (*Phyllotreta chotamica* Duv.). *Journal of Entomology and Zoology Studies*, 8(1), 1051–105.
- Vidanapathirana, N. P., Tharanga, S. J., & Siriwardana, A. J. M. C. M. (2022). Effects of cinnamon (*Cinnamomum zeylanicum*) powder extract against the pest of radish (*Raphanus raphanistrum* subsp. *sativus*).

- Voicea, I., Gageanu, I., & Fatu, V. (2021, September). Experimental research on obtaining extract with bio-insecticidal/bio-fertilizer action from *Ocimum basilicum* with application for organic agriculture. In *Engineering for Rural Development: Proceedings of the International Scientific Conference (Latvia)* (No. 20). Latvia University of Life Sciences and Technologies.
- Yousaf, M., Bashir, S., Raza, H., Shah, A. N., Iqbal, J., Arif, M., ... & Hu, C. (2021). Role of nitrogen and magnesium for growth, yield, and nutritional quality of radish. *Saudi Journal of Biological Sciences*, 28(5), 3021–3030.
- Subedi, S., Srivastava, A., Sharma, M. D., & Shah, S. C. (2018). Effect of organic and inorganic nutrient sources on growth, yield and quality of radish (*Raphanus sativus* L.) varieties in Chitwan, Nepal. *SAARC Journal of Agriculture*, 16(1), 61-69.

MONITORING OF FRUIT FLY POPULATION USING DIFFERENT LURES AND ATTRACTANTS ON CUCUMBER AT JHUMKA, SUNSARI, NEPAL

Kiran Acharya^{1*}, Jharana Shrestha¹, Madhu Kumari Ray¹, Deepu Kumar Tiwari¹ and Saraswati Shrestha²

¹ Faculty of Agriculture, Agriculture and Forestry University, Rampur, Chitwan, Nepal

² Plant Protection Laboratory, Koshi Province, Ramdhuni-5, Jhumka, Sunsari

ARTICLE INFO	ABSTRACT
Keywords: Attractants, Cucumber, Fruit fly, Lures, <i>Zeugodacus cucurbitae</i> *Correspondence: acharyakiran@gmail.com Tel: +977-9845965859	<i>Tephritid fruit flies pose a significant threat to cucumber production globally, including Nepal. The melon fruit fly (<i>Zeugodacus cucurbitae</i>) is a major pest that reduces both yield and quality. This research aimed to compare efficacy of different lures and attractants in monitoring population of fruit flies. The experiment was conducted at Ramdhuni-5, Jhumka, Sunsari from March to July 2024, using Hybrid F1 cucumber variety, 'Malini'. A Randomized Complete Block Design (RCBD) with five treatments and four replications was employed, resulting in 20 plots of (3m × 3m), with (75cm × 75cm) spacing. The treatments tested included two commercial lures (Cue-lure and methyl eugenol) and three natural attractants (Apple cider vinegar, yeast lure, and protein bait). Weekly monitoring of fruit fly population was conducted using lynfield traps made from recycled plastic bottles. Statistical analysis showed that cue-lure was most effective in attracting male fruit flies, with trap catches averaging from 79.5 flies per trap in first week to 44.75 in the fourth week. In contrast, apple cider vinegar lure was more successful in attracting females, with the highest catch recorded in the first week (13.50 flies/trap). Consequently, cue-lure treatment had the greatest impact on yield (7.43 ton/ha), enhancing cucumber productivity.</i>

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.), an important crop from the Cucurbitaceae family, is widely grown across Nepal, from the Terai plains to the high hills. It is a highly cultivated vegetable, known for its economic importance and nutritional value (Khanal et al., 2020; Pal et al., 2020). However, cucumber productivity is severely restricted by biotic factors, most notably the melon fly, *Zeugodacus (Bactrocera) cucurbitae*, which is a major economic pest in Nepal causing

yield losses from 30% to 100% through fruit drop and reduced productivity (Dhillon et al., 2005). Given the environmental and health risks of chemical pesticides, lure-based pest control offers a sustainable alternative within an Integrated Pest Management (IPM) framework. Common management methods include food-based protein baits, which attract female flies (Paneru & Giri, 2011), and pheromone-based synthetic attractants like cue-lure and methyl eugenol. Cue-lure is a powerful attractant for male *B.*

cucurbitae, while methyl eugenol targets other damaging fruit fly species like *B. dorsalis* (Manrakhan et al., 2017). This study was therefore conducted to evaluate the comparative effectiveness of different lure based treatments to enhance fruit fly monitoring and contribute to eco-friendly pest management strategies for cucumber farmers in Nepal.

2. MATERIALS AND METHODS

2.1. Research site and duration of research

The research was conducted at Ramdhuni-5, Jhumka, Sunsari, under the command of the Plant Protection Laboratory, Koshi Province.

Geographically, the research location is 26°39'48.2"N latitude and 87°11'40.3"E longitude, at an altitude of 85m (278.87 feet). The research was carried out from March 2024 to July 2024.

2.2. Treatment details

This experiment evaluated five distinct treatments (T1-T5) to test the effectiveness of different fruit fly attractants, with the specific compositions detailed in Table 1. Malathion was incorporated into most formulations to act as a killing agent for the trapped flies. Specifically, the treatments were prepared as follows:

Table 1. Different Treatments, Composition, and their Symbols

SN	Treatments Name	Symbol	Treatment Compositions
1	Methyl eugenol lure	T1	Methyl eugenol-2ml, Malathion-1ml
2	Cue lure	T2	Cue lure-2ml, Malathion-1ml
3	Apple cider vinegar lure	T3	Apple cider vinegar with mother-9ml, Malathion-1ml
4	Yeast lure	T4	Baker’s yeast-1gm, Sugar-4gm, Water-45ml, Malathion - 5ml
5	Protein bait	T5	Protein hydrolysate-5ml

2.3. Research design and field layout

The experiment was conducted using a Randomized Complete Block Design (RCBD) with five treatments and four replications. The experimental site covered a total area of 891 m². It was divided into 20 plots, each measuring 3 m × 3 m. Within each plot, cucumber seedlings (variety Malini F1) were planted at a spacing of (0.75 m × 0.75 m), accommodating 16 plants per plot for a total of 320 plants across the experiment. Following an initial three-week period of plant growth, baited traps were established in the field. A total of 20 traps were installed, with one trap placed at the center of each of the 20 plots at a height of 1.5 m.

2.4. Experimental procedure

The experiment utilized prototype Lynfield traps, as illustrated in Figure 1. These traps were crafted from repurposed plastic

drinking water bottles, each modified with 6-8mm entry holes to allow flies to enter. A cotton wick soaked in the bait solution was suspended inside each trap. The traps were hung using GI wires at an effective height of approximately 1.5 meters from the ground. This placement, corresponding to the main fruiting height of the Malini F1 Hybrid cucumber plants, was chosen to maximize trap effectiveness. The five treatments, which included two commercial lures (Cue lure and methyl eugenol) and three formulated baits, were prepared with Malathion as a knockdown agent. The application process involved soaking the cotton wicks in their respective bait solutions for 24 hours before installation. To assess efficacy, trapped flies were collected and counted every three days. To ensure the treatments remained potent, the baits were replaced every 15 days interval throughout the study.

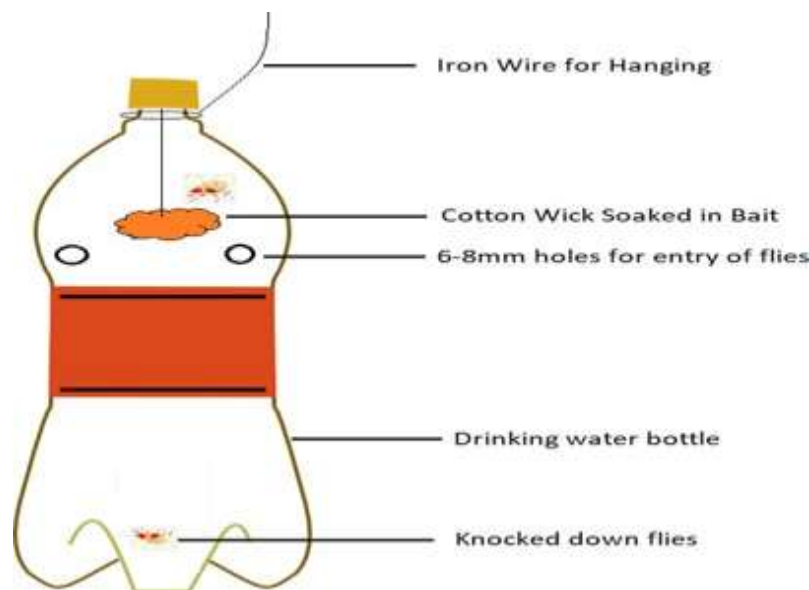


Figure 1. A Lynfield trap model crafted from repurposed plastic bottles, featuring a cotton wick soaked in lure (Gupta & Regmi, 2022).

2.5. Data collection

Data collection was divided into pre-treatment and post-treatment phases.

Pre-treatment Data: For three weeks prior to installing the traps, baseline agronomical data were collected weekly. This included measurements of plant height, leaf count, and flower numbers.

Post-treatment Data: After the installation of traps, data were collected for a period of four consecutive weeks. The primary observation was the number of fruit flies captured in each trap, which was recorded every three days to evaluate the efficacy of the different baits. To ensure consistent performance, the baits in

the traps were replaced every 15 days interval throughout the study.

2.6. Statistical analysis

The recorded data were systematically arranged and tabulated in MS Excel (version 2411). Data processing and analysis were conducted using R-Studio 4.3.1 with the Agricolae 1.3-6 package for ANOVA. Duncan's Multiple Range Test (DMRT) was applied for mean separation to assess treatments effect. ANOVA was performed to determine treatment significance using the model: Degrees of freedom (t-1) (r-1) and a 5% significance level. Treatments were further compared using Least Significant Difference (LSD) at a 95% confidence level.

3. RESULTS AND DISCUSSIONS

3.1. Number of female flowers per plant

At 37 days, female flower counts per plant (1.25–1.5) show no significant differences, but by 44 days, notable variations emerge (F-probability: ***), with apple cider vinegar (2.5 flowers) and yeast lure (2.25 flowers) performing best. DMRT at 5% groups treatments into distinct categories ("a" and

"b"), with LSD values of 0.70 (37 days) and 0.66 (44 days). The high CV (33.81%) at 37 days drops to 20.89% at 44 days, indicating improved consistency. The grand mean increases from 1.35 to 2.05, demonstrating enhanced flower production over time.

Table 2. Number of female flowers per plant influenced by lures and attractants at Jhumka, Sunsari, 2024

Treatments	No. of female flower per plant at 37 days	No. of female flower per plant at 44 days
Methyl eugenol lure	1.5	2 ^{ab}
Cue lure	1.25	1.5 ^b
Apple cider vinegar lure	1.25	2.5 ^a
Yeast lure	1.5	2.25 ^a
Protein bait	1.25	2 ^{ab}
LSD (0.05)	0.70	0.66
SEm (±)	0.10	0.10
F-probability	ns	***
CV, %	33.81	20.89
Grand Mean	1.35	2.05

Note: CV, Coefficient of variation; LSD, least significant difference; SEm (±), Standard error of mean; F-probability; f-value, not significant result; ns, Letters "a", "b" represent the ranking of treatments according to DMRT at 0.05 level of significance; (***) denote significance at p=0.05, p=0.001 respectively.

As shown in table 2, female flower production varied significantly across treatments, with apple cider vinegar and yeast lure treatments showing the highest counts, especially at 44 days. These treatments likely enhanced female flower production by reducing pest pressure, improving pollination opportunities, and maintaining hormonal balance. By attracting female fruit flies, they mitigated pest damage, allowing cucumber plants to allocate more resources to reproductive growth (Ahmad et al., 2023).

3.2. Mean yield of cucumber (ton/ha)

The lure treatments significantly influenced cucumber yield, with cue lure producing the highest yield (7.43 ton/ha), followed by methyl eugenol lure and protein bait (6.30–5.61 ton/ha). This variation is likely due to differences in female flower production, which affects fruiting. The coefficient of variation (3.98%) indicates low variability. Treatments with the same letter are not significantly different at the 0.05 level (Table 3). The statistically significant results suggest that effective lures, especially Cue lure,

enhance yield by improving pollination efficiency and reducing pest damage. These findings align with Vargas et al. (2015),

highlighting the role of efficient pest management in boosting crop productivity.

Table 3. Mean yield (ton/ha) of cucumber influenced by lures and attractants at Jhumka, Sunsari 2024

Treatments	Mean yield (ton/ha)
Cue lure	7.43 ^a
Methyl eugenol lure	6.30 ^b
Apple cider vinegar lure	5.41 ^c
Yeast lure	5.34 ^c
Protein bait	5.61 ^c
LSD (0.05)	0.37
SEm (±)	0.05
F-probability	***
CV, %	3.98
Grand Mean	6.01

Note: CV, Coefficient of variation; LSD, least significant difference; SEm (±), Standard error of mean; F-probability; f-value, Letters "a", "b", "c" represents the ranking of treatments according to DMRT at 0.05 level of significance; (*, ***) denote significance at p=0.05, p=0.001 respectively.

3.3. Number of male fruit flies at different observations

Table 4 indicates that Cue lure was the most effective in attracting male fruit flies, with the highest captures in NOM1 (79.5 flies) followed by a decline to NOM4 (44.75 flies). It consistently ranked "a" outperforming

other lures. Similarly, protein bait was entirely ineffective (0 flies) and ranked "e" in every observation, indicating it is not a suitable attractant for male fruit flies. The differences between the treatments were statistically significant, as indicated by the LSD values at the 0.05 level.

Table 4. Male fruit fly monitoring using different lures and attractants on cucumber at Jhumka, Sunsari,2024

Treatments	Number of male fruit fly of Observation 1 (NOM1)	Number of male fruit fly of Observation 2 (NOM2)	Number of male fruit fly of Observation 3 (NOM3)	Number of male fruit fly of Observation 4 (NOM4)
Methyl eugenol lure	71.50 ^b	64.75 ^b	54.50 ^b	36.00 ^b
Cue lure	79.50 ^a	77.00 ^a	64.00 ^a	44.75 ^a
Apple cider vinegar lure	24.50 ^c	24.75 ^c	13.75 ^c	9.00 ^c
Yeast lure	5.50 ^d	15.50 ^d	9.00 ^d	6.00 ^d
Protein bait	0.00 ^e	0.00 ^e	0.00 ^e	0.00 ^e
LSD (0.05)	3.48	2.29	2.62	1.86
SEm (±)	0.50	0.33	0.09	0.06
F- test	***	***	***	***
CV (%)	5.21	4.07	6.03	3.40
Grand mean	43.35	36.4	28.25	19.15

Note: CV, Coefficient of variation; LSD, least significant difference; SEm (±), Standard error of mean; F-probability; f-value, Letters "a", "b", "c", "d", "e" represent the ranking of treatments according to DMRT at 0.05 level of significance; (***) denote significance at p=0.001 respectively.

The effectiveness of Cue lure and methyl eugenol in attracting male fruit flies is due to their ability to mimic natural pheromones and kairomones. Methyl eugenol induces a strong olfactory response, increasing trap captures, while Cue lure effectively targets male fruit fly receptors. This study's findings align with Vargas et al. (2000), confirming the superior performance of these lures in reducing male fruit fly populations and limiting reproduction.

3.4. Number of female fruit flies at different observations

As shown in table 5, methyl eugenol and cue lure were ineffective in attracting female fruit flies (0.00 catch, ranked "c"). Apple cider vinegar was the most effective, peaking at NOF1 (13.50) but declining over time, ranked "a" and "b." Yeast lure also attracted females but less than vinegar, declining from NOF1 (10.25) to NOF4 (2.00), consistently ranked "b." Protein bait was initially ineffective (0.00) but improved in later observations (NOF3: 4.25, NOF4: 10.75), ranking "c," "b," and "a." Statistical analysis confirmed significant differences between treatments at the 0.05 level.

Table 5. Female fruit fly monitoring using different lures and attractants on cucumber at Jhumka, Sunsari, 2024

Treatments	Number of female fruit fly of Observation 1 (NOF1)	Number of female fruit fly of Observation 2 (NOF2)	Number of female fruit fly of Observation 3 (NOF3)	Number of female fruit fly of Observation 4 (NOF4)
Methyl eugenol lure	0.00 ^c	0.00 ^c	0.00 ^c	0.00 ^c
Cue lure	0.00 ^c	0.00 ^c	0.00 ^c	0.00 ^c
Apple cider vinegar lure	13.50 ^a	11.50 ^a	8.25 ^a	3.00 ^b
Yeast lure	10.25 ^b	7.50 ^b	3.75 ^b	2.00 ^b
Protein bait	0.00 ^c	0.00 ^c	4.25 ^b	10.75 ^a
LSD (0.05)	1.35	1.32	0.90	1.03
SEm (±)	0.04	0.04	0.03	0.03
F- test	***	***	***	***
CV (%)	18.44	22.53	18.00	21.30
Grand mean	4.75	3.8	3.25	3.15

Note: CV, Coefficient of variation; LSD, least significant difference; SEm (±), Standard error of mean; F-probability; f-value, Letters "a", "b", "c" represent the ranking of treatments according to DMRT at 0.05 level of significance; (***)denote significance at p=0.001 respectively.

Fermentation-based lures like apple cider vinegar and yeast attract female fruit flies by emitting volatiles that mimic rotting fruits and nutrient-rich substrates. Apple cider vinegar releases acetic acid, while yeast lures emit ethanol and CO₂, exploiting gravid females' foraging behavior for oviposition

and energy Studies by Landolt et al. (2014) and Jang et al. (2017) confirm the effectiveness of these lures in targeting gravid females, making them valuable tools in integrated pest management for reducing fruit fly populations.

3.5. Total number of fruit flies at different observations

Table 6 shows that methyl eugenol lure consistently attracted high number of fruit flies across four trials, with the highest capture in TN1 (71.50) and a gradual decline to TN4 (36.00). While, protein

bait was the least effective, capturing no flies in TN1 and TN2, and only a few in later trials (4.25 and 10.75), indicating its unsuitability for fruit fly management.

Table 6. Total number of fruit flies monitored using different lures and attractants on cucumber at Jhumka, Sunsari, 2024

Treatments	Number of adult fruit flies of Observation 1 (TN1)	Number of adult fruit flies of Observation 2 (TN2)	Number of adult fruit flies of Observation 3 (TN3)	Number of adult fruit flies of Observation 4 (TN4)
Methyl eugenol lure	71.50 ^b	64.75 ^b	54.50 ^b	36.00 ^b
Cue lure	93.75 ^a	77.00 ^a	64.00 ^a	44.75 ^a
Apple cider vinegar lure	44.25 ^c	36.25 ^c	22.00 ^c	12.00 ^c
Yeast lure	31.00 ^d	23.00 ^d	12.75 ^d	8.00 ^d
Protein bait	0.00 ^e	0.00 ^e	4.25 ^e	10.75 ^c
LSD (0.05)	3.61	3.27	2.68	1.80
SEm (±)	0.12	0.11	0.09	0.06
F- test	***	***	***	***
CV (%)	4.90	5.28	5.53	5.25
Grand mean	48.1	40.2	31.5	22.3

Note: CV, Coefficient of variation; LSD, least significant difference; SEm (±), Standard error of mean; F-probability, f-value; Letters "a", "b", "c" "d", "e" represent the ranking of treatments according to Duncan's Multiple Range Test (DMRT) at 0.05 level of significance; (***) denote significance at p=0.05, p=0.01, p=0.001 respectively.

The higher effectiveness of traps baited with cue lure and methyl eugenol is due to their chemical and physiological interactions with fruit flies. Methyl eugenol acts as a kairomone, a volatile plant chemical detected by the flies' olfactory receptors. It stimulates both olfactory and feeding responses, attracting fruit flies from considerable distances (Srinivasan et al., 2013).

3.6. Comparison of commercial lures and natural attractants

The study found that cue lure and methyl eugenol were highly effective in controlling male fruit flies, while apple cider vinegar and yeast lure were better at attracting females. This highlights a trade-off between the cost-

effectiveness of natural attractants and the superior efficacy of commercial lures, suggesting an integrated pest management approach. The findings align with previous research by Manrakhan et al. (2017), Gupta & Regmi (2022), and Bade et al. (2022), all of whom confirmed the effectiveness of cue lure and methyl eugenol in targeting male fruit flies. Similarly, studies by Hardy & Jessup (2012) and Bharathi et al. (2004) support the effectiveness of natural baits in attracting females. The study also demonstrated a strong correlation between effective fruit fly control and higher cucumber yield, with Cue lure yielding the highest production (7.43 tons/ha), reinforcing Dhillon et al. (2005)'s findings on pest management and crop productivity.

4. CONCLUSION

The findings showed that two commercial lures (Cue lure and methyl eugenol lure) were highly effective in trapping adult male fruit flies, particularly in the early observation periods. Cue lure consistently performed the best, trapping the highest number of fruit flies across all observation periods. Conversely, natural attractants (Apple cider vinegar and yeast lure) were more effective in trapping female fruit flies but less efficient overall compared to the male-targeting lures. This study revealed that the efficacy of lures decreased over time, suggesting the need for

periodic replacement to maintain trapping efficiency. Protein bait showed very low effectiveness, suggesting that it may not be a viable solution for cucumber fruit fly monitoring in this context. In terms of yield impact, the cue lure was associated with the highest yield (7.43 ton/ha), indicating a strong correlation between effective fruit fly management and crop productivity. In contrast, less effective lures like apple cider vinegar and yeast lure resulted in lower yield (around 5.34 - 5.61 ton/ha).

REFERENCES

- Ahmad, S., Jaworski, C. C., Ullah, F., Jamil, M., Badshah, H., Ullah, F., & Luo, Y. (2023). Efficacy of lure mixtures in baited traps to attract different fruit fly species in guava and vegetable fields. *Frontiers in Insect Science*, 2, 984348. DOI: <https://doi.org/10.3389/finsc.2022.984348>.
- Bade, A. S., Kulkarni, S. R., & Wani, V. S. (2022). Evaluation of protein food baits against *Bactrocera cucurbitae* (Coquillett) infesting cucumber.
- Bharathi, T. E., Sathiyandam, V. K., & David, P. M. M. (2004). Attractiveness of some food baits to the melon fruit fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae). *International Journal of Tropical Insect Science*, 24(2), 125-134.
- Dhillon, M. K., Singh, R., Naresh, J. S., & Sharma, H. C. (2005). The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *Journal of Insect Science*, 5(1), 40. DOI: <https://doi.org/10.1093/jis/5.1.40>.
- Gupta, A., & Regmi, R. (2022). Efficacy of different homemade and commercial baits in monitoring of fruit flies at Maranthana, Pyuthan, Nepal. *Malaysian Journal of Sustainable Agriculture*, 6(2), 101-109.
- Hardy, S., & Jessup, A. (2012). Managing Queensland fruit fly in citrus. Department of Primary Industries, NSW Government, 1-4.
- Jang, E. B., & Light, D. M. (2017). Attraction of female fruit flies to yeast-based lures in field trails in Hawaii. *Environmental Entomology*, 35(3), 987-994.
- Khanal, S., Shrestha, J., & Lamichhane, J. (2020). Economics of production and marketing of cucumber in Nawalpur district of Nepal. *Azarian Journal of Agriculture*, 7(3), 93-101.
- Landolt, P. J., Adams, T., & Rogg, H. (2014). Trapping spotted wing drosophila, *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), with combinations of vinegar and wine, and their effects on attraction of non-target flies. *Journal of Applied Entomology*, 138(9), 700-705.
- Landolt, P. J., Adams, T., & Zack, R. S. (2014). Trapping fruit flies (Diptera: Tephritidae) with combinations of floral lure, synthetic food-odor chemicals, and ammonium acetate. *Journal of Economic Entomology*, 107(2), 699-705.
- Manrakhan, A., Venter, J. H., Hattingh, V., & Weldon, C. W. (2017). Managing fruit flies (Diptera: Tephritidae) in South African commercial export fruit crops. *African Entomology*, 25(2), 499-509.
- Ministry of Agriculture and Livestock Development (MOALD). (2020). Agriculture Statistics. https://www.moald.gov.np/publication/Agriculture_Statistics
- Pal, A., Adhikary, R., Shankar, T., Sahu, A. K., & Maitra, S. (2020). Cultivation of cucumber in greenhouse. In *Protected Cultivation and Smart Agriculture*. New Delhi Publishers. New Delhi: 2020, (pp. 139-145). DOI: 10.30954/NDP-PCSA.2020.14.
- Paneru, R. B., & Giri, Y. P. (2011). Management of economically important agricultural and household pests of Nepal. Entomology Division, Nepal Agricultural Research Council (NARC).
- Srinivasan, R., et al. (2013). Behavioral response of fruit flies to methyl eugenol and its application in integrated pest management. *Pest Management Science*, 69(2), 220-227.
- Vargas, R. I., Leblanc, L., Pinero, J. C., & Mau, R. F. (2014). Population dynamics, ecological interactions, and future directions in the integrated pest management of fruit flies in Hawaii. *Journal of Insect Science*, 14(1), 1-17.
- Vargas, R. I., Piñero, J. C., & Leblanc, L. (2015). An overview of pest species of *Bactrocera* fruit flies (Diptera: Tephritidae) and the integration of biopesticides with other biological approaches for their management with a focus on the Pacific region. *Insects*, 6(2), 297-318. DOI: <https://doi.org/10.3390/insects6020297>.
- Vargas, R. I., Stark, J. D., Kido, M. H., Ketter, H. M., & Whitehand, L. C. (2000). Methyl eugenol and cue-lure traps for suppression of male oriental fruit flies and melon flies (Diptera: Tephritidae) in Hawaii: Effects of lure mixtures and weathering. *Journal of Economic Entomology*, 93(1), 81-87. DOI: <https://doi.org/10.1603/0022-0493-93.1.81>.

EFFECT OF MULCHING MATERIALS AND VARIETIES ON GROWTH AND YIELD OF OKRA (*Abelmoschus esculentus* (L.) Moench) IN NUWAKOT, NEPAL

Aarati Rashaily ^{1*}, Tej Narayan Bhusal ², Pabitra Bhujel ³ and Amrit Adhikari ⁴

¹ Faculty of Agriculture, Agriculture and Forestry University, Nepal

² Department of Genetics and Plant Breeding, Agriculture and Forestry University, Nepal

³ Faculty of Agriculture, Agriculture and Forestry University, Nepal

⁴ Department of Horticulture, Faculty of Agriculture, Agriculture and Forestry University, Nepal

ARTICLE INFO

Keywords:

Cultivar,
mulching,
okra,
yield

* Correspondence:

rashailyaarati@gmail.com

ABSTRACT

A field experiment was conducted to determine the effect of mulching materials on yield and yield attributing parameter of two varieties of okra at Shivapuri-8, Nuwakot district from March to May, 2023. The experiment was laid out in factorial Randomized Complete Block Design (RCBD) with two factors. The factor comprised of mulching materials (a. black plastic mulch b. silver plastic mulch c. rice straw mulch and d. no mulch) and two cultivars (a. Arka Anamika and b. Venus Plus). The eight treatments were replicated thrice. Black plastic mulch significantly enhanced the emergence (9 days after sowing) while cv. Venus Plus emerged earlier (10 days after sowing). Silver plastic mulch enhanced the plant height (131.42 cm), leaf number (35.83) and canopy area (4905.62 cm²). The highest yield (18.10 Mt/ha) was obtained with silver plastic mulch while lowest yield (13.67 Mt/ha) was found in control. Among the cultivars, yield (16.21 Mt/ha) was significantly higher in cv. Venus Plus compared to cv. Arka Anamika (14.83 Mt/ha). The highest yield (19.53 Mt/ha) was obtained in the cv. Venus Plus with silver plastic mulch. The highest benefit cost ratio (B: C ratio) (2.25) was obtained from the combination of silver plastic mulch and 'Venus Plus'. The use of silver plastic mulch with cv. Venus Plus is the most cost-effective approach for maximizing profitability in okra cultivation.

1. INTROCUCTION

Okra (*Abelmoschus esculentus* L. Moench) is an annual herbaceous plant with a bisexual flower and an upright vegetable branch. It is a warm-season crop that does best in temperatures between 22°C and 35°C (Devkota et al., 2022). Okra thrives on soil that is well-drained, loamy in texture, has a high organic matter content, and has a pH between 6 and 7.5 (Salik et al., 2021). The crop's various uses for fresh leaves, buds, blooms, pods, stems, and seeds make it a versatile crop. (Gemede et al., 2015). Okra is also a rich source of numerous minerals, vitamins, and carbohydrates. It contains multiple nutrients in 100 g of fresh okra fruit,

including 2.1 g protein, 0.2 g fat, 8 g carbohydrates, 36 calories, 1.7 g fiber, 175.2 mg minerals, and 88 ml water (Shivaramgowda et al., 2016).

According to FAO, the okra production of the world increased from 1.82 million tons in 1972 to 10.8 million tons in 2021 growing at an average annual rate of 3.85%. India is the world's largest producer of okra producing 6,371,000 tons of okra in 2020-21 ("The Okra Production in the World - knoema.com,"). The okra commonly known as Lady's finger or Bhindi in Nepali language, is grown as a summer and rainy season vegetable in Nepal. It is widely cultivated in districts Jhapa, Morang, Saptari,

Dhanusha, Mohattari, Rautahat, Bara, Chitwan, and Kailali (Kattel *et al.*, 2023). In Nepal, okra is cultivated in an area of 9,397 ha with production of 112,260 Mt and productivity of 11.95 Mt/ha (MoALD, 2022/23). In Nuwakot district, okra is cultivated in 105 ha of land with production of 1,387 Mt and productivity 13.25 Mt/ha (MoALD, 2021/22).

Mulching is covering the soil's surface surrounding plants with an organic or synthetic mulch in order to promote plant development and effective crop production (Ojiako *et al.*, 2018). Natural mulches like straw, hay, and compost have been used for generations, while synthetic mulches such as polythene, paper, and aluminum have recently gained popularity for enhancing soil productivity (Kumar & Lal., 2012). Mulching helps to protect against temperature extremes, save soil moisture, minimize infiltration rate, reduce fertilizer leaching, inhibit weed growth, and eventually boost crop production (Jha *et al.*, 2018). The primary purpose of mulching is to prevent the initial stage of drying, which helps maintain the soil's ideal moisture level, lower soil temperature, and improve crop stand (Peera, *et.al.*, 2020). Some beneficial environmental impacts of mulching include regulating soil and plant root temperature, minimizing nutrient losses, reducing soil erosion and compaction, and improving the physical qualities of soil (Iqbal *et al.*, 2020).

Cultivars Parvati and Arka Anamika are open-pollinated varieties recommended for

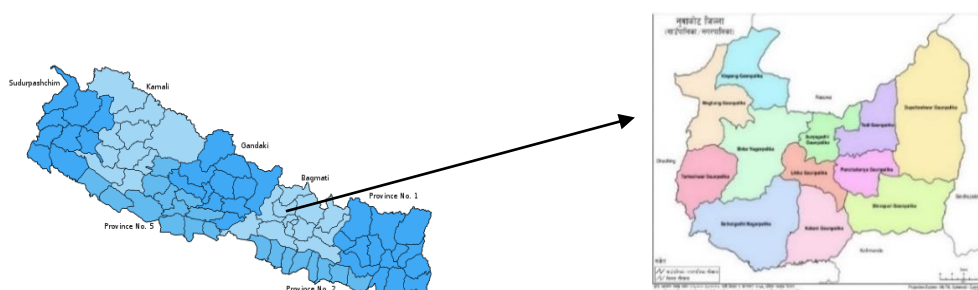
terai, mid-hills and high hills of Nepal while Jaya is the hybrid variety recommended for terai. Moreover, many Indian cultivars like Pusa Swami, Parbhani Kranti, Pusa Makhmali, Pusa A-4, Varsha Upahar, Venus Plus, Hybrid DVR-1, DVR-2, Varsha, Vijay, Adhunik and Panchali are also available in the market of Nepal.

This study aims to evaluate the impact of different mulching materials and okra cultivars on crop performance and yield in Nuwakot district. Despite increasing productivity, okra farmers face challenges such as unfavorable weather conditions, poor seed quality, and limited market availability. Given the proven benefits of mulching in other crops, this research examines its effectiveness in improving soil moisture retention, temperature regulation, and overall plant growth. By assessing the performance of two okra varieties under different mulching treatments, the study seeks to provide insights that can enhance productivity and encourage the adoption of improved cultivation practices among farmers.

2. MATERIALS AND METHODS

2.1. Experimental site

The research was conducted in Shivapuri Rural Municipality ward no. 8, Nuwakot from 12th March to the 29th May, 2023 in the field of Krishi Kunja Krishi Farm. It is situated at 27°52'21"N latitude and 85°21'57"E longitude at an altitude of 1022 masl.



Map of Nepal

Figure 1. Administrative Map of Nepal showing Nuwakot district and Map of Shivapuri Rural Municipality

2.2. Climatic condition of experimental site

Data regarding metrological parameters of experimental site viz. relative humidity (RH), precipitation, maximum and minimum temperature during the experimental period were taken from the nearest weather station.

The total rainfall of 27.72 mm was recorded during the entire period of experimentation. The highest rainfall of 6.67 mm was recorded during May. The average maximum and minimum temperature of that period was 21.38°C and 9.92°C respectively. The average relative humidity of that period was 54.93 %.

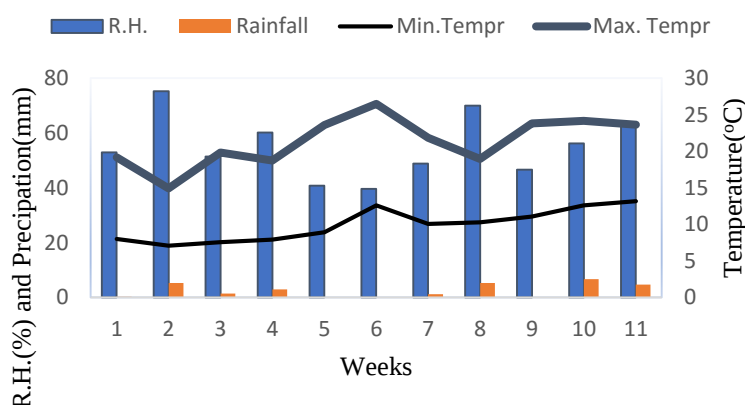


Figure 2. Climatic condition of experimental site

2.3. Planting and mulching materials

Cultivars Venus Plus and Arka Anamika were included in the experiment due to their wide usage in Nuwakot. Black plastic, silver plastic and rice straw was included in the study. The crop was sown on the 12th of March, 2023.

2.4. Design of the experiment

The four different mulching materials; black plastic, silver plastic, rice straw and without any mulch as control were tested in two different cultivars (Arka Anamika and Venus Plus). The treatments were arranged in two factorial Randomized Complete Block Design (RCBD) with three replications and eight treatments in each. Size of individual plot was 3.5 m² with total 24 plots and each plot consisted of twenty plants.

2.5. Data collection

Five sample plants excluding border rows were randomly selected from each plot to observe various growth and yield parameters.

Number of days to 100 % germination was recorded at alternate days. Plant height was taken from five sample plants from each plot as the distance from the soil surface to the top most growth point of above ground was measured and the value were averaged. Plant height (cm) were observed at 15, 30, 60 and 75 days after sowing. The number of leaves per plant was recorded by counting the leaves arising from main stem and other branches at 15, 30, 45, 60 and 75 days after sowing. The canopy of the plant was recorded at 45, 60 and 75 DAS by taking the two diagonal measurements of the canopy coverage of the plant with the help of measuring scale from the five sample plants from each plot. Number of days to flowering and fruiting were observed. The number of fruit per plant was calculated by counting all the fruits from each treatment in each harvest. The total numbers of fruits were reported and average was determined. Five matured fruits were randomly taken from five sample plants of each plot to measure fruit length. The length of the fruit was measured and the average length for each treatment

was calculated. Same fruits were used for recording the fruit diameter with the help of Vernier calipers. Average fruit diameter in cm for each treatment was determined. The weight of fruits per plant, expressed in grams, was calculated by averaging the total weight of fruits collected from five selected plants from each treatment in each harvest. Total fruit yield in Mt/ha was determined by multiplying total weight of fruits per plant by plant population in a hectare. The data was organized systematically, treatment-wise, across three replications, based on the numerous measured parameters. MS-EXCEL and R-STUDIO was used as statistical software for analysis of variance and Duncan's Multiple Range Test (DMRT) was used for mean separation. The significance differences among the means were tested using least significance difference (LSD) at 5 % level of significance (Gomez & Gomez., 1984).

3. RESULTS AND DISCUSSION

3.1. Days to germination, flowering and fruiting

The number of days to germination significantly affected by mulching materials and cultivars. Early germination was recorded on black plastic mulch (8.67 days) whereas the late germination was recorded in control (11.34 days) as shown in Table 1. Likewise, earlier germination was recorded on Venus Plus (9.50 days) compared to Arka Anamika (11.16 days). No interaction effect was observed between the mulching and cultivars of okra on number of days to germination. This finding is consistent with Ahmed et al. (2017), who observed similar effects of plastic mulching on seedling emergence due to higher soil temperatures and humidity. Mahadeen (2014) also reported faster germination under mulch conditions, attributing the acceleration to increased soil

temperature compared to control plots, which corroborates our results. Amjad *et al.* (2001) found major differences in seed germination, linking the variations to genetic factors, production methods, and storage practices. These findings align with our observations, suggesting that while mulching enhances germination, genetic differences may still play a role in the overall performance of the crops.

Similarly, data revealed that the average number of days to flowering and fruiting was 58.54 and 61.33 days respectively. Number of days to flowering and fruiting differed significantly among the different mulching materials and cultivars as depicted by Table 1. Significantly earlier flowering and fruiting i.e. at 56.83 days and 59.50 days respectively was recorded in silver plastic mulch. Late flowering and late fruiting at 59.83 and 62.66 days respectively was recorded in control which was found to be statistically similar with rice straw and black plastic mulching. Earlier flowering and fruiting was observed in cv. Venus Plus at 58 days and 60.75 days respectively. There was no combined effect of mulching and cultivars in number of days to flowering and fruiting. The accelerated early growth and flowering observed in our study align with Iqbal et al. (2020), who noted that higher soil moisture content and temperature under plastic mulch promote early plant development and flowering. Similarly, Mshelia & Muhammad (2018) reported significant variations in days to flowering and fruiting between different varieties, which may be influenced by genetic factors, environmental conditions, and the plant's ability to utilize solar radiation effectively. Dash *et al.* (2013) also observed varietal differences in flowering time, with Arka Anamika taking longer for first flowering, a pattern consistent with our results.

Table 1. Effect of mulching on number of days to germination, flowering and fruiting of two okra cultivars in Nuwakot, Nepal, 2023

Treatments	Days to germination	Days to flowering	Days to fruiting
Mulching			
Black Plastic	8.67 ^b	58.67 ^a	61.33 ^a
Silver Plastic	11.00 ^a	56.83 ^b	59.50 ^b
Rice Straw	10.34 ^a	58.83 ^a	61.83 ^a
Control	11.34 ^a	59.83 ^a	62.66 ^a
F value	4.85	7.60 ^{**}	8.11 ^{**}
SEm	0.53	0.45	0.47
LSD (0.05)	1.63 [*]	1.37	1.42
Cultivars			
Arka-Anamika	11.16	59.08	61.91
Venus Plus	9.50	58.00	60.75
F value	9.58 ^{**}	5.71 [*]	6.15 [*]
SEm	0.38	0.32	0.33
LSD (0.05)	1.15	0.97	1.00
CV	12.75	1.89	1.87
Grand Mean	10.33	58.54	61.33

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, ^{*}Significant at 5% level of significance, ^{**}Significant at 1% level of significance

3.2. Plant height

Plant height differed significantly among different mulching materials at 45, 60 and 75 days after sowing but no significant difference was observed at 15 and 30 days after sowing as shown in Table 2. The highest plant heights (20.80 cm, 53.98 cm and 131.42 cm) were recorded in silver plastic mulch at 45, 60 and 75 DAS respectively. The lowest plant heights (16.62 cm, 41.19 cm and 111.96 cm) were recorded in control at 45 DAS, 60 DAS and at 75 DAS respectively.

Plant height was significantly influenced by varieties at 60 and 75 DAS as shown in table

2. Higher plant height of 52.93 cm and 127.73 cm was recorded in cv. Venus Plus at 60 and 75 DAS respectively. There was no combined effect between the mulching and cultivars of okra on plant height. Puri *et al.* (2022) observed that silver plastic mulching significantly increased plant height compared to other mulch types. This could be due to its superior moisture retention, improved nutrient uptake, and availability, factors that likely contributed to the accelerated growth in our study as well. Our results also echo the findings of Yadav *et al.* (2023), who found that the okra cv. Anamika exhibited the smallest plant height, likely due to inherent genotypic differences.

Table 2. Effect of mulching materials on plant height of two okra cultivars in Nuwakot, Nepal, 2023

Treatments	Plant height (cm)				
	15DAS	30DAS	45DAS	60DAS	75DAS
Mulching					
Black Plastic	5.05	6.85	20.79 ^a	53.53 ^a	130.65 ^a
Silver Plastic	4.07	6.74	20.80 ^a	53.98 ^a	131.42 ^a
Rice Straw	4.57	6.24	16.70 ^b	43.83 ^b	121.73 ^a
Control	3.87	5.97	16.62 ^b	41.19 ^b	111.96 ^b
F value	2.88 ^{NS}	1.97 ^{NS}	3.97 [*]	7.10 ^{**}	8.51 ^{**}
SEm	0.31	0.29	1.19	2.47	3.12
LSD (0.05)	0.94	0.90	3.63	7.49	9.47

Cultivars					
Arka-Anamika	4.18	6.62	19.02	43.33	120.15
Venus Plus	4.60	6.27	18.43	52.93	127.73
F value	1.80 ^{NS}	1.34 ^{NS}	0.24 ^{NS}	15.09**	5.88*
SEm	0.21	0.20	0.84	1.74	2.20
LSD (0.05)	0.66	0.63	2.57	5.30	6.69
CV	17.38	11.27	15.68	12.57	6.17
Grand Mean	4.39	6.45	18.73	48.13	123.94

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, *Significant at 5% level of significance, **Significant at 1% level of significance, NS: Non-significant

3.3. Number of leaves per plant

Number of leaves per plant differed significantly among different mulching materials and cultivars at 45, 60 and 75 days after sowing but effect remains non-significant at 15 and 30 days after sowing (Table 3). The maximum number of leaves per plant was recorded in silver plastic mulching at 45 DAS (14.36), 60 DAS (25.33) and 75 DAS (35.83). The lowest number of leaves per plant was recorded in control at 45 DAS (11.93), 60DAS (20.55) and 75 DAS (28.2). Similarly, greater number of leaves per plant at 45 DAS (13.80), 60 DAS (23.19) and 75 DAS (31.52) was recorded in Venus Plus than that of Arka Anamika. No significant interaction effect was found

between the mulching and cultivars of okra on average number of leaves.

Thakur et al. (2020) supported our findings, noting that plastic mulches absorb solar radiation, raising soil temperature and promoting leaf formation. Similarly, Regmi *et al.* (2021) found that silver plastic mulch resulted in the highest number of leaves per plant, suggesting that the improved microclimatic conditions provided by mulching favored leaf production. According to Kumar Jangde *et al.* (2019) the increased rates of photosynthesis and photosynthates' supply for maximum growth and apical dominance among different cultivars are most likely the cause of the increased number of leaves.

Table 3. Effect of mulching on number of leaves of two okra cultivars in Nuwakot, Nepal, 2023

Treatments	Number of leaves per plant				
	15DAS	30DAS	45DAS	60DAS	75DAS
Mulching					
Black Plastic	3.21	4.98	12.73 ^{ab}	22.58 ^b	29.10 ^b
Silver Plastic	2.98	5.06	14.36 ^a	25.33 ^a	35.83 ^a
Rice Straw	2.81	4.91	12.23 ^b	20.71 ^b	28.91 ^b
Control	2.90	4.81	11.93 ^b	20.55 ^b	28.2 ^b
F value	1.64 ^{NS}	1.58 ^{NS}	3.78*	8.48**	15.11***
SEm	0.13	0.08	0.55	0.76	0.55
LSD (0.05)	0.40	0.25	1.69	2.31	2.78
Cultivars					
Arka-Anamika	3.09	4.87	11.83	21.40	29.50
Venus Plus	2.86	5.01	13.80	23.19	31.52
F value	2.79 ^{NS}	2.84 ^{NS}	12.43**	5.50*	4.86*
SEm	0.09	0.05	0.39	0.54	0.39
LSD (0.05)	0.28	0.63	1.19	1.63	1.96
CV	11.06	4.15	10.66	8.39	7.36
Grand Mean	2.97	4.94	12.81	22.29	30.51

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, *Significant at 5% level of significance, **Significant at 1% level of significance, ***Significant at 0.1% level of significance, NS: Non-significant

3.4. Canopy area

Canopy area differed significantly among different mulching materials at 45,60 and 75 DAS (Table 4). The maximum canopy area of 1627.18 cm², 411528 cm²and 4905.62 cm²

was recorded in silver plastic mulching at 45, 60 and 75 DAS respectively. The smallest canopy area was recorded in rice straw mulching with 905.39 cm², 2351.33 cm² and 3650.91 cm² at 45, 60 and 75 DAS which was found to be statistically at par with

control. Cultivars have no significant influence in the canopy area of Okra. Likewise, there was no combined effect between mulching materials and cultivars on canopy area of okra.

Sharma and Kumar (2015) further supported this, noting that the genetic makeup of cultivars influences their capacity for nutrient absorption and photosynthetic efficiency, factors that likely contributed to the observed

differences in growth among cultivars. Further supporting our results, Jha *et al.* (2018) found that silver plastic mulch enhanced all key growth parameters, including plant height, number of leaves, and plant canopy, which aligns with our findings. The increase in these parameters may be attributed to the optimal conditions provided by mulching.

Table 4. Effect of mulching on canopy area of two okra cultivars in Nuwakot, Nepal, 2023

Treatments	Canopy area (cm ²)		
	45 DAS	60 DAS	75 DAS
Mulching			
Black Plastic	1377.68 ^{ab}	3643.89 ^a	4371.56 ^{ab}
Silver Plastic	1627.18 ^a	4115.28 ^a	4905.62 ^a
Rice Straw	905.39 ^c	2351.33 ^b	3650.91 ^b
Control	952.70 ^{bc}	2375.93 ^b	3701.56 ^b
F value	5.67**	8.85**	4.24*
SEm	145.61	301.09	289.88
LSD (0.05)	441.68	913.28	879.27
Cultivars			
Arka-Anamika	1145.38	3121.05	4051.15
Venus Plus	1286.09	3122.17	4263.68
F value	0.93 ^{NS}	0.001 ^{NS}	0.53 ^{NS}
SEm	102.96	212.90	204.97
LSD (0.05)	312.31	645.79	621.74
CV	29.33	23.62	17.07
Grand Mean	1215.74	3121.61	4157.41

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, *Significant at 5% level of significance, **Significant at 1% level of significance, NS: Non-significant

3.5. Number of fruits per plant, fruit diameter and fruit length

Table 5 shows that the number of fruits per plant, fruit diameter and fruit length differed significantly among different mulching materials and cultivars. The maximum number of fruits (5.60), fruit diameter (2.91 cm) and fruit length (14.63 cm) were recorded in silver plastic mulching followed by black plastic mulching. The minimum number of fruits (3.46), fruit diameter (2.48 cm) and fruit length (13.06 cm) were observed in control condition. Similarly, the higher number of fruits per plant (5.00), fruit diameter (2.77 cm) and fruit length (14.31 cm) were recorded in Venus Plus as

compared to Arka Anamika. There was no significant interaction effect of mulching and cultivars in number of fruits per plant, fruit diameter and fruit length.

In terms of yield parameters, our results align with those of Mishra *et al.*, (1996), Saifullah and Rabbani (2009) who reported significant differences in okra cultivars in terms of fruit length, fruit diameter, fruit weight and the number of fruits per plant. This variation can be attributed to genetic differences, as highlighted by Mohammed & Saeid (2019), who noted improved crop yield and fruit number under mulching.

Table 5. Effect of mulching on number of fruits per plant, fruit diameter and fruit length of two okra cultivars in Nuwakot, Nepal, 2023

Treatments	Number of fruits/plant	Fruit diameter (cm)	Fruit length (cm)
Mulching			
Black Plastic	4.95 ^{ab}	2.73 ^a	14.08 ^{ab}
Silver Plastic	5.60 ^a	2.91 ^a	14.63 ^a
Rice Straw	3.70 ^b	2.50 ^b	13.73 ^{bc}
Control	3.46 ^b	2.48 ^b	13.06 ^c
F value	8.13**	7.85**	8.78**
SEm	0.35	0.073	0.22
LSD (0.05)	1.08	0.22	0.67
Cultivars			
Arka-Anamika	3.85	2.54	13.44
Venus Plus	5.00	2.77	14.31
F value	10.26**	9.90**	15.25**
SEm	0.25	0.052	0.15
LSD (0.05)	0.76	0.15	0.47
CV	19.71	6.78	3.91
Grand Mean	4.42	2.65	13.87

Mean followed by common letter(s) within columns are non-significantly different based on DMRT $P=0.05$, **Significant at 1% level of significance

3.6. Yield

Okra yield was significantly influenced by mulching materials and cultivars as depicted by Table 6. The statistical analysis confirmed significant differences among treatments with silver plastic mulch and Venus Plus showing the best yield performance. Maximum fruit yield/plant (271.5 g) was found in silver plastic mulching whereas minimum fruit yield/plant (205.0 g) was found in control condition. The fruit yield/plant was found to be higher in Venus Plus (243.25 g) compared to Arka Anamika (223.25 g). The highest yield/hectare (18.10 Mt) was found in silver plastic mulching whereas, lowest value (13.67 Mt) was observed in control condition. Higher yield/hectare was observed in cv. Venus Plus (16.21 Mt) compared to cv. Arka Anamika (14.83 Mt).

There was a significant combined effect between mulching and okra cultivars on fruit yield/plant and yield/hectare as shown in Table 7. The highest fruit yield/plant (293.00 g) and yield/hectare (19.53 Mt) were recorded in cv. Venus Plus when used silver plastic mulch. Whereas, lowest fruit yield/plant (202 g) and yield/hectare (13.46

Mt) were recorded in cv. Arka Anamika under control condition.

The effectiveness in controlling weeds, reducing soil erosion, conserving moisture, and enhancing soil organic matter likely contributed to the observed increase in yield in our study. Faisal *et al.* (2020) also reported the lowest pod yield for the okra cv.'Anamika,' which they attributed to genotypic differences and environmental suitability. This is consistent with our findings, where differences in yield were observed between cultivars, suggesting that both genetic and environmental factors play a crucial role in determining crop performance. Falusi *et al.* (2012) suggested that non-significant differences in yield may indicate that the genetic components of cultivars remain unchanged, while variations in yield parameters could be attributed to environmental factors. Our study supports this notion, as we observed significant differences in yield and other growth parameters, such as plant height and fruit production, which are likely influenced by a combination of genetic makeup and environmental conditions.

Table 6. Effect of mulching and cultivars on fruit yield per plant and yield per hectare of okra in Nuwakot, Nepal, 2023

Treatments	Fruit yield / plant(g)	Yield/hectare (Mt)
Mulching		
Black Plastic	245.0 ^b	16.33 ^b
Silver Plastic	271.5 ^a	18.10 ^a
Rice Straw	211.5 ^c	14.10 ^c
Control	205.0 ^c	13.67 ^c
F value	40.32***	40.32***
SEm	4.87	0.32
LSD (0.05)	14.77	0.98
Cultivars		
Arka-Anamika	223.25	14.83
Venus Plus	243.25	16.21
F value	16.84**	16.84**
Sem	3.44	0.22
LSD (0.05)	10.44	0.69
CV	5.11	5.11
Grand Mean	233.25	15.55

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, **Significant at 1% level of significance, ***Significant at 0.1% level of significance

Table 7. Interaction effect of mulching and cultivar on fruit yield per plant and yield per hectare of okra in Nuwakot, Nepal, 2023

Treatments	Fruit yield /plant (g)	Yield/hectare (Mt)
Mulching × Cultivars		
Black Plastic × Arka-Anamika	231 ^{cd}	15.40 ^{cd}
Black Plastic × Venus Plus	259 ^b	17.26 ^b
Silver Plastic × Arka-Anamika	250 ^{bc}	16.67 ^{bc}
Silver Plastic × Venus Plus	293 ^a	19.53 ^a
Rice Straw × Arka-Anamika	210 ^{de}	14.00 ^{de}
Rice Straw × Venus Plus	213 ^{de}	14.20 ^{de}
Control × Arka-Anamika	202 ^e	13.46 ^e
Control× Venus Plus	208 ^e	13.86 ^e
F value	3.78*	3.78*
SEm	6.88	0.45
LSD (0.05)	20.90	1.39
CV	5.11	5.11
Grand Mean	233.25	15.55

Mean followed by common letter(s) within columns are non-significantly different based on DMRT P=0.05, *Significant at 5% level of significance

3.7. Economics of okra production using different mulching materials and cultivars

The Table 8 presents the economic analysis of different mulching materials and okra cultivars based on total cost of production, gross return, gross profit and benefit-cost (B:C) ratio per hectare. Among the treatments, the combination of silver plastic mulch with cv. Venus Plus had the highest

gross return (NRs. 1759200), gross profit (NRs. 978200) and B:C ratio (2.25), making it the most profitable option. In contrast, the lowest profitability was observed in the control treatment with Arka Anamika which had the least gross return (NRs. 12,00,000), gross profit (NRs. 2,45,200), and the lowest B:C ratio (1.25). Generally, Venus Plus cv. performed better than Arka Anamika across all treatments, while silver plastic mulch resulted in the highest economic benefits.

This study suggests that using silver plastic mulch with cv. Venus Plus is the most cost-

effective approach for maximizing profitability in okra cultivation.

Table 8. Economic analysis of different treatments on okra production in Nuwakot, Nepal, 2023

Treatments	Total cost of production (NRs./ha)	Gross return (NRs./ha)	Gross Profit (NRs./ha)	B:C ratio
Mulching × Cultivars				
Black Plastic × Arka-Anamika	9,57,400	13,68,000	4,10,600	1.42
Black Plastic × Venus plus	8,81,400	15,48,000	6,66,600	1.75
Silver Plastic × Arka-Anamika	8,57,000	14,88,000	6,31,000	1.73
Silver Plastic × Venus plus	7,81,000	17,59,200	9,78,200	2.25
Rice Straw × Arka-Anamika	9,54,800	12,52,800	2,98,000	1.31
Rice Straw × Venus plus	8,78,800	12,72,000	3,93,200	1.44
Control × Arka-Anamika	9,54,800	12,00,000	2,45,200	1.25
Control× Venus plus	8,78,800	12,48,000	3,69,200	1.42
Average	8,93,000	13,92,000	4,99,000	1.57

4. CONCLUSION

The study revealed that yield and yield parameters were significantly affected by different mulching materials and cultivars of okra. Among four mulching treatments used, the growth and yield parameters were superior in silver plastic mulch as compared to other mulching materials. Cultivar Venus Plus exhibited superior performance in the majority of the growth and yield parameters in comparison to Arka Anamika. Cv. Venus

Plus produced higher yield. Silver mulching was found durable and cost-effective in Nuwakot and can be an appropriate option for enhancing the commercial production and quality yield of okra. The use of silver plastic mulch in cultivar Venus Plus could be the most profitable approach for okra production in Nuwakot district.

REFERENCES

- Ahmed, N. U., Mahmud, N. U., Hossain, A., Zaman, A. U., & Halder, S. C. (2017). Performance of mulching on the yield and quality of potato. *International Journal of Natural and Social Sciences*, 4(2), 7-13.
- Amjad, M., Sultan, M., Anjum, M. A., Ayyub, C. M., & Mushtaq, M. (2001). Comparative study on the performance of some exotic Okra cultivars. *International Journal of Agriculture & Biology*, 3(4), 423-425.
- Dash, P. K., Rabbani, M. G., & Mondal, M. F. (2013). Effect of variety and planting date on the growth and yield of okra. *International Journal of Biosciences (IJB)*, 3(9), 123-131. <https://doi.org/10.12692/ijb/3.9.123-131>
- Devkota, S., Kumar, J., Silas, V. J., Nivas, R., Khanal, P., & Dahal, M. (2022). Effect of organic sources of nutrients on growth and yield of Okra (*Abelmoschus esculentus* L. Var. Pusa Makhamali) under the agro-climatic condition of Kanpur. *The Pharma Innovation Journal*, 11(7), 1757-1760.
- Faisal, S., Muhammad Bangulzai, F., Ahmed Alizai, N., Ahmed, S., Rauf Zehri, A., Alam, S., Ghaffar, A., Shah, S., Najeebullah, Khan, Z., Pasand, S., & Sibghatullah. (2020). Evaluation of different varieties of okra (*Abelmoschus esculentus* L.) under the climatic conditions of Tandojam. *Pure and Applied Biology*, 10(3), 878-885. <https://doi.org/10.19045/bspab.2021.100090>
- Falusi, O. A., Dangana, M. C., Daudu, O. Y., & Teixeira da Silva, J. A. (2012). Studies on morphological and yield parameters of three varieties of Nigerian Okra (*Abelmoschus esculentus* [L.] Moench). *Journal of Horticulture and Forestry*, 4(7), 126-128. <https://doi.org/10.5897/JHF11.072>
- Gemed, H. F., Ratta, N., Haki, G. D., & Woldegiorgis, A. Z. (2014). Nutritional quality and health benefits of Okra (*Abelmoschus Esculentus*): A Review. *Global Journal of Medical Research: K Interdisciplinary* 14(5), 2249-4618. <https://doi.org/10.4172/2157-7110.1000458>
- Iqbal, R., Sammar Raza, M. A., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, S., Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches—a review. *Bulletin of the National Research Centre*, 44-75. <https://doi.org/10.1186/s42269-020-00290-3>
- Jha, K. R., Neupane, R. B., Khatiwada, A., Pandit, S., & Dahal, B. R. (2018). Effect of different spacing and mulching on growth and yield of Okra (*Abelmoschus esculentus* L.) in Chitwan, Nepal. *Journal of Agriculture and Natural Resources*, 1(1), 168-178.
- Kattel, D., Gajurel, K., Thapa, S., Panthi, B., Subedi, S., & Khanal, B. (2023). Investigating the effect of pinching on plant growth, yield, and quality of different varieties of okra (*Abelmoschus esculentus*, L.). *Asian Journal of Research and Review in Agriculture*, 5(1), 24-33. <https://www.jagriculture.com/index.php/AJRR/article/view/76>
- Kumar Jangde, S., Jaiswal, R. K., Jangde, S., & Kurre, D. K. (2019). Impact of different varieties/hybrids of Okra [*Abelmoschus esculentus* (L.) Moench.] on yield and growth parameters under late sown condition of Malwa region. *The Pharma Innovation Journal*, 8(3), 303-305.
- Kumar, S., & Lal, B. (2012). Effect of mulching on crop production under rainfed condition: a review. *International Journal of Research*, 8-20.
- Mahadeen, A. Y. (2014). Effect of polyethylene black plastic mulch on growth and yield of two summer vegetable crops under rain-fed conditions under semi-arid region conditions. *American Journal of Agricultural and Biological Sciences*, 9(2), 202-207. <https://doi.org/10.3844/ajabssp.2014.202.207>
- Ministry of Agriculture and Livestock Development (MoALD). (2023). Statistical information on Nepalese agriculture 2078/79 (2021/22). Singhadurbar, Kathmandu: MoALD. moald.gov.np: <https://moald.gov.np/>
- Mshelia, J. S., & Muhammad, I. S. (2018). Performance of different varieties of Okra (*Abelmoschus esculentus* (L.) Moench) grown under irrigation in Kashere, Gombe State. In *Proceedings of the 36th Annual Conference of Horticultural Society of Nigeria (Hortson)*, 48-56.
- Ojiako, F. O. (2018). Effect of varieties and mulch types on foliar insect pests of Okra [*Abelmoschus Esculentus* L. (Moench)] in a humid tropical environment. *Agrosearch*, 18 (2), 38-58.
- Parmar, H. N., Polara, N. D., & Viradiya, R. R. (2013). Effect of mulching material on growth, yield and quality of Watermelon (*Citrullus Lanatus Thunb*) Cv. Kiran. *Universal Journal of Agricultural Research*, 1(2), 30-37.
- Puri, P., Dhungana, B., Adhikari, A., Chaulagain, M., Dipiza, O., & Shrestha, B. (2022). Effect of mulching material on the vegetative growth and yield of Okra (*Abelmoschus esculentus* L. var US 7109) in Bharatpur, Chitwan. *Sustainability in Food and Agriculture (SFNA)*, 3(1), 24-27. <https://doi.org/10.26480/sfna.01.2022.24.27>
- Rao, K. V. R., Bajpai, A., Gangwar, S., Chourasia, L., & Soni, K. (2017). Effect of mulching on growth, yield and economics of Watermelon (*Citrullus lanatus Thunb*). *Environment & Ecology*, 35(3D), 2437—2441
- Regmi, N. R., Bhusal, N. N., & Neupane, N. S. (2021). Efficacy of Mulching Materials on Growth Performance and Yield Characters of Summer Squash (*Cucurbita pepo* cv Shlesha 1214) in Mahottari, Nepal. *International Journal for Research in Applied Sciences and Biotechnology*, 8(1), 57–63. <https://doi.org/10.31033/ijrasb.8.1.7>
- Saifullah, M., & Rabbani, M. G. (2009). Evaluation and characterization of Okra (*Abelmoschus esculentus* L. Moench.) genotypes. *SAARC Journal of Agriculture*, 7(1), 92-99.
- Salik, A. W., Coşkun, Z., & Amini, M. Z. (2021). Study on Okra (*Abelmoschus esculentus* L.) Response to salt stress environment under Kabul climatic conditions, Afghanistan. *Journal of Advanced Research in Natural and Applied Sciences*, 7(2), 295-303.
- Sharma, R., & Prasad, K. (2015). Genetic divergence, correlation and path coefficient analysis in Okra. *Indian Journal of Agricultural Research*, 49(1), 77-82. <https://doi.org/10.5958/0976-058X.2015.00011.6>

- Shivaramgowda, K. D., Krishnan, A., Jayaramu, Y. K., Kumar, V., Yashoda, & Koh, H. J. (2016). Genotypic variation among Okra (*Abelmoschus esculentus* (L.) Moench) germplasms in South India. *Plant Breeding and Biotechnology*, 4, 234-241.
- Thakur, S, Cahuhan, R.P., Singh, O.P. (2020). Effect of different mulching materias on growth and yield of Okra (*Abelmoschus esculentus* L.). *Journal of the Institute of Agriculture and Animal Science*, 36, 197-205.
- The Okra production in the World - knoema.com. (n.d.). Retrieved from <https://knoema.com/data/agriculture-indicators-production+Okra>
- World Okra Production by Country. (n.d.). Retrieved from Atlas Big: <https://www.atlasbig.com/en-us/countries-Okra-production>
- Yadav, S. P. S., Bhandari, S., Ghimire, N., Nepal, S., Paudel, P., Bhandari, T., Paudel, P., Shrestha, S., & Yadav, B. (2023). Varietal trials and yield components determining variation among okra varieties (*Abelmoschus esculentus* L.). *Journal of Agriculture and Applied Biology*, 4(1), 28–38. <https://doi.org/10.11594/jaab.04.01.04>

DIETARY INTAKE AND NUTRIENT ADEQUACY AMONG VEGETARIANS AND NON-VEGETARIANS

Rubina Karki^{1, 2*} and Prateek Joshi³

¹ CAFODAT COLLEGE, Kumaripati, Nepal

² Andhra University, Visakhapatnam, India

³ Ministry of Agriculture and Livestock Development, Kathmandu, Nepal

ARTICLE INFO

Keywords:

Vegetarianism,
nutrient adequacy,
KAP,
protein intake,
iron deficiency,
calcium intake,
dietary behavior

*Correspondence:
rubukarki4@gmail.com
Tel: +9779841899303

ABSTRACT

Vegetarianism has gained considerable prominence due to its health, ethical, and environmental benefits. In this paper, the adequacy of the diet of vegetarians and differences and similarities between vegetarians and non-vegetarians in terms of nutrient intake were examined. A cross-sectional study of 104 vegetarians and 82 non-vegetarians from online forums and vegetarian organizations was conducted. Data collection encompassed standard dietary questionnaires of intake, anthropometric measurements, and nutrient content using 24-hour dietary recall and food frequency questionnaires. Both vegetarian and non-vegetarian participants showed comparable Body Mass Index (BMI) distributions in which most participants had a normal BMI. Vegetarian men had more elevated Waist-to-Hip Ratios (WHR) compared to their non-vegetarian counterparts. Nutrient analysis revealed that while vegetarians had much higher intakes of calcium and folate, they were also more likely to be deficient in vitamin B12 and iron. None of the dietary group met the Recommended Dietary Allowance (RDA) for energy and a number of micronutrients, including iron and vitamin B12, though vegetarians were slightly more compliant with recommendations for folate and calcium. Correlation studies showed positive correlation between fat intake and BMI, while vegetable and protein intake per kilogram body weight showed negative correlation with BMI. There was no significant difference in the total protein intake among vegetarians and non-vegetarians even when there were differences in the patterns of nutrient intake. The findings show the necessity of meticulous diet planning to satisfy the nutritional needs, particularly among individuals on plant-based diets. This study affirms the existence of some health advantages of vegetarian diets but also that such diets are susceptible to some nutrient deficiencies, and therefore, balanced meal planning and adequate supplementation must be maintained. Future studies should investigate long-term health implications of vegetarianism and appropriate steps to improve nutritional adequacy of vegetable-based diets.

1. INTRODUCTION

The dietary habit of vegetarianism has attracted a lot of interest lately because of its possible health advantages, moral implications, and environmental sustainability. Different diets are included in vegetarianism, which is categorized according on how restricted they are. Although

cutting out meat from one's diet is the common definition of vegetarianism, the term can also refer to other less stringent eating habits. These include, for instance, pescatarians, who abstain from all meat save fish and shellfish, flexitarians, who sometimes or even weekly

consume meat, and ovolactovegetarians, who abstain from all meat but eat dairy and eggs. strict vegetarianism excludes any animal-based foods. A more comprehensive definition of veganism includes adhering to a strict vegetarian diet and avoiding other commercial goods like apparel and cosmetics that are derived from animal exploitation or animal products (Clarys P., 2014) (D.E. & São Paulo, 2015). A rigorous vegetarian diet is often called a vegan diet for didactic reasons. Vegetarian diets have gained recognition in the context of global health for their ability to lower the risk of chronic conditions including heart disease, hypertension, type 2 diabetes, and several malignancies (Dinu M, 2017) (Orlich MJ, 2013). A vegetarian diet can offer a sufficient amount of nutrients (Craig WJ, 2009). Certain elements, such as fiber, magnesium, and potassium, are emphasized by Bedford and Barr as being where a vegetarian diet either fulfills or surpasses the level of nutritional demands (Bedford J, 2005). According to a different study, eating a vegetarian diet is a superior way to meet and maintain your nutritional demands than eating an omnivore one (Shickle D, 1989). People who wish to eat vegetarianism do so because they want to be healthy and because they are more likely to care about the environment and animal welfare (Leite AC, 2019).

Concerns about religion, the idea of vegetarianism, ecofeminism, and weight control are other reasons to choose a vegetarian diet (A, 2009). Furthermore, a lower body mass index (BMI) and a lower risk of obesity are frequently linked to vegetarian diets (Sabaté J, 2010). Numerous of these factors might combine or change over time to provide a stronger or distinct incentive to adopt a vegetarian diet. For any reason, it's critical to remember that maintaining a healthy vegetarian diet requires careful planning and food balance. The production of meat uses a lot of resources

and results in considerable emissions of greenhouse gases and environmental damage, being a vegetarian is in line with ethical concerns about sustainability and animal welfare (Loughnan S, 2014)

Vegetarians' understanding of nutrition has not been extensively studied. There is a chance that vegetarians know more about nutrition than non-vegetarians since the vegetarian diet often consists of a pattern of more diversified, nutrient-dense consumption. Healthy living habits are followed by more vegetarians than by non-vegetarians. The concept's most recurring conclusion was that smokers were less common among vegetarians than among non-vegetarians. There was a difference in the proportion of smokers who identified as vegetarians and nonvegetarians; the vegetarians were identified as having a lower percentage (Skevington, Lotfy, & O'Connell, 2004). Additionally, vegetarians routinely consume less calories and have a lower Body Mass Index (BMI) (Parker & Vadiveloo, 2019). This gives rise to the misconception that vegetarians prioritize eating a nutritious diet above all other healthy lifestyle choices. Despite the paucity of research on the nutrition knowledge of vegetarians, several papers have examined the eating habits of those who have made the decision to adopt a vegetarian lifestyle. The study's most notable finding was that vegetarians consume less calories overall, which lowers their rates of overweight and obesity and raises their BMI within an acceptable range. This runs counter to research showing that the majority of non-vegetarians consume more caloric, protein, total fat, and saturated fat in addition to having a wider range of BMIs (Academy of Nutrition and Dietetics, 2016).

Vegetarians were more likely to consume larger amounts of fruits and vegetables, according to one of the most prevalent tendencies discovered. Vegetarians eat less meat and dairy and more vegetables, legumes, and nuts in their place.

Even though vegetarianism is becoming more and more popular, thorough study is still needed to examine all facets of vegetarian diets, including knowledge, attitudes, and behaviors among those who follow this dietary pattern. It is essential to comprehend the reasons for, difficulties with, and myths associated with vegetarianism in order to encourage a diverse range of foods, guarantee adequate nutritional intake, and assist people in embracing and sticking to a plant-based diet.

A vegetarian diet has been linked to several health advantages, such as a lower risk of type 2 diabetes, obesity, cardiovascular disease, and several types of cancer (Dinu, 2017). Furthermore, plant-based diets often have a lower carbon footprint and need less natural resources than omnivore diets, which has led to the increased awareness of vegetarianism's favorable environmental effects (Sabaté, 2014). There is a great deal of variety in people's understanding, attitudes, and actions regarding vegetarian diets, even if vegetarianism may have certain advantages. Vegetarian diet adoption and adherence can be influenced by a number of factors, including cultural background, socioeconomic situation, education level, and access to nutrient-dense foods (Lea, 2003). Furthermore, one of the most often mentioned obstacles to becoming a vegetarian is worry about not getting enough nutrients, namely in the areas of protein, iron, calcium, vitamin B12, and omega-3 fatty acids (Craig, 2009).

This research seeks to examine the nutritious adequacy of a vegetarian's diet as well as the knowledge, attitudes, and behaviors of those who adhere to this diet. This research aims to give insights into the variables that promote and

hinder vegetarianism by looking at factors that affect dietary choices, cultural views, socioeconomic issues, and access to nutrition education as well as compare the nutrient intakes with the non-vegetarian counterparts.

2. MATERIALS AND METHODS

2.1 Research Design:

A Cross-sectional study design with random sampling at a single point in time was conducted. We selected 104 vegetarian and 82 non-vegetarian participants via online platforms, vegetarian communities, and social media. The participants who were vegetarians over 18 years old, following a vegetarian diet for at least one year were included in the vegetarian group whereas participants above 18 years of age following a non-vegetarian diet were included in the non-vegetarian group. A structured questionnaire was used to assess the dietary intake. Pretesting was carried out to ensure clarity and reliability.

2.2 Nutritional Status Assessment:

Nutritional status of the participants was assessed through BMI and Waist-to-Hip Ratio. Body Mass Index (BMI) was calculated using the formula: Weight (kg) divided by Height (m²). The measurement was taken using calibrated equipment according to WHO classification.

Based on BMI values nutritional status was classified as:-

BMI(kg/ m ²)	Classification
<18.5	Underweight
18.5-24.9	Normal
25-29.9	Overweight
>30	Obese

(The Waist-to-Hip Ratio (WHR) was measured using a flexible, non-stretchable tape. A normal WHR was taken as ≤0.85 for women and ≤0.90 for men).

2.3 Nutrient Analysis

Dietary intake was assessed using food frequency questionnaires and 24-hour dietary recalls. Portion sizes were estimated using standardized household measurements. To calculate the nutrient value of the recorded foods, NIN Food Composition Table was used. To estimate the nutrient adequacy, the dietary intake was compared to that of RDA (ICMR).



Figure 1. Household Measurements

2.4 Data Analysis

Quantitative analysis was carried out using descriptive statistics, correlation analysis, and inferential tests (t-test, ANOVA).

3. RESULTS AND DISCUSSION

3.1 Socio-demographic characteristics

	Vegetarians		Non vegetarians	
	Count	%	Count	%
Gender				
Male	20	3%	21	26%
Female	84	81%	61	74%
Occupation				
Private employee	25	24%	18	22%
Government employee	3	3%	2	2%
Self employed	3	3%	1	1%
Home maker	10	10%	4	5%
Student	2	30%	46	56%
Assistant Professor/Professor	2	2%	0	0%
Research Scholar	2	2%	1	1%
Teacher	1	1%	3	4%

Others	15	15%	7	9%
Education Level				
High School	2	2%	1	1%
Under graduate	29	28%	18	22%
Post Graduate	68	65%	62	76%
Prefer not to say	5	5%	1	1%
Type of Family				
Nuclear	84	81%	68	83%
Joint	20	19%	16	17%

Most vegetarians and non-vegetarians were females, postgraduates, and belonged to nuclear families. Students formed the largest occupational group, especially among non-vegetarians. A higher percentage of vegetarians were female and postgraduates compared to non-vegetarians.

3.2 Nutritional status of vegetarians and non-vegetarians

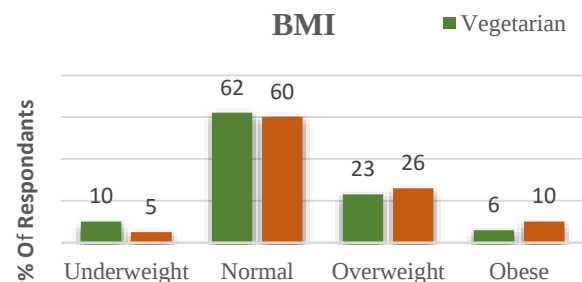


Figure 2. Nutritional Status of the respondents

The BMI group indicates that 62% of the vegetarians and 60% of the non-vegetarians fall into the category of normal weight (BMI: 18.5–24.9). This means that the majority of both groups possess a healthy weight, in accordance with studies which indicate that well-planned vegetarian diets can promote a normal BMI (Melina et al., 2016). Vegetarians did have a slightly higher percentage who were underweight (10%) compared to non-vegetarians (5%). This may be accounted for by decreased total protein and calorie intake in some

vegetarians, with the importance of maintaining adequate energy provision (Craig & Mangels, 2009).

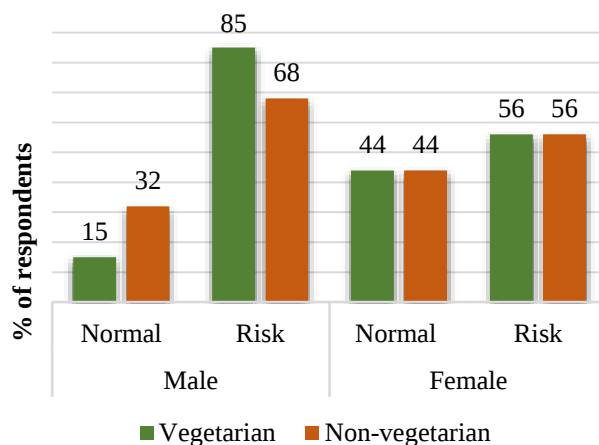


Figure 3. Waist to hip ratio of male and female respondents

The WHR data indicate high gender differences. In men, vegetarians only had 15% with normal WHR, whereas 32% of the non-vegetarians had normal WHR, indicating a higher percentage of vegetarians at risk (85%) compared to the non-vegetarians (68%). This indicates that dietary habits alone may not regulate fat distribution, and activity levels and lifestyle also play their part. Strikingly, in females, WHR distribution was identical for the two groups (44% normal and 56% at risk), indicating that diet did not play any specific part in determining WHR in female participants. Despite previous studies showing that plant-based diets decrease central adiposity (Dhanwal, 2015), our findings indicate that vegetarians do not necessarily have a lower WHR, warranting further investigation.

3.3 Nutrient intake and evaluation of nutrient adequacy

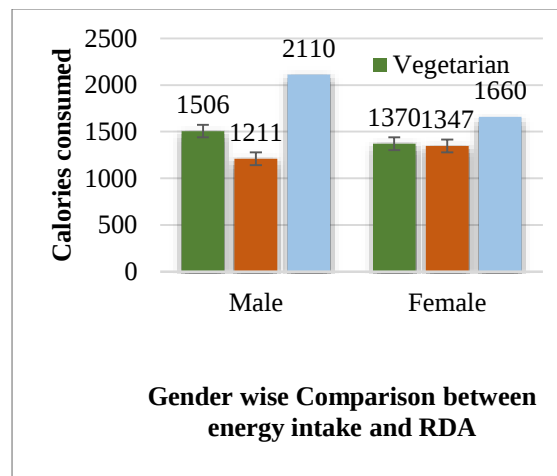


Figure 4. Energy Intake of male and female respondents

None of the groups attained the RDA for energy. Vegetarian men consumed considerably more energy than non-vegetarian men, but among female participants, the difference was not significant. This suggests that vegetarian men may have better dietary planning to compensate for potential energy shortfall, yet overall energy deficiency is still prevalent in all groups.

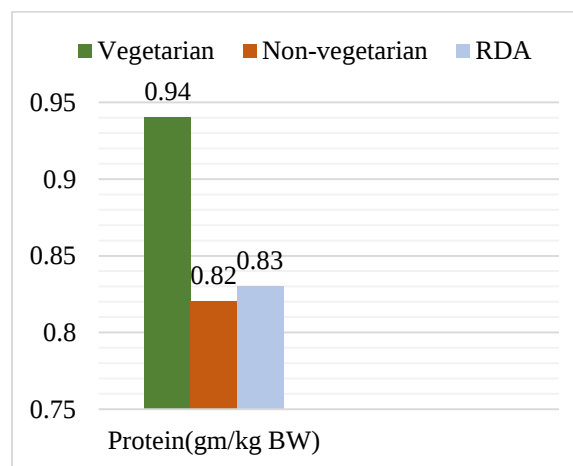


Figure 5. Protein intake of the respondents

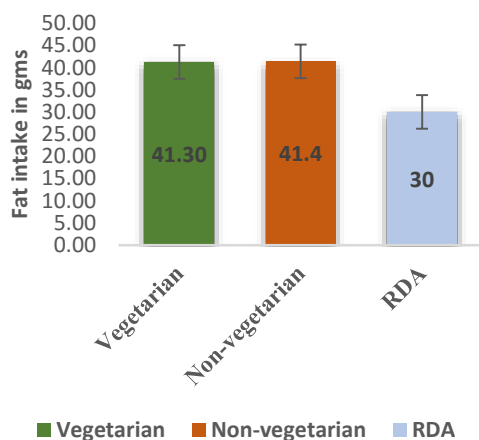


Figure 6. Fat intake of the respondents

Protein consumption was not appreciably different in vegetarians (0.85 g/kg BW) and non-vegetarians (0.82 g/kg BW, $p = 0.64$), which demonstrates that a vegetarian diet can be well-planned to ensure protein adequacy. This agrees with earlier research demonstrating that vegetarians who have a varied intake of protein sources like legumes and dairy foods are able to achieve their protein requirements (Melina et al., 2016). However, BMI was weakly and negatively correlated with protein intake (-0.48), which suggests that greater protein intake may be linked with better weight management.

Fat intake was similar between groups (41.3 g for vegetarians and 41.4 g for non-vegetarians), both of which exceeded the RDA (30 g). Excessive intake of fat regardless of diet has long-term health implications.

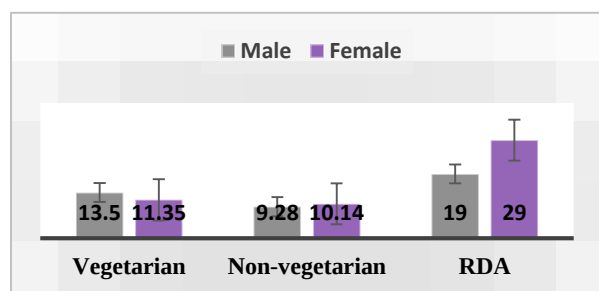


Figure 7. Iron intake of respondents

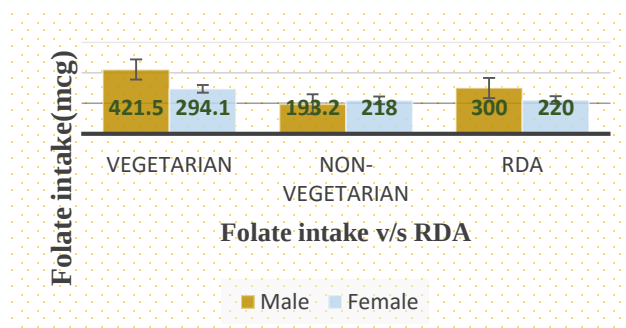


Figure 8. Folate intake of the respondents

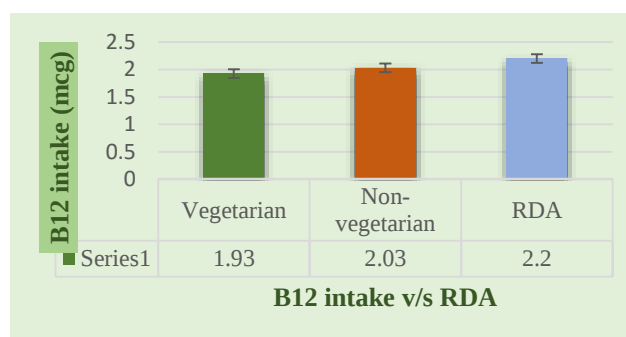


Figure 9. B12 intake of the respondents

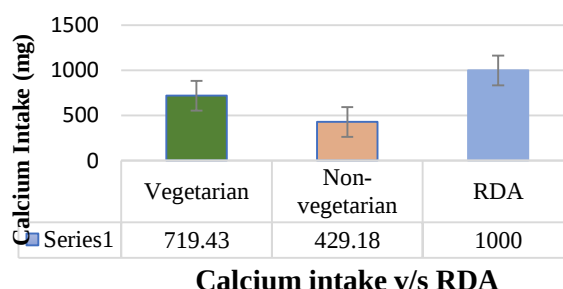


Figure 10. Calcium intake of the respondents

Iron: As opposed to the common belief that non-vegetarians are better placed when it comes to iron intake, vegetarian men consumed more iron (13.5 mg as opposed to 9.28 mg in non-vegetarians), though both were much below the RDA (19 mg/day). Similarly, vegetarian women also had slightly better intake (11.35 mg) than non-vegetarians (10.14 mg), but both were lower than the RDA (29 mg/day). The findings of study is also supported by few other studies.

Vegetarian diets typically include higher iron intake, with studies showing vegetarians and vegans consuming more iron than omnivores (Śliwińska et al., 2018) (Wilson & Ball, 1999).

Main sources of iron in vegetarian diets include cereals, vegetables, and legumes, with vitamin C-rich foods enhancing non-heme iron absorption (Gorczyca et al., 2013) (Saunders et al., 2012). However, as non-heme iron from plant sources is of poorer bioavailability (Dinu et al., 2017), co-ingestion with vitamin C and other measures must be taken to optimize absorption.

Calcium: Vegetarians had significantly higher calcium intakes (719.52 mg) than non-vegetarians (429.18 mg, $p < 0.0001$). While vegetarians enjoyed this intake benefit, neither group met the RDA (1000 mg), a long-term bone health concern (Craig & Mangels, 2009). A study indicated similar findings that vegetarians maintain calcium intake comparable to omnivores, which is crucial for bone health and overall physiological functions (Bickelmann et al., 2022). Higher calcium intake by vegetarians is likely due to higher dairy intake and plant food sources like leafy greens and fortified foods (Heaney et al., 1990).

Folate: Vegetarian males and females met their folate requirements, while non-vegetarian males (193 mcg vs 300 mcg RDA) were well short which was similar to another study which indicated that vegetarians have higher dietary fiber and folate levels, contributing to better overall nutrient density (Bowman, 2020). Non-vegetarian females (218 mcg) were close to meeting the RDA (220 mcg). This is consistent with studies that plant-based diets, being high in legumes and green leafy vegetables, have higher folate content (Perry et al., 2002).

Vitamin B12: Neither group met the RDA for B12, but non-vegetarians had a bit more (2.03

mcg) compared to vegetarians (1.93 mcg) which was similar to the findings in which vegans typically consume less B12 than omnivores, with studies showing a mean intake of 1.5 mcg compared to 4.6 mcg in non-vegans (Dubinsky et al., 2023). The RDA is 2.2 mcg, implying supplementation or fortified foods are needed, particularly for vegetarians.

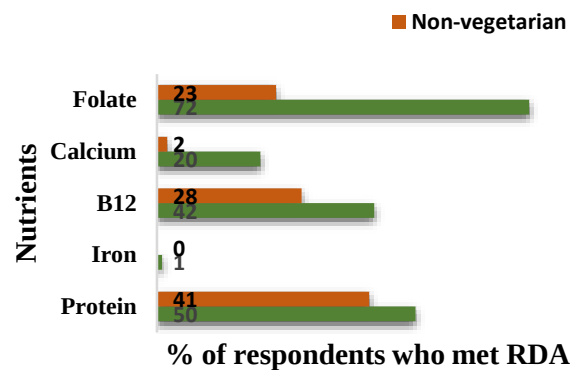


Figure 11. Percentage of respondents who met RDA

The figure illustrates the percentage of respondents meeting the Recommended Dietary Allowance (RDA) for essential nutrients between vegetarians and non-vegetarians. The findings indicate considerable variation in the adequacy of nutrients between the two groups. The non-vegetarians had very high adherence to the RDA for folate (72%) compared to the vegetarians (23%), revealing a substantial difference in the consumption of folate among the vegetarians. Calcium intake was very low in both groups, and just 20% of non-vegetarians and 2% of vegetarians met the RDA, indicating a potential risk to bone health. Vitamin B12 adequacy was also low but comparatively higher in non-vegetarians (42%) compared to vegetarians (28%), given that B12 is primarily available in foods of animal origin. The greatest disparity was for iron intake, where virtually no respondents met the RDA, with 1% of non-vegetarians and 0% of vegetarians being at or above recommended levels. Protein adequacy was higher among non-vegetarians (50%) than

vegetarians (41%), though the disparity was relatively less than for other nutrients. These findings emphasize the challenges of both diet groups in meeting requirements for essential

nutrients, particularly micronutrients such as calcium, iron, and B12.

Table 2. Comparison of the intake of selected nutrients by vegetarians and non-vegetarians

Nutrients (serving per day)	Vegetarian		Non-vegetarian		p-value
	Mean & SD	Median	Mean & SD	Median	
Energy (kcal)	1437.8±290.39)	1471.1	1279.3±289	1267.5	0.3
Protein (gm/kg BW)	0.85±0.27	0.83	0.82±0.4	0.77	0.64
Fat (gm)	41.3±14.56	38.24	41.4±12.75	39.53	0.87
Iron (mg)	12.42±3.76	11.33	9.7±2.6	9.38	0.01(p<0.05)
Calcium (mg)	719.52±338.11	750.25	429.17±226.2	416	< 0.0001(p<0.05)
Folate (mcg)	359.46±157.07	329.8	205.6±109.7	171.72	0.0002(p<0.05)
B12 (mcg)	1.93±0.82	1.9	2.04±1.19	1.9	0.5

*p value is based on independent t-test (p<0.05 is considered significant)

The table illustrates a comparison of daily nutrient intake between vegetarians and non-vegetarians. The results were that vegetarians had a slightly higher mean energy intake of 1437.8kcal than non vegetarians at 1279.3 kcal, though the difference was not statistically significant (p = 0.3). Protein intake was also the same for both groups, with vegetarians having an intake of 0.85 g/kg BW and non-vegetarians at 0.82 g/kg BW (p = 0.64).

Fat intake showed no significant difference, as the two groups showed very close values (41.3 g in vegetarians and 41.4 g in non-vegetarians, p = 0.87). However, there were differences in the consumption of iron, calcium, and folate. Iron intake was higher in vegetarians (12.42 mg) compared to non-vegetarians (9.7 mg), and the difference was statistically significant (p = 0.01).

Similarly, calcium intake was also much higher among vegetarians (719.52 mg) compared to non-vegetarians (429.17 mg), with a highly significant p-value (< 0.0001). Folate intake also followed the same trend, with vegetarians consuming 359.46 mcg and non-vegetarians consuming 205.6 mcg (p = 0.0002). In contrast, vitamin B12 intake was similar in both groups, with vegetarians and non-vegetarians consuming 1.93 mcg and 2.04 mcg, respectively (p = 0.5). These findings suggest that while vegetarian diets are more probable to provide higher amounts of iron, calcium, and folate, they are not probable to influence vitamin B12 status. The findings emphasize the importance of meal planning, especially in vegetarians, in order to reach an adequate level of nutrients and prevent potential deficiencies.

Table 3. Measure of variance in protein intake, BMI and Waist to hip ratio between vegetarian and non-vegetarian

	Mean	SD	p-Value
Protein intake/kg BW			
Vegetarian	0.85	0.07	0.62
Non-Vegetarian	0.82	0.16	
BMI			
Vegetarian	23.15	16.32	0.5
Non-Vegetarian	23.56	17.04	
Waist to hip ratio			
Vegetarian	0.89	0.01	0.045
Non-Vegetarian	0.86	0.02	

The table presents a comparison of protein intake, BMI, and waist-to-hip ratio between vegetarian and non-vegetarian individuals. Protein intake per kilogram of body weight was slightly higher in vegetarians (0.85 ± 0.07) compared to non-vegetarians (0.82 ± 0.16), though this difference was not statistically significant ($p = 0.62$). BMI values were similar in both groups, with vegetarians having a mean BMI of 23.15 ± 16.32 and non-vegetarians having a slightly higher BMI of 23.56 ± 17.04 , with no significant difference ($p = 0.5$).

However, a significant difference was observed in the waist-to-hip ratio, where vegetarians had a higher ratio (0.89 ± 0.01) compared to non-vegetarians (0.86 ± 0.02), with a statistically significant p-value of 0.045. These findings suggest that while protein intake and BMI do not differ significantly between vegetarians and non-vegetarians, the waist-to-hip ratio appears to be higher in vegetarians, potentially indicating differences in fat distribution patterns between the two dietary groups.

Table 4. Correlation between BMI, fat, vegetable and protein intake among vegetarians

	BMI (kg/m ²)	fat(gm)	Vegetables intake	Protein /kgBW
BMI (kg/m ²)	1			
fat(gm)	0.08	1		
Vegetables intake	-0.08	0.14	1	
Protein intake/kgBW	-0.48	0.32	0.09	1

The correlation coefficients for the BMI, fat intake, vegetable intake, and protein intake per kg body weight are presented in the table. BMI weakly correlates with fat intake (0.08) but weakly inversely correlates with vegetable intake (-0.08). Protein intake in relation to body weight in kilos shows a weak negative relationship with BMI (-0.48) and suggests that

higher BMI Individuals have a lower intake of protein as a proportion of body weight. Protein intake has a moderate relationship with fat intake (0.32) and is weakly correlated with vegetable intake (0.09). These findings suggest potential associations between body composition and food composition, where those with greater protein intake have lower BMI, while fat intake is not associated with BMI or vegetable intake.

4. CONCLUSION

We found that vegetarians had a more favourable dietary intake profile than non-vegetarians as shown by the higher intake of plant-based foods and lower intake of nutrients and foods associated with detrimental health effects such as ultra-processed products. Non-vegetarians were found to have a higher proportion of obese individuals; however, in contrast to vegetarians, they had a lower intake of certain nutrients, including iron, folate, and calcium. Both vegetarians and non-vegetarians had difficulties meeting their nutritional requirements, mainly with regard to iron and B12. Vegetarians had a higher protein intake in contrast to the non-vegetarians, possibly due to their making efforts to add protein to their diet as they perceive that

they may be possibly lacking it, whereas the non-vegetarians regarded them to automatically have a protein-adequate diet due to which they didn't put much effort to add protein to each meal's basis. There was no significant difference in BMI between the two groups; however, the waist-to-hip ratio had a marked variation. There were also correlations between BMI and dietary factors such as fat and protein intake, as well as between fat intake and vegetable consumption. Similarly, there was a positive correlation between BMI and fat intake and a negative correlation between BMI and vegetable intake; at the same time, there was a stronger negative correlation between BMI and protein intake per kg of body weight.

REFERENCES

- Bickelmann, F., Leitzmann, M. F., Keller, M., Baurecht, H., & Jochem, C. (2022). *Calcium intake in vegan and vegetarian diets: A systematic review and Meta-analysis*. <https://doi.org/10.6084/m9.figshare.20004990>
- Bowman, S. (2020). A Vegetarian-Style Dietary Pattern Is Associated with Lower Energy, Saturated Fat, and Sodium Intakes; and Higher Whole Grains, Legumes, Nuts, and Soy Intakes by Adults: National Health and Nutrition Examination Surveys 2013-2016. *Nutrients*, 12(9), 2668. <https://doi.org/10.3390/NU12092668>
- Clarys P., D. T. (2014). Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. *Nutrients*, 1318–1332.
- D.E., S., & São Paulo, B. 2. (2015). In: *Alimentação Sem Carne—Um Guia Prático Para Montar a sua Dieta Vegetariana com Saúde*. 2nd ed. Alaúde Editorial LTDA, editor. . São Paulo, Brasil: Alaúde Editorial LTDA.
- Dinu M, A. R. (2017). Vegetarian, vegan diets and multiple health outcomes: A systematic review with meta-analysis of observational studies. *Crit Rev Food Sci Nutr*, 3640-3649.
- Dubinsky, E. P., Shaham, S., Zelber-Sagi, S., Avnon, T., Yogev, Y., & Anbar, R. (2023). Nutritional intake comparison of vegan and non-vegan pregnant women. *Clinical Nutrition ESPEN*. <https://doi.org/10.1016/j.clnesp.2023.09.549>
- Orlich MJ, S. P. (2013). Vegetarian dietary patterns and mortality in Adventist Health Study 2. *JAMA Intern Med*, 1230-1238.
- Craig WJ, M. A. (2009). Position of the American dietetic association: vegetarian diets. *J Am Diet Assoc.*, 1266-1282.
- Bedford J, B. S. (2005). Diets and selected lifestyle practices of self-defined adult vegetarians from population-based sample suggest they are more health conscience. *Int J Behav Nutr Phys Act.*, 4-6.
- Shickle D, L. P. (1989). Differences in health, knowledge and attitudes between vegetarians and meat eaters in random population sample. *J R Soc Med.*, 18-20.
- Leite AC, D. K. (2019). Longitudinal effects of human supremacy beliefs and vegetarianism threat on moral exclusion (vs. inclusion) of animals. *Eur J Soc Psychol*, 179-189.
- A, L. K. (2009). Christian rationale for vegetarianism. *Dialog.*, 147-157.
- Sabaté J, W. M. (2010). Vegetarian diets and childhood obesity prevention. *Am J Clin Nut*, 1525-1529.
- Loughnan S, B. B. (2014). The psychology of eating animals. *Curr Dir Psychol Sci.*, 104-108.
- Skevington, S., Lotfy, M., & O'Connell, K. (2004). The World Health Organization's WHOQOL-BREF quality of life assessment: Psychometric properties and results of the international field trial. A Report from the WHOQOL Group. *Quality of Life Research*, 299–310.
- Parker, H., & Vadiveloo, M. (2019). Diet quality of vegetarian diets compared with nonvegetarian diets: A systematic review. *Nutr. Rev.* , 1–19.
- Dinu, M. A. (2017). Vegetarian,vegan diets and multiple health outcomes:A systematic review with meta-analysis of Observational studies. *Critical Reviews in Food Science and Nutrition*, 3640-3649.
- Sabaté, J. S. (2014). Environmental nutrition: A new frontier for public health. *American Journal of Public Health*, 940-949.
- Śliwińska, A., Luty, J., Aleksandrowicz-Wrona, E., & Małgorzewicz, S. (2018). Iron status and dietary iron intake in vegetarians. *Advances in Clinical and Experimental Medicine*, 27(10), 1383–1389. <https://doi.org/10.17219/ACEM/70527>
- Lea, E. &. (2003). Benefits and barriers to the consumption of a vegetarian diet in Australia. *Public Health Nutrition*, 505-511.
- Craig, W. J. (2009). Position of the American Dietetic Association: vegetarian diets. *Journal of the American Dietetic Association*, 1266-1282.
- Wilson, A. K., & Ball, M. J. (1999). Nutrient intake and iron status of Australian male vegetarians. *European Journal of Clinical Nutrition*, 53(3), 189–194. <https://doi.org/10.1038/SJ.EJCN.1600696>

ASSESMENT OF FARMERS’ KNOWLEDGE OF COFFEE WHITE STEM BORER (Xylotrechus quadripes) AND IT’S MANAGEMENT STRATEGIES IN GULMI, NEPAL

Prarthana Joshi¹, Bipin Joshi^{1,*}, Sabita Poudel¹ and Amrita Basnet¹

¹ Agriculture and Forestry University, Chitwan, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Arabica coffee, Coffee White Stem Borer (CWSB), Pest, Integrated Pest management *Correspondence: bipeenjoshi2002@gmail.com Tel: +977 9815697551	The Coffee White Stem Borer (<i>Xylotrechus quadripes</i>) is a major pest affecting Arabica coffee production in Nepal, leading to significant yield losses and economic setbacks for farmers. This study assesses farmers' knowledge, perception, and adoption of Coffee White Stem Borer (CWSB) management strategies in Gulmi, Nepal. A mixed-method approach was employed, utilizing structured surveys and key informant interviews among 129 coffee farmers selected using proportionate stratified sampling. Descriptive statistics, forced ranking, and binary logistic regression were used for data analysis. The results showed that 94.4% of farmers were aware of CWSB, but only 2% had knowledge of its life cycle. The most commonly adopted management strategies included orchard sanitation and mechanical control, while the use of bio-pesticides and pheromone traps remained limited. Binary logistic regression analysis revealed that education level, training participation, age, and the number of coffee plants grown significantly influenced the adoption of management practices ($p < 0.05$). The study highlights the need for targeted farmer training programs and integrated pest management strategies to enhance CWSB control. Strengthening extension services and promoting sustainable pest management practices could mitigate infestation risks and improve coffee productivity in Nepal

1. INRODUCTION

Coffee (*Coffea arabica* L.) is one of the most economically significant crops globally, providing livelihoods for millions of smallholder farmers (Shrestha, 2023). In Nepal, coffee cultivation has gained substantial importance due to its high export potential and increasing domestic demand (Sharma *et al.*, 2020).

Approximately, in the Year 1938 AD, a hermit Mr. Hira Giri bought some seeds of coffee from the Sindhu Province of Myanmar (then Burma) and planted them in the Aanpchaur of Gulmi District for the first time in Nepal (Gautam, 2022). Then it spread from one farmer to another as a curiosity plant for about 4 decades (NTCDB, 2010). The mid-hill regions of Nepal, particularly Gulmi, have favourable climatic conditions for coffee

production, making it a crucial source of income for smallholder farmers (Bhattarai and Pant, 2021). However, the sustainability of coffee farming is increasingly threatened by pest infestations, particularly the Coffee White Stem Borer (CWSB) (*Xylotrechus quadripes*), which has become a major challenge for Nepalese coffee growers (Bhattarai and Pant, 2021). It alone is responsible for up to 70% of the loss in coffee production in Nepal (NARC, 2007). Infestation by CWSB can cause severe damage to coffee plants by tunnelling into stems, leading to wilting, yield losses, and plant mortality, significantly affecting production levels (Gautam *et al.*, 2019). Once plant is infected, the whole plant has to be uprooted (Venkatesh and Dinesh, 2012). As a control measure, there are very limited or no available options over which the pest is controlled. Because of its increasing losses, coffee growers have led to the uprooting of the coffee and subsequently replanting (CoPP, 2004).

The infestation of CWSB is exacerbated by changing climatic conditions, poor orchard management, and a lack of awareness among coffee growers regarding integrated pest management (IPM) techniques (Gautam *et al.*, 2019). Furthermore, Nepalese genotype of arabica coffee i.e., Bourbon and Typica are more susceptible to coffee white stem borer (Aryal *et al.*, 2022). Management strategies such as cultural control, mechanical removal of infested plants, and the use of biological agents have been recommended, but their adoption among smallholder farmers remains limited (Pandey *et al.*, 2022). Although several studies have been conducted on CWSB infestation, research focusing on farmers' knowledge, perception, and management practices remains insufficient in the Nepalese context. There is a need to understand the factors influencing the adoption of pest management strategies to develop more effective farmer-centred interventions (Khanal and Dhakal, 2020).

Existing research on CWSB management suggests that knowledge and perception play a crucial role in determining farmers' willingness to adopt control measures. Studies from India and Ethiopia have shown that

farmers with better access to agricultural extension services and training programs are more likely to implement preventive and curative measures against CWSB (Mekonnen *et al.*, 2021). However, in Nepal, limited research has explored how factors such as education level, prior pest encounters, and farm characteristics influence pest management decisions among coffee farmers. Moreover, the effectiveness of different management approaches, including biological and pheromone-based control methods, remains underexplored in smallholder coffee farming systems (Adhikari *et al.*, 2024).

This study seeks to fill this knowledge gap by analysing the factors affecting the adoption of CWSB management practices among coffee farmers in Gulmi, Nepal. Despite efforts to promote sustainable coffee farming practices, many farmers continue to struggle with recurring CWSB infestations. The lack of access to timely information, inadequate pest control measures, and weak institutional support have been identified as major barriers to effective pest management (Bishowkarma and Shrestha, 2023). The research also aligns with Nepal's goal of promoting organic and sustainable coffee production by reducing dependency on chemical pesticides and encouraging environmentally friendly pest control strategies (Poudel *et al.*, 2020).

2. MATERIALS AND METHODS

This study employed a survey design to assess farmers' knowledge, perceptions, management practices, and the factors influencing the adoption of Coffee White Stem Borer (CWSB) management practices among coffee farmers in Gulmi, Nepal. A mixed-method approach was utilized, incorporating both quantitative and qualitative data collection. The study was conducted from March, 2024 to August, 2024.

2.1 Study Area and Sampling Technique

The research was carried out in 5 municipalities of Gulmi namely Musikot municipality, Styawati Rural Municipality, Chandrakot Rural municipality, Chhtrakot Rural Municipality and Ruru Rural

Municipality. The area is a major coffee-producing area where CWSB infestation has been a persistent challenge. Gulmi is characterized by diverse topographical and climatic conditions that influence coffee farming practices. The region's dependence on smallholder coffee farming makes it an ideal setting for studying pest management behaviours.



Source: Google.com

Figure 1. Map of Nepal and Gulmi district showing study area

A proportionated stratified sampling technique coupled with simple random sampling was used to select respondents from key coffee-growing regions within the district. This method ensured the inclusion of farmers actively engaged in coffee production and facing CWSB infestation. The sample size was calculated by using Yamane's formula for sample size calculation (Yamane,1967).

$$\text{Sample size (n)} = \frac{N}{1+N(e)^2}$$

Where, N= Population size,

n= Sample size,

e= Margin of error.

Population (N)=900.

Considering the margin of error as 8% i.e., e=0.08.

Applying this formula, the calculated sample size was approximately 129 farmers.

2.2 Data Collection

Primary data were collected through face-to-face interviews using a structured questionnaire. The questionnaire covered demographic information, farmers' knowledge and perception of CWSB, adoption of management practices, and influencing factors. In addition, key informant interviews were conducted with agricultural officers and cooperative representatives to validate survey responses and gain expert insights. Field observations were also carried out to assess the actual presence of CWSB infestation and verify farmers' reported practices.

2.3 Data Analysis

The collected data were analysed using both descriptive and inferential statistical methods. Descriptive statistics, including frequency distributions, means, and standard deviations, were used to summarize socio-demographic characteristics and general trends in CWSB management practices. Tables and charts were used to illustrate key findings.

Forced Ranking Method was used to assess the preference CWSB management strategies, the forced ranking method was employed. Forced ranking is a structured technique used to prioritize a set of choices by compelling respondents to rank them in order of preference.

In this study, farmers were presented with a list of CWSB management practices, including cultural methods (orchard sanitation, shade regulation), mechanical methods (uprooting and burning infested plants), biological methods (use of bio-pesticides), chemical control, and pheromone-based methods (Xylo-lure traps). Respondents were asked to rank these practices based on perceived effectiveness and ease of implementation, with 1 representing the most preferred strategy and 5 the least preferred. The rankings were analysed using weighted

averages to determine the most widely adopted and effective management strategies.

$$I_{imp} = \sum \frac{S_i F_i}{N} \quad (\text{Ghose, 1981})$$

Where:

I_{imp} = Index of importance

S_i = Scale value of i^{th} priority

F_i = Frequency of i^{th} priority

N = Total number of respondents

Binary logistic regression analysis was conducted to identify the key factors influencing the adoption of CWSB management practices, binary logistic regression was employed. This statistical method is appropriate when the dependent variable is categorical and binary in nature. In this study, the dependent variable was coded as 1 for farmers who adopted pest management practices and 0 for those who did not. The independent variables included training participation, education level, number of coffee plants grown, previous encounters with CWSB, and knowledge of the pest's life cycle.

The logistic regression model is specified as:

$$\text{Log} \left(\frac{p}{1-p} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon$$

(Ojha *et al.*, 2023)

Where:

P = Probability of adopting CWSB management practices

β_0 = Intercept

β_n = Regression coefficients

X_n = Independent variables

ε = Error term

The model's goodness-of-fit was assessed using the Hosmer-Lemeshow test, and significance levels were set at $p < 0.05$. The odds ratios ($\text{Exp}(B)$) were used to interpret the strength of association between predictor variables and the likelihood of adopting management practices. The Nagelkerke R^2 has also been calculated and published in this study. Nagelkerke R^2 value ranges from 0 to 1.

3. RESULTS AND DISCUSSION

This section presents the findings of the study conducted among coffee farmers in Gulmi, Nepal.

3.1 Sociodemographic Status

The socio-demographic characteristics of the respondents play a crucial role in determining their knowledge, perception, and adoption of pest management strategies. The study surveyed 129 coffee farmers from different municipalities in Gulmi. The respondents' gender distribution showed a predominance of male farmers, accounting for 61% of the total sample, while female farmers represented 39%. Regarding ethnicity, the majority of the respondents belonged to the Brahmin community (63.3%), followed by Janjatis (25.6%), Chhetri (7.8%), and Dalits (3.3%). The age of the farmers ranged from 31 to 81

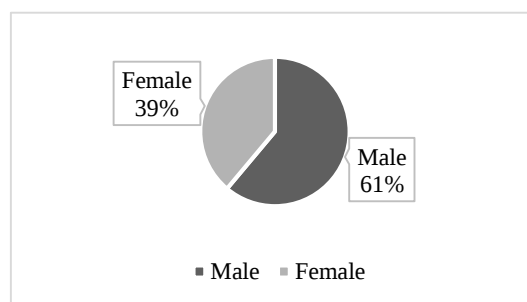


Figure 2. Distribution of respondents based on gender

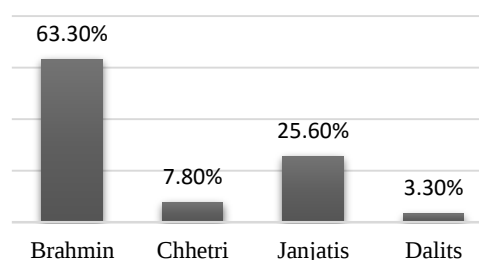


Figure 3. Distribution of respondents based on ethnicity

years, with an average age of 52.17 (± 11.9) years. The educational background of the farmers varied, with 33.3% having received schooling up to five years, 63.3% having 6-10 years of formal education, and only 7.8% possessing more than 10 years of schooling.

The average family size among respondents was 5.87(± 2.4) members. Agriculture was the primary occupation for all respondents and landholding size ranged from 2-60 ropani, with an average of 18.4 ropani. The number of coffee plants per household varied significantly, ranging from 50 to 3500, with an average of 381 plants per farm.

Table 1. Demographic Information of respondents

Categories	Minimum	Maximum	Mean	Standard deviation
Age	31	81	51.8	11.9
Family size	2	13	5.8	2.4
No. of males in the family	1	8	3.1	1.6
No. of females in the family	1	7	2.7	1.2
Schooling years	0	15	6.8	3.6
Land holding (Ropani)	2	60	18.4	11.64
No. of coffee plants grown	50	3500	381.4	768.5

3.2 Knowledge and Perception about Coffee White Stem Borer (CWSB)

Farmers' awareness and perception of CWSB are critical for effective pest management. Out of 129 respondents, 94.4% individuals reported being aware of CWSB, and 91.1% individuals stated that they could easily identify the pest. The key symptoms used to identify CWSB infestation included yellowing and wilting of leaves (96.3%), stem cracking (57.3%), the presence of excreta near feeding holes (23.2%), and yield loss (64.63%). All respondents who could identify CWSB had encountered it in their orchards in previous years. Among them, 81.7% had observed the pest afrequently, while 18.3% reported occasional sightings. Farmers' perception of the severity of infestation varied, with 44% reporting that over 40% of their coffee plants were affected, while 28% estimated a 20-40% infestation rate. The majority (47.5%) perceived yield losses due to CWSB to be between 50-75%, and 25.5% estimated losses exceeding 75%. Farmers identified flowering

(54%) and fruiting (35%) stages as the most vulnerable periods for CWSB infestation.

When asked about the infestation trend, 88.8% of farmers believed that the rate of infestation was increasing, attributing it to lack of proper cure followed by lack of irrigation similar to Pandey *et al.*, (2022). Only 2.2% of farmers believed that the infestation rate remained constant, and none believed it was decreasing.

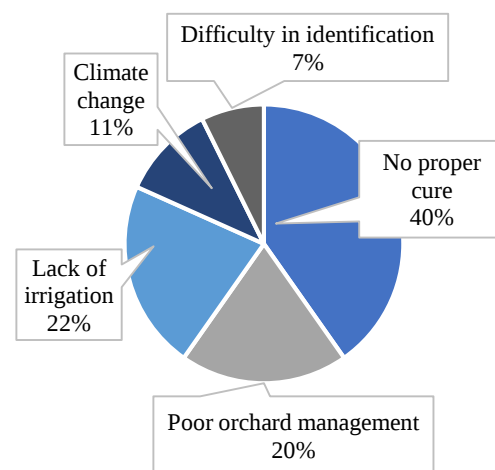


Figure 4. Reason behind rising infestations

Regarding the nature of damage of pest, 71% respondents believed CWSB damage by boring stem followed by 17% believing damaging cherry was the nature. Life cycle of CWSB, only 2% of respondents were aware of the life cycle of the pest, highlighting a significant knowledge gap.

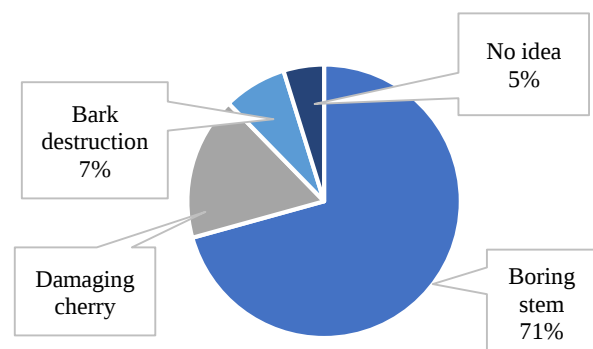


Figure 5. Damaging nature of pest

3.3 Management Practices

Adoption of management practices is key to controlling CWSB infestation. The study found that 86% of farmers implemented some form of pest management, while 14% did not take any measures. The most commonly adopted strategies included cultural practices such as orchard sanitation and shade management, followed by mechanical methods like uprooting and burning infected plants. Biological control methods, including the use of bio-pesticides, were employed by some farmers, but their adoption remained low compared to cultural and mechanical approaches.

Table 2. ranking of most commonly followed management practices

Methods	Index	Rank
Cultural (Orchard management)	0.838	I
Mechanical (Uprooting, Burning, etc)	0.778	II
Bio-pesticide (Jhol mal)	0.544	III
Chemical (Bordeaux paste, Kerosene)	0.470	IV
Innovative (Xylo-lure)	0.370	V

Awareness and use of Xylo-lure, a pheromone-based trap for monitoring and managing CWSB, were notably low. Only 20.3% of farmers were aware of Xylo-lure, and 18.5% had used it in their orchards. Among those who used it, 66.7% reported no visible reduction in infestation levels, while 33.3% noted the unintended trapping of beneficial insects, indicating a lack of effectiveness.

Training played a crucial role in the adoption of management practices. The study found that 64.4% of farmers had attended training sessions related to coffee farming, with the majority receiving training from the Coffee Development Centre (46.5%). Other training

providers included NGOs, INGOs, and cooperatives.

3.4 Factors Affecting Management Practices:

Binary logistic regression was conducted to determine the factors influencing farmers' adoption of CWSB management practices. The dependent variable was the adoption of management practices, where farmers who adopted any management strategy were coded as 1 (Yes) and those who did not adopt any strategy were coded as 0 (No). The model was statistically significant ($\chi^2 = 19.404$, $p < 0.05$), explaining 12.1% of the variance in adoption behavior (Nagelkerke $R^2 = 0.121$).

The findings indicate that education level ($p = 0.027$), training participation ($p = 0.016$), age ($p = 0.033$), and plant number ($p = 0.044$) had a statistically significant influence on the adoption of CWSB management practices. Farmers with higher education levels were 3.678 times more likely to adopt management practices, while those who had participated in training were 5.833 times more likely to implement them.

Older farmers showed a higher likelihood of adoption, with an odds ratio of 1.444, and the number of coffee plants cultivated also had a small but significant effect ($\text{Exp}(B) = 1.027$). On the other hand, family size ($p = 0.814$), and previous encounters with CWSB ($p = 0.997$) were found to be insignificant predictors. These results highlight the importance of education and training programs in promoting effective pest management strategies as reported by Bishowkarma *et al.*, (2024).

Table 3. Logistic Regression Results for Factors Influencing Adoption of CWSB Management Practices

Dependent Variables	B	S.E.	Wald	df	Sig. (p-value)	Exp (B)	95% C.I. for Exp (B)	
							Lower	Upper
School Years	1.302	0.590	4.865	1	0.027*	3.678	1.156	11.702
Family size	0.070	0.298	0.056	1	0.814	1.073	0.599	1.923
Training taken	1.764	0.735	5.762	1	0.016*	5.833	0.558	16.839
Previous encounter with pest	-19.12	4899.25	0.000	1	0.997	0.000	0.000	.
Age	0.367	0.172	4.560	1	0.033*	1.444	1.031	2.023
Plant number	0.026	0.013	4.042	1	0.044*	1.027	1.001	1.054

* Indicates significance at 5% level of significance

4. CONCLUSION

The study highlights the significant impact of Coffee White Stem Borer (CWSB) on Arabica coffee production in Nepal and the varying levels of awareness and management strategies among coffee farmers. While most farmers recognize CWSB as a major pest, only a small proportion possess in-depth knowledge of its life cycle and effective control measures.

The findings indicate that education level, training participation, and farm size significantly influence the adoption of pest management strategies. Farmers rely primarily on cultural and mechanical control methods, while the adoption of bio-pesticides and pheromone traps remains limited. The study underscores the urgent need for targeted training programs to enhance farmers' technical knowledge and encourage the adoption of integrated pest management (IPM) practices. Strengthening extension services, increasing access to sustainable pest control techniques, and promoting farmer-led initiatives are essential for mitigating CWSB infestation risks and improving coffee productivity in Nepal. Future research should focus on evaluating the effectiveness of different pest management strategies and exploring innovative, eco-friendly control methods to ensure sustainable coffee production.

ACKNOWLEDGEMENTS

The authors would like to acknowledge all the staffs of Coffee Development Centre, Gulmi for their assistance and guidance.

REFERENCES

- Adhikari, S., Culas, R., Storer, C., & Timsina, K. (2024, February). *Analyzing the trends in organic coffee cultivation and farm-level production constraints in Nepal* [Conference abstract]. 68th Annual Conference of the Australasian Agricultural and Resource Economics Society, Canberra, ACT, Australia.
- Aryal, L., Basnet, S., & Aryal, S. (2022). Field screening of Arabica coffee genotypes against Coffee White Stem Borer (*Xylotrechus quadripes*) and Leaf Rust (*Hemileia vastatrix*) infestation in Kaski, Nepal. *Journal of Agriculture and Environment*, 23(1), 156–165.
- Bhattarai, K., & Pant, B. (2021). Challenges and prospects of coffee production in Nepal. *Nepal Journal of Agriculture*, 15(2), 78–92.
- Bishwakarma, K., & Shrestha, R. (2023). The role of farmer training in pest management adoption among Nepalese coffee growers. *International Journal of Pest Management*, 10(4), 150–168.
- Coffee Promotion Program (CoPP). (2004). *Annual report*. Nepal Coffee Promotion Office.
- Gautam, R. (2022). History and development of coffee cultivation in Nepal. *Himalayan Agriculture Review*, 5(1), 34–48.
- Gautam, S., Adhikari, B., & Kafle, P. (2019). Impact of Coffee White Stem Borer infestation on Nepalese coffee production. *Journal of Plant Protection Research*, 14(3), 56–69.
- Ghose, B. (1981). *Scientific methods and social research*. Sterling Publications Pvt. Ltd.
- Khanal, N., & Dhakal, S. (2020). Factors influencing the adoption of integrated pest management in Nepalese coffee farms. *Journal of Sustainable Agriculture*, 9(2), 87–102.
- Mekonnen, T., Ayalew, G., & Tesfaye, D. (2021). Adoption of pest management strategies among coffee farmers in Ethiopia: Lessons for Nepal. *Ethiopian Journal of Agricultural Science*, 19(4), 110–128.
- Nepal Agricultural Research Council (NARC). (2007). *Annual progress report on coffee research*. Nepal Agricultural Research Council.
- National Tea and Coffee Development Board (NTCDB). (2010). *A report on coffee production in Nepal*. Ministry of Agriculture.
- Ojha, B., Giri, H. N., Regmi, B., Pokharel, A., & Parajuli, D. (2023). Factors affecting awareness on good agricultural practices among citrus growers in Palpa, Nepal: Through binary logistic regression approach. *Archives of Agriculture and Environmental Science*, 8(4), 565–572.
- Pandey, R., Thapa, K., & Sharma, M. (2022). Effectiveness of bio-pesticides in controlling Coffee White Stem Borer in Nepal. *Nepalese Journal of Agronomy*, 11(1), 92–105.
- Panthi, R., Adhikari, S., & Bista, P. (2022). Comparative analysis of traditional and modern pest control methods in Nepalese coffee farms. *Nepal Agricultural Review*, 20(2), 132–148.
- Poudel, L., Rijal, P., & Shrestha, K. (2020). Organic coffee farming and its impact on pest infestation: A Nepalese perspective. *International Journal of Organic Agriculture*, 7(3), 200–215.
- Sharma, D., Gautam, B., & Shrestha, H. (2020). Economic potential of coffee cultivation in Nepal: Trends and future prospects. *Nepal Journal of Economic Studies*, 8(1), 57–74.
- Shrestha, S. (2023). The role of coffee in the livelihoods of Nepalese smallholder farmers. *Journal of Rural Development and Agriculture*, 16(1), 45–63.
- Venkatesh, M., & Dinesh, R. (2012). Impact of Coffee White Stem Borer on coffee yield: An integrated pest management approach. *Indian Journal of Agricultural Research*, 25(3), 78–94.
- Yamane, T. (1967). *Statistics: An introductory analysis* (2nd ed.). Harper & Row.

CARBON SEQUESTRATION BY DIFFERENT CITRUS SPECIES IN NEPAL: AN EMPIRICAL STUDY

UK Acharya¹, A Katuwal² and AK Acharya³

¹ National Commercial Crop Research Center, Lalitpur, Nepal

² National Citrus Research Program, Dhankuta, Nepal

³ Forest Research and Training Centre, Babarmahal, Kathmandu, Nepal

ARTICLE INFO

Keywords:

acid lime

carbon

mandarin

Sequestration

*Correspondence:

umeshach@gmail.com

ABSTRACT

Nepal has significant potential for citrus cultivation with these tree crops serving as a valuable source of carbon sequestration. However, the carbon sequestration potential of these fruit orchards remains unaccounted for in the carbon trading business, likely due to limited information on the amount of carbon sequestered by different citrus species. This study was conducted in Dhankuta, Nepal to estimate the carbon sequestration by grafted mandarin, acid lime, and sweet orange trees aged 16-18 years. The study found that mandarin trees sequestered 11.8-58.3 tons/ha, sweet orange trees sequestered 2.75-35.14 tons/ha, and acid lime trees sequestered 2.35-46.9 tons/ha of carbon. The rate of carbon accumulation was 1.7, 1.08 and 1.99 tons/ha/yr for mandarin, sweet orange and acid lime trees, respectively. It is estimated that Nepali citrus orchards could sequester at least 75613 tons of carbon annually, regardless of tree species. Similar studies should be conducted in different parts of the country using various age groups and varieties of citrus species at different topology to establish more robust estimation. Additionally, the government of Nepal should consider fruit orchards in carbon trading initiatives.

1. INTRODUCTION

Tree fruit crops are regarded as significantly important commodities in the mid-hills to the Terai region of Nepal (Acharya *et al.*, 2021; Browns, 1997). These crops hold ecological, economic, and environmental importance (Sharma *et al.*, 2021). Citrus fruit trees, which thrive well in altitudes ranging from 100 to 1600 meters, are no exception. Nepal has been actively

involved in initiatives such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) and forest carbon trading. REDD+ aims to incentivize developing countries to reduce emissions from deforestation and forest degradation while promoting forest conservation, sustainable management, and carbon stock enhancement (MOFE, 2018). Through REDD+ mechanisms, countries like Nepal could receive financial incentives for preserving their forests,

which are crucial carbon sinks (MOFE, 2018). However, trees outside forests, including fruit orchards, have not been accounted for carbon financing in Nepal. As a result, the citrus trees planted over 50,253 hectares in Nepal have been overlooked because they are classified as out of the forest trees. Additionally, other fruit trees like mango, litchi, apple, and pears, which cover more than 177,569 hectares in Nepal (MoALD, 2023), need to be considered in carbon trading. For example, in Australia, the government is utilizing Macadamia plantations for carbon trading (Murphy *et al.*, 2012), indicating that Nepal should include tree fruits in carbon trading soon. A fruit tree is considered a good source for balancing ecosystems with the deposition of carbon and it is also considered an excellent medium to cope with the effects of climate change (Wembede *et al.*, 2022). Many modern countries are providing funds to off-set their carbon foot print and this is time word is investing on climate financing. Hence Nepal government has obtained a good appraisal of carbon balance from the global arena. However, the fruit trees covering a 177,569 ha area remain unaccounted for carbon credit (MoALD, 2023). Among these fruit crops, mandarin alone accounts for 26,591 ha area coverage in Nepal. There is limited

information found on carbon sequestration by citrus fruit crops in Nepal and this study could serve as a model for future investigation. Therefore, an empirical study on carbon sequestration has been conducted, considering different varieties of mandarin, sweet orange, and lime in 2023.

2. MATERIALS AND METHODS

2.1 Geography and Climate of the study area

The National Citrus Research Program, Paripatle lies in Dhankuta Municipality, Dhankuta District, Nepal (Fig. 1). It lies at 26°59'54.3" N latitude to 87°18'44.6" E longitude and 1250 to 1390 meter after sea level (NCRP 2003). The average annual maximum and minimum temperature is 29.36oC and 4.33oC, respectively. The station received 1024 mm of annual rainfall in the year 2019 (NCRP 2020). The soil texture is sandy to sandy loam with gravel in some terraces. The soil pH was 4.5 to 6.2 with low (0.04 %) to medium (3.33%) organic matter. The sampled citrus species were 16-18 years old grafted sapling trees planted at a 4 m x 4 m distance in terraced land. The samples were collected on 21th October 2023. The sample number was 3 to 8 trees for each species.

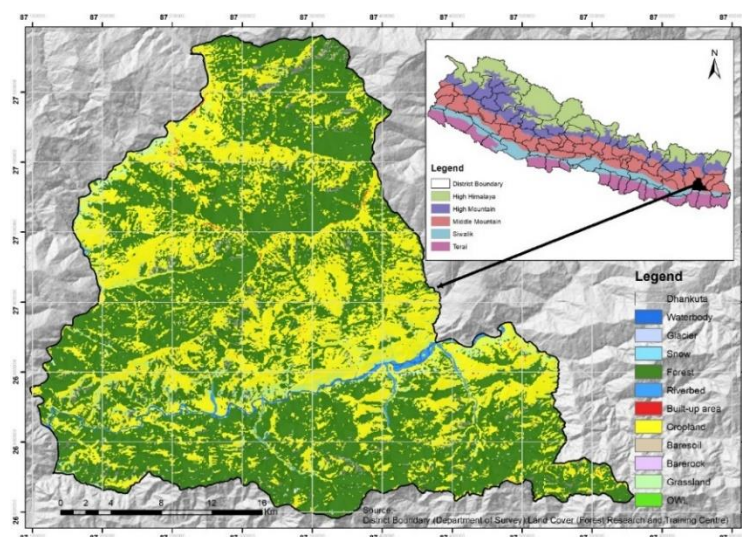


Figure 1. Location map of the study area



Figure 2. Features of Trees application

2.2 Calculation of Physical parameters

Two important physical parameters for tree biomass calculations are tree height and weight which are needed for the calculation of tree biomass (Timsina *et al.* 2018)). The use of the allometric method needs the destruction of a tree sample which was not possible and an Empirical (allogometric) approach has been employed in this study. The tree height was measured using a mobile application (Trees Ver 4.1.8 2023/5/10 @ 2019 Forest Monitoring Tools; Fig. 2) from Android platform. The trunk diameter at breast height (1.3 m) was measured using a measuring tape. All the branches of a tree at breast heights were measured and added to get final DBH value. Considering the irregular shape of citrus trees, the tree volume is calculated using the Equation 1 as suggested by Jonckheere *et al.* (2004).

Tree volume (cm^3) = $\frac{2}{3} (\pi r^2 * h)$ -----
- Equation 1

Where, $\pi = 3.14$, r = radius at breast height of tree and h = height of tree

2.3 Allometric calculation of tree carbon content

The above ground biomass (AGB) and the below ground biomass (BGB) constitute the total biomass of a tree. The AGB accounts for all the visible plant parts like bark, leaves, branches, stem, fruit, seeds etc. above the soil while the BGB accounts for all the live roots at least 2 mm in diameter below the soil surface (Murphy *et al.*, 2012). Both biomasses constitute the total biomass of a tree and are generally expressed in ton per hectare (Ravindranath and Ostwald 2008).

The AGB was calculated using Equation 2 as proposed by Cotta (1804).

Dry weight of the tree as AGB (kg) = $[V \times WD (\text{g/cm}^3)] / 1000$ ----- Equation 2

Where, V = Tree volume (cm^3), WD = Wood density (g/cm^3)

The volume of tree was calculated as equation 1 stated above. The wood density values differ with plant type and species. The value for citrus species is considered 0.59 as reported by Cairns *et al.* (1997).

The BGB measurement is very costly and time-consuming. Hence it is estimated based on the above-ground biomass measurement using an allometric Equation 3.

The dry weight of the root biomass as BGB (kg) = $R \times \text{dry weight of AGB (kg)}$ ---- Equation 3.

Where, R = root to shoot ratio. The R value is derived from literature as 0.26 as reported by Cairns *et al.* (1997).

2.4 Estimation of carbon sequestration

The total biomass of a tree is the sum of the AGB and BGB. The total biomass is used for the calculation of carbon dioxide sequestered by a tree (IPCC 2006) and expressed as a ton per hectare using the Equation 4.

CO_2 sequestered (t/ha) = Total biomass $\times 1.835$ -----Equation 4

Dividing the value obtained from the Equation 4 by the age of the tree provides the value for carbon sequestered by a particular tree species in tons per year. A total of 236 citrus trees were sampled based on species and varieties as shown in Table 1-3. While selecting trees for each species/varieties, 33% trees purposively sampled from small, medium and highly dense trees groups. The classification was done to get a better picture of various aspects of the study. The allometric estimation was done for each sampled tree and converted to a hectare basis using the total plant population per hectare (625) as shown below. The data were recorded on MS Excel and analyzed using R-based open-source software Jamovi stat V 2.4.14 (2023).

3.RESULTS AND DISCUSSION

Table 1. Acid lime (*Citrus aurantifolia*) tree physical parameter and estimated carbon pool of various varieties grafted trees of age 12 years.

S.N.	Variety	DBH (cm)	Plant height (cm)	Tree volume (cm ³)	AGB (Kg)	BGB (Kg)	Total Biomass / tree (Kg)	CO ₂ Sequestered (t/ha)	CO ₂ Sequestered (t/ha/yr)
1	NCRP-52	12.6	283	24405	14.4	3.74	18.1	20.8	1.73
2	NCRP-50	11.4	250	17287	10.2	2.65	12.9	14.7	1.23
3	NCRP-48	12.4	227	20513	12.1	3.15	15.2	17.5	1.46
4	NCRP-47	14.4	227	26071	15.4	4	19.4	22.2	1.85
5	NCRP-56	12.0	240	19206	11.3	2.95	14.3	16.4	1.36
6	NCRP-59	16.6	188	29649	17.5	4.55	22	25.3	2.11
7	NCRP-60	13.1	208	18781	11.1	2.88	14	16	1.33
8	NCRP-53	11.9	165	12628	7.45	1.94	9.39	10.8	0.89
9	NCRP-46	14.8	223	32554	19.2	4.99	24.2	27.8	2.31
10	NCRP-51	22.5	203	54996	32.4	8.44	40.9	46.9	3.91
11	NCRP-57	6.37	130	2757	1.63	0.423	2.05	2.35	0.19
12	Sunkagati-1	16.6	328	49366	29.1	7.57	36.7	42.1	3.51
13	Sunkagati-2	11.1	339	22199	13.1	3.41	16.5	18.9	1.58
14	Terhathum Local	13.0	257	24776	14.6	3.8	18.4	21.1	1.76
Grand mean		13.9	253	25370.6	15.0	3.89	18.86	21.63	1.80
Standard deviation		4.7	71.7	13528.6	7.97	2.08	10.06	11.54	0.96

DBH- Diameter at breast height, AGB- Above ground biomass, BGB- Below ground biomass

3.1 Tree height

The tree height ranged from 130 (NCRP-57 genotypes) to 339 cm (Sunkagati-2) (Table 1) for acid lime; 183 cm (LueGim Gong variety) to 396 cm (Tamango variety) for sweet orange (Table 2) and 198-466 cm for mandarin trees (Table 3) with an average of 253, 280 and 317 cm, respectively (Table 1-3). The 16-year-old acid lime (NCRP 57) tree has the lowest plant height (130 cm) and Pixie mandarin orange has the tallest tree (466 cm). Among the tree species, the mandarin tree has the tallest tree (317 cm) followed by sweet orange (280) and acid lime with the lowest tree height (253 cm) (Table 1-3).

3.2 Diameter at breast height (DBH)

The DBH of the acid lime tree was in a range of 6.37 (NCRP-57 genotypes) to - 22.5 cm (NCRP-51 genotypes) (Table 1) while the same of sweet orange was in a range of 5.36 (LueGim Gong variety) to 14.2 cm (Valencia late variety) (Table 2) and that of mandarin was 9.34 cm (Kara variety) to 16.9cm (Avana Aprino variety) (Table 3). The average thickest tree among the three citrus species was acid lime (13.9 cm) followed by mandarin (13.7 cm) and the thinnest was sweet orange (10.6 cm) (Table 1-3).

3.3 The tree volume

The tree volume of acid lime was 2757 cm³ (NCRP-57 genotype) to 54996 cm³ (NCRP-51 genotype) with an average of 25370 cm³, while that of mandarin trees ranged from 13843 (URSS variety) to 68352 cm³ (Avana Aprino variety) with an average of 35927 cm³ (Table 3) and that of sweet orange ranged from 3228 cm³ (LueGim Gong variety) to 41116 cm³ (Tamango variety-

(Table 2) with an average of 18902.5 cm³. In average the mandarin tree has the highest tree volume followed by acid lime and the least was from sweet orange trees (Table 1-3). The tree volume has shown a highly positive correlation with DBH (0.88) but a weak positive correlation (0.50) with tree height (Figure 3). A similar trend of correlation between tree volume and DBH has been reported by Yashin et al. (2021).

Table 2. Sweet orange (*Citrus sinensis*) tree's physical parameter and estimated carbon pool of various varieties of grafted trees of age 16 years.

S.N .	Variety	DBH (cm)	Tree height (cm)	Tree volume (cm ³)	AGB (Kg)	BGB (Kg)	Total Biomass/ tree (Kg)	CO ₂ Sequestere d (t/ha)	CO ₂ Seques tered (t/ha/yr)
1	Tamango	13.4	396	41116	24.3	6.31	30.6	35.1	2.19
2	Delicious seedless	11.6	237	17705	10.4	2.72	13.2	15.1	0.943
3	Hamlin	7.80	205	7480	4.41	1.15	5.56	6.38	0.399
4	Vanille	7.26	220	8466	4.99	1.3	6.29	7.22	0.451
5	Malta blood red	12.9	248	24554	14.5	3.77	18.3	20.9	1.31
6	Succari	7.80	220	7455	4.4	1.14	5.54	6.36	0.397
7	Washington navel	13.4	235	25646	15.1	3.93	19.1	21.9	1.37
8	Valencia Late	14.2	337	37034	21.9	5.68	27.5	31.6	1.97
9	Pineapple	7.50	284	9284	5.48	1.42	6.9	7.92	0.495
10	Dhankuta Local	12.3	229	20082	11.8	3.08	14.9	17.1	1.07
11	LueGim Gong	5.36	183	3228	1.9	0.495	2.4	2.75	0.172
12	Salustiana	11.6	399	28731	17	4.41	21.4	24.5	1.53
13	Lane late	10.5	350	20940	12.4	3.21	15.6	17.9	1.12
14	Cara Cara navel	9.61	258	12914	7.62	1.98	9.6	11	0.688
Grand mean		10.6	280	18902.5	11.16	2.89	14.07	16.12	1.01
Standard deviation		4.07	87.3	11594.7	6.86	1.78	8.63	9.90	0.62

DBH- Diameter at breast height, AGB- Above ground biomass, BGB- Below ground biomass.

Table 3. Mandarin (*Citrus reticulata/unshi*) tree physical parameter and estimated carbon pool of various varieties grafted trees of age 18 years.

S.N	Variety	DBH (cm)	Tree height (cm)	Tree volume (cm ³)	AGB (Kg)	BGB (Kg)	Total Biomass/ tree (Kg)	CO ₂ Sequestere d (t/ha)	CO ₂ Seques tered (t/ha/yr)
1	Nules	12.6	283	24146	14.2	3.7	18	20.6	1.14
2	Marisol	13.4	353	35450	20.9	5.44	26.4	30.2	1.68
3	Commune	16.4	352	52145	30.8	8	38.8	44.5	2.47
4	Oraval	16.6	373	53400	31.5	8.19	39.7	45.5	2.53
5	Hernandina	13.4	327	30838	18.2	4.73	22.9	26.3	1.46
6	Paige	14.3	382	44914	26.5	6.89	33.4	38.3	2.13
7	Avana Aprino	18.1	378	68352	40.3	10.5	50.8	58.3	3.24
8	Pixie	14.1	466	51891	30.6	7.96	38.6	44.2	2.46
9	Nova	11.5	268	19747	11.7	3.03	14.7	16.8	0.94
10	Kara	9.34	333	15601	9.2	2.39	11.6	13.3	0.74
11	Fortune	16.0	373	57839	34.1	8.87	43	49.3	2.74
12	Okitsu	12.8	286	24395	14.4	3.74	18.1	20.8	1.16
13	URSS	11.1	198	13843	8.17	2.12	10.3	11.8	0.66
14	Satsuma mino	14.6	220	32157	19	4.93	23.9	27.4	1.52
15	Satsumawase	12.3	258	21186	12.5	3.25	15.8	18.1	1.0
16	Pongan	11.1	358	23665	14	3.63	17.6	20.2	1.12
17	Miyagavawse	13.9	210	23145	13.7	3.55	17.2	19.7	1.1
18	Okitsuwase	11.4	200	14195	8.38	2.18	10.6	12.1	0.67
19	Banskharka	12.8	380	37406	22.1	5.74	27.8	31.9	1.77
20	Sikkime	14.2	423	45989	27.1	7.05	34.2	39.2	2.18
21	Khoku	16.9	335	64177	37.9	9.84	47.7	54.7	3.04
Grand mean		13.7	317	35927.7	21.2	5.5	26.7	30.6	1.7
Standard deviation		4.4	85.5	27959.2	16.5	4.3	12.99	23.84	1.32

DBH- Diameter at breast height, AGB- Above ground biomass, BGB- Below ground biomass

3.4 The Above ground biomass (AGB)

The above-ground biomass of acid lime trees ranged between 1.63 kg (NCRP-57 genotypes) to 32.4 kg (NCRP-51) (Table 1), while the AGB of sweet orange tree ranged between 1.95 Kg (LueGim Gong variety) to 24.3 Kg (Tamango variety) (Table 2) and that of mandarin trees ranged from 8.17 Kg (URSS variety) to 40.3 Kg (Avana Aprino variety) (Table 3). The highest average above ground biomass was from

mandarin trees (21.2 Kg) followed by acid lime trees (15.08 Kg) and the least was from sweet orange trees (11.16 kg) (Table 1-3). The AGB has shown very positive and significant correlation with trunk diameter at breast height (DBH) and tree volume but a weak positive correlation with tree height (Figure 3).

3.5 The Below Ground Biomass (BGB)

The acid lime tree biomass below ground ranged from 0.423 kg (NCRP-57 genotypes) to 8.44 Kg

(NCRP-51 genotypes) (Table 1), while that of sweet orange ranged from 0.495 Kg (LueGim Gong variety) to 6.31 Kg (Tamango variety) (Table 2) and that of mandarin trees ranged from 2.12 (URSS variety) to 10.5 Kg (Avana Aprino variety) (Table 3). Among three citrus species the highest average BGB was from mandarin (5.5 Kg) followed by acid lime trees (3.89 Kg) and the lowest was from Sweet orange trees (2.89 Kg) (Table 1-3). The relationship of BGB was significantly positive with DBH, ABG and tree volume but a weak positive with tree height (Figure 3).

3.6 The Total Biomass

The total tree biomass is the sum of AGB and BGB and acid lime tree's total biomass ranged from 2.05 Kg (NCRP-57 genotypes) to 40.9 Kg (NCRP-51 genotypes) (Table 1), while that of sweet orange ranged from 2.4 Kg (LueGim Gong variety) to 30.6 Kg (Tamango variety) (Table 2) and that of mandarin trees ranged from 10.3 Kg (URSS variety) to 25.4 Kg (Avana Aprino variety) with an average of 50.8 kg (Table 3). The total biomass production was correlated highly significant to tree volume, ABG and BGB (Figure 3).

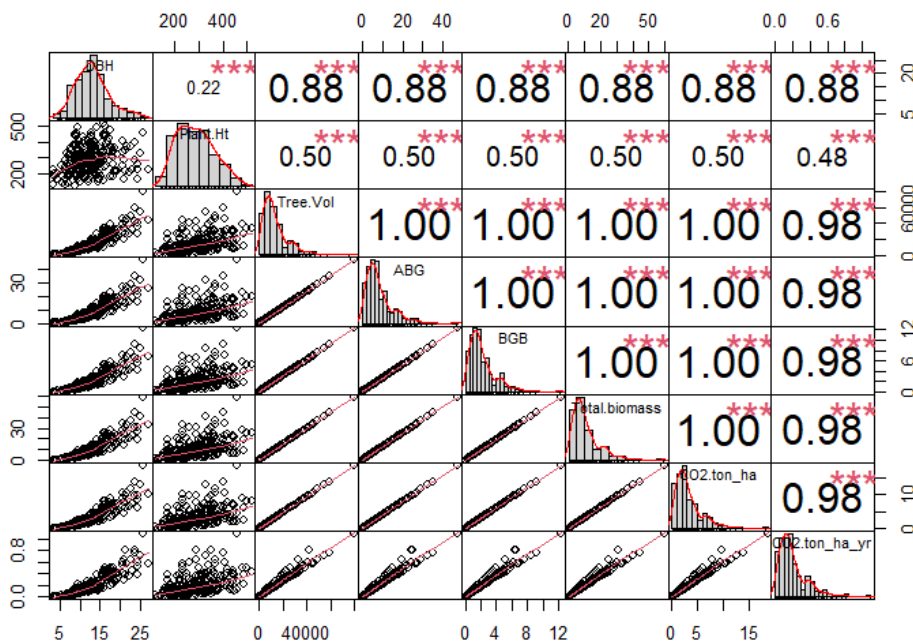


Figure 3. Chart of the correlation matrix of all citrus tree physical parameters and sequestered carbon content. The distribution of each variable is shown on the diagonal of the plot. On the bottom of the diagonal: the bivariate scatter plots with a fitted line are displayed. On the top of the diagonal: the value of the correlation plus the significance level shown as stars (p-values (0, 0.001, 0.01, 0.05, 0.1, 1) $\Rightarrow$ symbols (“***”, “**”, “*”, “.”, “.”))

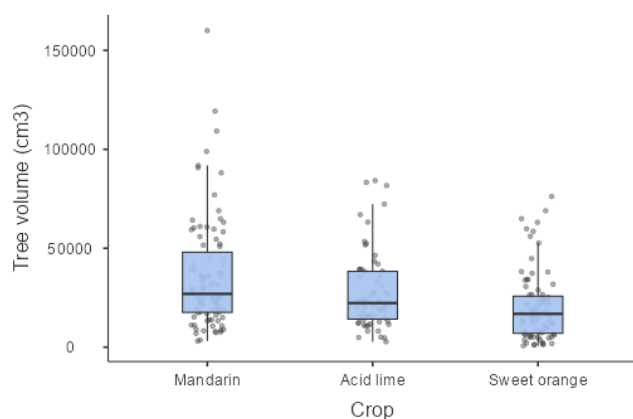


Figure 4. Citrus tree volume based on species

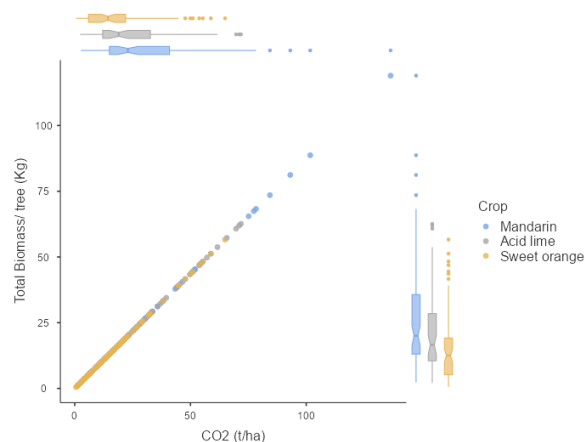


Figure 5. Relationship of tree biomass with the amount of carbon sequestered by citrus tree (CO_2 ton/ha)

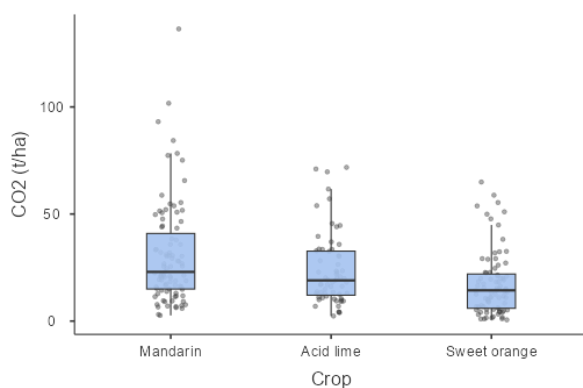


Figure 6. Amount of carbon sequestered (t/ha) by citrus tree based on species

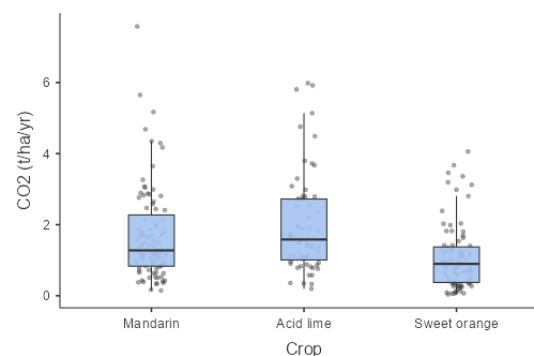


Figure 7. Amount of carbon sequestered by citrus orchards based on tree species (t/ha/yr)

3.7 Carbon sequestered per hectare

The carbon sequestered (CO_2/ha) by acid lime tree ranged between 2.35 to 46.9 with an average of 21.63 (t/ha) (Table 1). Similarly, the carbon sequestered by sweet orange trees ranged between 2.75-35.14 t/ha with an average of 16.12 t/ha (Table 2). In the same line, 18-year-old mandarin trees sequestered carbon ranged between 11.8-58.3 t/ha with an average of 30.6 (Table 3). Among the three species, mandarin

tree sequestered more carbon followed by acid lime and sweet orange (Figure 6). Further, the carbon sequestered by mandarin orchard per hectare per year was in a range of 0.66 to 3.24 with an average of 1.7 t/ha/yr (Table 3). Similarly, the rate of carbon sequestration by the acid lime orchard was in the range of 0.19-3.91 t/ha/yr (Table 1) and that of the sweet orange orchard was 0.172-2.19 t/ha/yr (Table 2). The rate of carbon sequestration was the highest from mandarin orchard followed by acid lime and

sweet orange orchard (Figure 7). The carbon sequestered (ton/ha and ton/ha/yr) was found to be highly correlated with DBH and species of grafted citrus trees (Table 1-3 and Fig. 3).

A study from India on 6-year-old Nagpure mandarin found that the carbon sequestration was 1.65 ton/ha (Mehta *et al.* 2016) whereas it was 30.6 t/ha for the grafted 18-year-old tree with a rate of 0.234 t/ha/yr from this study (Table 3 and Figure 5). The difference in tropical Nagpur climate and sub-tropical Dhankuta climate as well as different management practices could be the reason for this difference (Wembede *et al.*, 2022). The carbon sequestered by sweet orange orchard/ year (1.01) (Table 2, Figure 5) in this study is comparable with the finding of Liguori *et al.* (2009) where they reported it was 0.023-0.186 ton/ha/yr. This could be due to differences in tree age, and climatic and spatial differences of the two locations (Sharma *et al.*, 2021). The interesting finding from the present study is that irrespective of tree age mandarin, sweet orange, and acid lime orchards of Nepal could sequester 1.7; 1.99 and 1.08 tons of carbon/ha/yr, respectively. Further to this based on citrus orchard statistics of MoALD (2023) the present-day mandarin (28451 ha), sweet orange (6227 ha), and acid lime (10321 ha) orchards could

sequester 48367, 6725, and 20521 tons of carbon from the environment each year.

4. CONCLUSION

This study illustrates the potential of integrating fruit orchards into carbon trading systems, a prospect particularly beneficial for Nepal, where nearly 200,000 ha orchards remain unaccounted for. Based on the findings, Nepalese citrus orchards could sequester an estimated 75,613 tons of carbon per hectare per year, regardless of the citrus species involved. While this research marks an initial step toward quantifying carbon sequestration in citrus trees, further studies are essential. These should include multiple citrus species of varying ages and varieties, assessed under diverse environmental conditions, to develop a more comprehensive and reliable carbon estimation model. Moreover, the Government of Nepal is encouraged to consider the inclusion of fruit orchards in future carbon trading assessments.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the staff of NCRP, Dhankuta for their support while collecting study data.

.

REFERENCES

- Acharya, U.K., Pakka, R., Adhikari, D., & Joshi, S.L (2021). Improve citrus production technology. National Citrus Research Program, Dhankuta, Nepal. (Booklet in Nepali language).
- Brown, S., (1997). Estimating Biomass and Biomass Change of Tropical Forests: a Primer. FAO Forestry Paper. FAO, Rome.
- Cairns, M.A., Brown, S., Helmer, E.H., & Baumgarder, G.A. (1997). Root biomass allocation in the World's upland forest. *Oecologia*, 111 (1): 1-11
- Cotta, J. H. (1804). Tafeln zur Bestimmung des Inhalts und Wertes unverarbeiteter Hölzer [Tables for determining the volume and value of unprocessed timber]. Dresden, Germany.
- IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use. <https://www.ipcc-nggip.iges.or.jp/public/2006gl/>
- Jonckheere, I., Fleck, S., Nackaerts, K., Muys, B., Coppin, P., Weiss, M., & Baret, F. (2004). Review of methods for in situ leaf area index determination: Part I. Theories, sensors and hemispherical photography. *Agricultural and Forest Meteorology*, 121(1–2), 19–35. <https://doi.org/10.1016/j.agrformet.2003.08.027>
- Liguori, G., Gugliuzza, G., Inglese, P. (2009). Evaluating carbon fluxes in orange orchards in relation to planting density. *Journal of Agricultural Sciences*, 147: 637-645.
- Mehta, L.C. Singh J., Chauhan, P.S., Singh B., Manhas, R.K. (2016). Biomass accumulation and carbon storage in six-year old *Citrus reticulata* Blanco plantation. *Indian Forestry*, 142:563-568
- MoALD (2023). Statistical information on Nepalese Agriculture 2078/79. Ministry of Agriculture and Livestock Development, Singhdubbar, Kathmandu, Nepal
- MoFE. (2018). Nepal National REED+ Strategy (2018-2022). Ministry of Forest and Environment, Government of Nepal.
- Murphy, T., Jones, G., Vanclay, J., & Glencross, K. (2012). Preliminary carbon sequestration modelling for Australian macadamia industry. *Agroforest Syst*, 87:698-698
- NCRP (2003). Annual Report 2061. National Citrus Research Program, Paripatle, Dhankuta.
- NCRP (2020). Annual Report 2078. National Citrus Research Program, Paripatle, Dhankuta.
- Ravindranath, N.H. & Oswalt, H. (2008). Carbon inventory methods- Handbook for greenhouse inventory, carbon mitigation and round wood production projects. *Advances in Global Changes Research*, Springer, Verlag, Berlin 304.
- Sharma, S., Rana, V.S., Prasad, H. Lakra, J. & Sharma, U. (2021). Appraisal of carbon capture, storage, and utilization through fruit crops. *Frontiers in Environment Science*. 9: 1-10
- The jamovi project (2023). *jamovi*. (Version 2.4) [Computer Software]. Retrieved from <https://www.jamovi.org>.
- Timilsina, A.P., Gaire, A., Malla, G., Rimal, R. & Bhandari, H. (2019). Estimation of carbon sequestration in Macadamia nut in Kaski district, Nepal. *Journal of Agriculture and Environment*, 20:144-151.
- Wambede, M.N., Akello, G., Lugmira, S. J., Barasa, B., Amwonya, D., & Mulabbi, A. (2022). Carbon sequestration of fruit trees under contrasting management regime. *Indonesian Journal of Geography* 54:420-427.
- Yasin, G., Farrakh Nawaz, M., Zubair, M., Qadir, I., Saleem, A. R., Ijaz, M., Gul, S., Amjad Bashir, M., Rehim, A., Rahman, S. U., & Du, Z. (2021). Assessing the Contribution of Citrus Orchards in Climate Change Mitigation through Carbon Sequestration in Sargodha District, Pakistan. *Sustainability*, 13(22), 12412. <https://doi.org/10.3390/su132212412>

DEGREE DAY MODEL OF GRAPEVINE PHENOLOGY IN THE MID-HILL CONDITIONS OF NEPAL

Anil Kumar Acharya^{1*}, Durga Mani Gautam¹, Bhim Bahadur Khatri¹, Puspa Raj Poudel¹ and Kishor Chandra Dahal¹

¹ Institute of Agriculture and Animal Science, Tribhuvan University, Kathmandu, Nepal

ARTICLE INFO	ABSTRACT
Keywords: Budburst, grapevine, heat unit, post-flowering, vineyards *Correspondence: acharyanilku@gmail.com Tel: +9779841714554	Nepal has more than 9000 km² potential area for the viticulture, however, it has yet to be prioritized. Nepal imports huge amount of fresh and dried grapes every year and the trend is increasing. Commercial viticulture has been initiated in recent years in private farms. This study assessed to develop a model to predict budburst, flowering and harvest stage of three grapevine cultivars evaluating the phenological observations in the commercial vineyard during 2023-2024 at Kewalpur Agro-farm of the Patleban Vineyard and Winery, Dhading. Hourly logged data in the vineyard were used to calculate the Growing Degree Days (GDD) and then cumulative degree days from budburst to flowering, budburst to harvest and flowering to harvest stages to determine the GDD model. Cultivars did not show much differences in early growth and phenological stages but during flowering to harvest stage, cultivars showed high variation. The number of GDD and number of days required from budburst to harvest were 1485 and 113; 1513 and 116; and 1592 and 123 for cvs. Talizman, Poloskei Muskotaly and Cabernet Sauvignon, respectively. This GDD model of grape phenology stands potential to optimizing the establishment, expansion and management of productive vineyards at least in mid-hill conditions of Nepal.

1. INTRODUCTION

Viticulture is a recent agro-industry in Nepal. Acharya et al., (2023) documented that established vineyards were limited to small areas in research centers and government farms, such as Directorate of Agricultural Research, (DoAR), Nepal Agricultural Research Council (NARC), Khajura, Banke; Warm Temperate Horticulture Center, Kritipur and Temperate Horticulture Development Center, Marfa under the Department of Agriculture (DoA). Few private farms, such as Kewalpur Agro Farm, Dhading and The Fruits Land Nepal, Bandipur, Tanahu have also established vineyards and winery in their farms. In recent years, commercial vineyards introduced table grapevines cvs. Talizman

and Poloskei Muskotaly in 2020 and wine type seeded cv. Cabernet Sauvignon in 2016 (Kumar Karki 2025, Personal Comm.). In Nepal, around 10,437 grapevines are planted in 38.6 hectares of land excluding home garden purpose.

There is a huge potential to increase the area and production of quality grapes in Nepal to substitute imports and maintain food and nutrition security. The value of Nepal’s fresh grapes import was increased from NPR 674.7 million in 2014 to NPR 2,147 million in 2024. Similarly, the value of dried grapes import was increased from NPR 43.5 million in 2014 to NPR 226.8 million in 2024 (Acharya et al., 2025). In addition, Acharya and Yang (2015) revealed that around 9669

km² (6.6%) area of Nepal is highly favorable for viticulture. These areas have perfect south-facing slope and enough sunshine in the growing season. However, the government priority to viticulture is insufficient and there is no commercial table grape production in Nepal (Dahal et al., 2017).

Several scales of phenological observation for the grapevine (*Vitis vinifera* L.) are available, but the most frequently used is Eichhorn and Lorenz (EL) modified by Coombe (1995). The major phenological stages such as budburst, flowering and harvest are described and denoted by EL number 4, 23 and 38 respectively. The budburst stage is a key phenological stage for grapevine with large site and cultivar variability (Cortazar-Atauri et al., 2009). Calculation of the date of budburst of the grapevine has real predictive value as an indicator of earliness, and thus of the adaptability of cultivars. They also revealed that phenological models assume that budburst is regulated by temperature and is induced by a period with chilling temperatures (dormancy) followed by a period with forcing temperatures (post-dormancy).

Until now, process-based phenological models for the grapevine work on the assumption that phenological development is mainly regulated by temperature (Jones, 2003, Van Leeuwen et al., 2008; Cortazar-Atauri et al., 2009; Caffarra and Eccel, 2010, Duchene et al., 2010, Nendel, 2010). These models are driven by a temperature summation from a defined date and above a minimum temperature (threshold) until the appearance of a phenological stage (often judged at 50% level of appearance). Parker et

al., (2011) reported that, classically, the Spring Warming (SW) model (also known as Growing Degree Days (GDD) is the simplest model used to estimate grapevine phenology (bud break, flowering and veraison). This model calculates a summation of daily heat requirements calibrated from a base temperature (usually 10°C for grapevine) and from a given date. The sum of the resulting values gives a measure of the state of forcing (heat requirements) in degree days (°C). This study aimed to propose a model able to predict budburst, flowering and harvest stage of grapevine cultivars in particular Cabernet Sauvignon, Poloskei Muskotaly and Talizman at Kewalpur, Dhading, mid-hill of Nepal.

2. MATERIALS AND METHODS

In this study, phenological observations were collected in the commercial vineyard at Kewalpur Agro Farm (27.75°N, 85.11°E) of Patleban Vineyard and Winery, located in Dhading, Nepal in 2023 and 2024. The observations were undertaken in three cultivars viz. Cabernet Sauvignon, Poloskei Muskotaly and Talizman of grapevine. During the experiment period, weather data (temperature and relative humidity) were logged using HOBO® (<https://www.onsetcomp.com/>) in the vineyard. The average daily temperature was recorded from January 27 to June 11 in 2023 and 2024 so that the date of major phenological stages such as budburst, flowering and harvest could be compared within the observed period. Figure 1 shows the temperature and relative humidity variation in 2023 and 2024 within the range period.

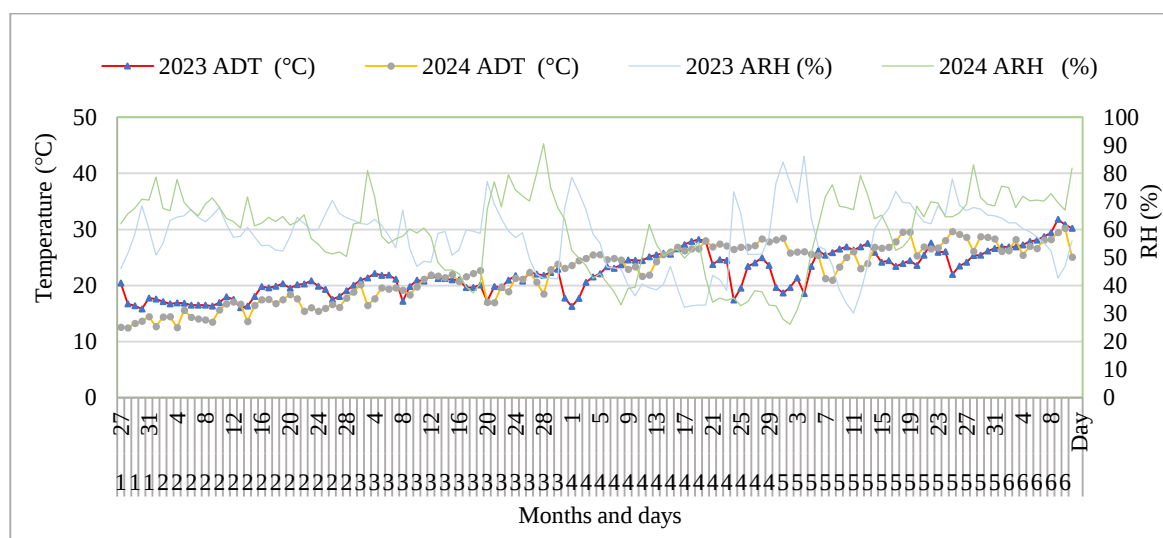


Figure 1. Average daily temperature (ADT) and average relative humidity (ARH) during Jan.-Jun, 2023 and 2024 in the vineyard of Kewalpur Agro Farm, Dhading

Phenological stages were recorded based on modified Eichhorn and Lorenz annual growth stages (EL stages 1-45) of grapevine which describes the phenological stages such as budburst (EL stage 4), flowering (EL stage 23), veraison (EL stage 35), and harvesting (EL stage 38) provided by Coombe and Dry (2004). Budburst (50% buds at EL stage 4), post-flowering (50% cap fall) and harvesting (majority of berries have

>16°Brix) dates of each cultivar were recorded. For budburst, more than 50% budburst stage (plate 1), for flowering more than 50% i.e. post-flowering (plate 2) and harvest day were recorded. Galet (1976) defined budburst as the stage corresponding to 50% of the buds of a given grapevine are having burst.



Plate 1. More than 50% budburst stage

The observations were recorded during the study period which shows the date of >50%



Plate 2. Post-flowering (>50% flowering) stage

budburst, >50% flowering and harvest date of the three grapevine cultivars (Table 1).

Table 1. Observed budburst, flowering and harvest date of grapevine cultivars grown in mid-hill conditions, Nepal

Cultivar	≥50% budburst date		≥50% flowering date		Harvest date	
	2023	2024	2023	2024	2023	2024
Cabernet Sauvignon	6-February	10-February	24-March	2-April	11-June	10-June
Poloskei Muskotaly	15-February	12-February	8-April	2-April	8-June	9-June
Talizman	19-February	12-February	2-April	2-April	9-June	7-June

Growing degree day model (GDD; Equation 1) as described by Cortazar-Atauri et al., (2009), the classical thermal time concept (Bonhomme, 2000), i.e., cumulative daily (n) mean temperatures minus a base (or threshold) temperature (T_0) (assumed constant) was used for the calculation of budburst to flowering and budburst to harvest stage. Budburst to flowering and budburst to harvest occurred when a critical sum (G_c) of growing degree hours (Ac) was reached:

$$\text{Equation 1: } G_c = \sum_{n=1}^{N_{bb1}/N_{bb2}} Ac(n)$$

3. RESULTS AND DISCUSSION

3.1 Grapevine model

Three cultivars viz. Cabernet Sauvignon, Poloskei Muskotaly and Talizman showed slight variation on important phenological observations i.e. 4-5 days in $\geq 50\%$ budburst, 8-9 days in $\geq 50\%$ flowering and 2-3 days in harvest (table 1).

Phenological models of each cultivar are summarized in figure 2. The phenological GDD model representing the average number of days and G_c values from budburst to flowering, flowering to harvest and from budburst to harvest during 2023-2024 was projected. In the earlier growth stages, differences among the cultivars were small due to low G_c value (Figure 2). Talizman

With $Ac(n) = \text{Max. } (T(n) - T_0, 0)$

where, $T(n)$ is the daily mean temperature, n is the day, N_{bb1} is the date of budburst to flowering and N_{bb2} is the date of budburst to harvest. A base temperature (T_0) of 10°C , generally accepted for grapevine (Cortazar-Atauri et al., 2009; Winkler, 1962; Williams et al., 1985; Carbonneau et al., 1992) was used GDD10. The recorded data were managed by using MS Excel and descriptive analysis was done.

required the lowest G_c value (1485.03 hours), followed by Poloskei Muskotaly (1512.75 hours) and Cabernet Sauvignon (1592.21 hours) in between the budburst and harvest which showed that they were early, mid and late cultivars in mid-hill condition. Between post-flowering and fruit development (EL stages between 23 and 38), early cultivars (Poloskei Muskotaly and Talizman) showed a marked acceleration on this development rate with respect to late cultivar (Figure 5). Indeed, this observation led different cultivars to have different degree-days requirements, and to convert degree-day into development units. Santibanez et al., (2014) found the similar result in the table grape phenology.

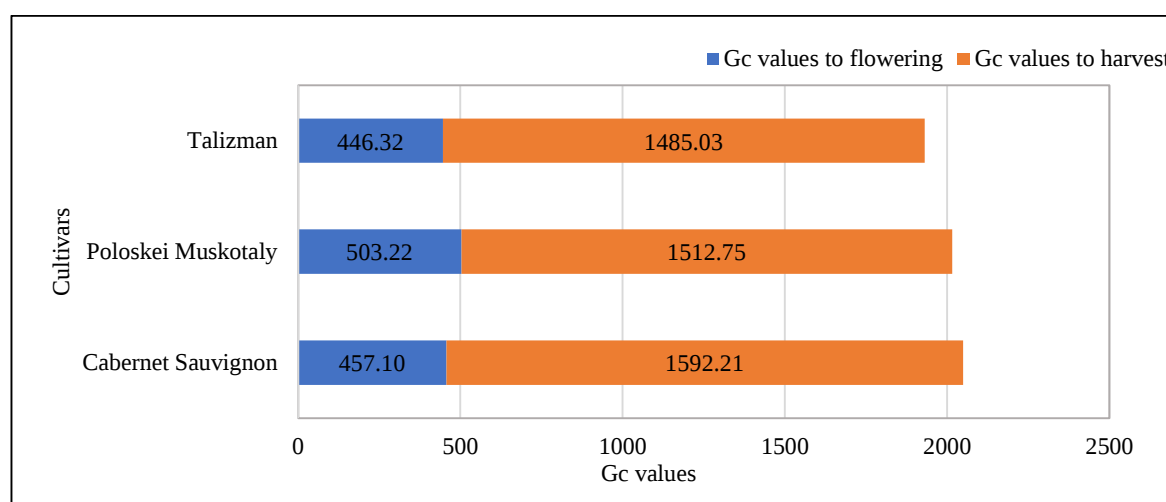


Figure 2. The cumulative hours of GDD for key phenological stages of three grapevine cultivars in mid-hill conditions of Nepal

Figure 3 shows the cultivar wise number of days and G_c value required from budburst to flowering. On the basis of duration between budburst to flowering, cv Talizman showed earliness (46 days), whereas Poloskei Muskotaly showed the late (51 days). Cv.

Cabernet Sauvignon was seemed mid type (49 days) from budburst to flowering stage. The correlation coefficient of determination (R^2) showed a perfect fit of the model to the budburst to flowering stage of the three cultivars.

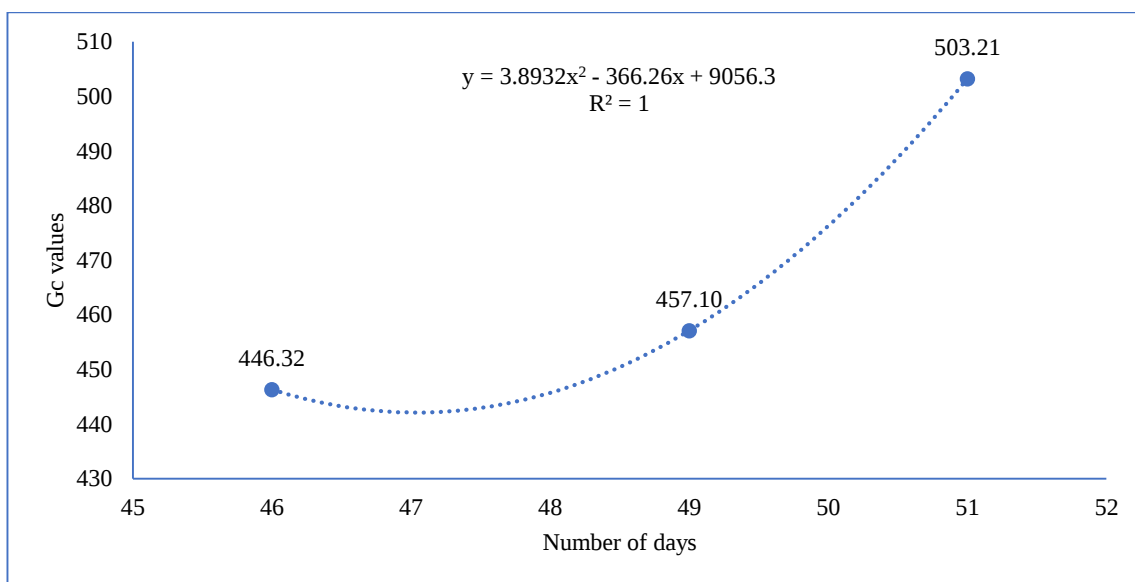


Figure 3. The cumulative hours of GDD from budburst to flowering stage of three grapevine cultivars in mid-hill conditions of Nepal

Three cultivars showed a different phenological model from budburst to harvest (figure 4). The maturity period differed greatly. Cv. Talizman (113 days) was ready for harvest 10 days earlier than cv. Cabernet Sauvignon (123 days). The G_c value of cv. Cabernet Sauvignon (1592.21) was the largest required and number of days from budburst to harvest and was so far late as compared to Poloskei Muskotaly (1512.75) and Talizman (1485.02). As shown in figure 4, the coefficient of determination (R -squared) value is 1, which indicates a perfect fit of the model to the budburst to harvest stage of all three cultivars.

Due et al., (1993) reported that the duration of the phenophase from budburst to flowering varied by less than 2 weeks, whereas from flowering to harvest the range was more than 6 weeks. The phenological differences between varieties are therefore mostly owing to differences in their behaviour between flowering and harvest. They also concluded that the models demonstrated a strong association between harvest date and the weather throughout the season.

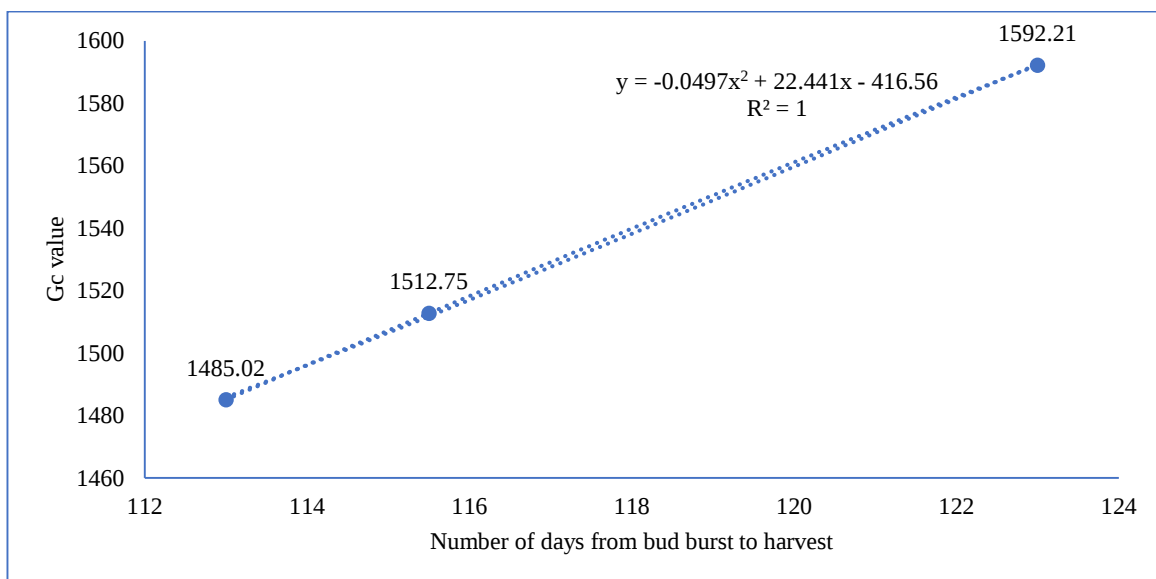


Figure 4. The cumulative hours of GDD from budburst to harvest stage of three grapevine cultivars in mid-hill conditions of Nepal

As the critical factor of cumulative hours of GDD and number of days between flowering to harvest, the finding was found contrast as compared to figure 3 and figure 4. In figure 5, number of days and cumulative hours between flowering to harvest were found the lowest (64.5 and 1009.54) for Poloskei

Muskotaly. Number of days and cumulative hours was found 67 and 1038.71 in Talizman, slightly higher than Poloskei Muskotaly. Out of these three varieties, cv. Cabernet Sauvignon required the longest duration (74 days) and cumulative hours (1135.11) from flowering to harvest stage.

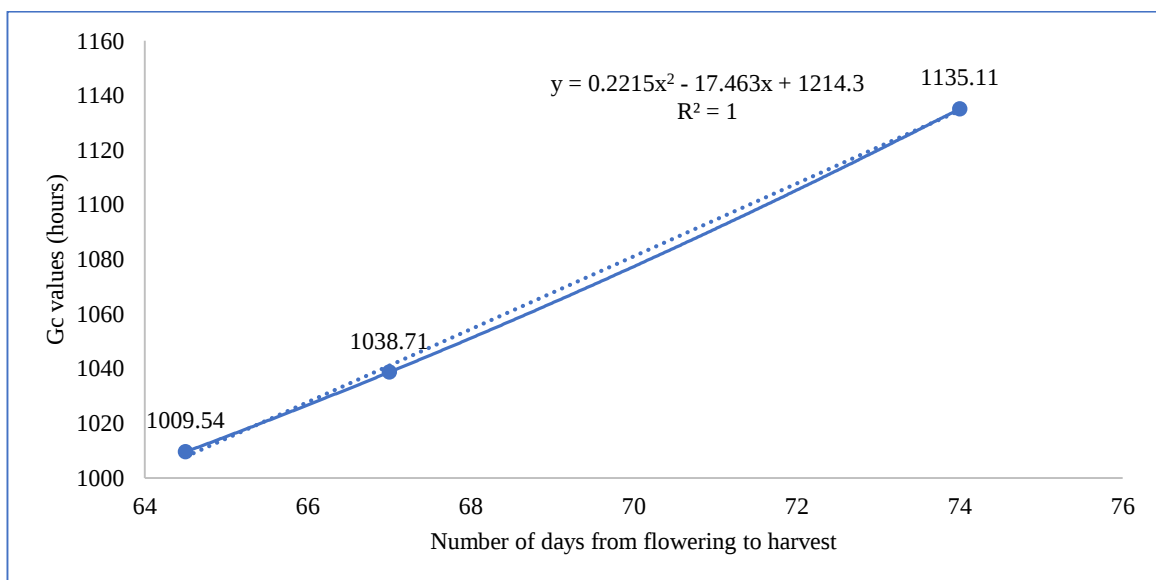


Figure 5. The cumulative hours of GDD from flowering to harvest stage of three grapevine cultivars in mid-hill conditions of Nepal

4. CONCLUSION

Phenological development of grapevine is mainly regulated by temperature. Cultivars did not show a big difference at the early phenological stage i.e. from budburst to flowering but between the reproductive to maturity stage, cultivars showed high variation. The number of growing degree days and number of days required from budburst to harvest were found 1485.02 and 113 for early cultivar i.e. Talizman, 1512.75 and 115.50 for mid cultivar i.e. Poloskei Muskotaly, and 1592.21 and 123 for late

cultivar i.e. Cabernet Sauvignon, respectively. This indicates the winter bud burst before the second fortnight of February enables the successful harvesting during the first fortnight of June i.e. before the onset of monsoon. Harvesting before monsoon is the plausible strategy for successful cultivation of grapevines in Nepal. This GDD model of grape phenology stands potential to optimize the establishment, expansion and management of productive vineyards in mid-hill conditions of Nepal.

REFERENCES

- Acharya, T.D., & Yang, I.T. (2015). Vineyard suitability analysis of Nepal. *International Journal of Environmental Sciences*, 6(1), 13-19.
- Acharya, A.K., Acharya, S., Kushwaha, A., & Dahal, K. C. (2023). Understanding bud fruitfulness and importance of gibberellic acid (GA₃) application(s) in successful grapevine cultivation. 2nd International Conference on Horticulture from 3 to 4 April 2023 (Advancing Horticulture in Changing Climate & Biodiversity), Godavari Village Resort, Lalitpur, Nepal.
- Acharya, A.K., Gautam, D.M., Khatri, B.B., Poudel, P.R., & Dahal, K.C. (2025). Effect of gibberellic acid application on berry yield and quality of grapevine cv. Cabernet Sauvignon. *Crop Res.*, 60, doi::10.31830/2454-1761.2025.CR-1008
- Bonhomme, R. (2000). Bases and limits to using “degree-day” units. *Eur. J. Agron.*, 13, 1-10, doi:10.1016/S1161-0301(00)00058-7
- Caffarra, A., & Eccel, E. (2010). Increasing robustness of phenological models for *Vitis vinifera* cv. Chardonnay. *International Journal of Biometeorology*, 54, 255–267.
- Carbonneau, A., Riou, C., Guyon, D., Riou J., & Schneider, C. (1992). Agrométéorologie de la vigne en France. EUR-OP, Luxembourg, p 168.
- Coombe, B.G. (1995). Adoption of a system for identifying grapevine growth stages. *Aust. J. Grape Wine. Res.*, 1, 104-110.
- Coombe, B.G., & Dry, P.R. (2004). *Viticulture Volume 1 - Resources* (2nd edition). Winetitles Pvt Ltd, Adelaide, South Australia.
- Cortazar-Atauri, I.G.D., Brisson, N., & Gaudillere, J.P. (2009). Performance of several models for predicting budburst date of grapevine (*Vitis vinifera* L.). *Int. J. Biometeorol.*, 53, 317–326.
- Dahal, K.C., Bhattarai, S.P., Midmore, D.J., Oag, D., & Walsh, K.B. (2017). Table grape production in the subtropics and prospects for Nepal. *Nepalese Horticulture*, 12, 6-15.
- Duchene, E., Huard, F., Dumas, V., Schneider, C., & Merdinoglu, D. (2010) The challenge of adapting grapevine varieties to climate change. *Climate Research*, 41, 193–204.
- Due, G., Morris M., Pattison, S., & Combe, B.G. (1993). Modelling grapevine phenology against weather: considerations based on a large data set. *Agricultural and Forest Meteorology*, 65, 91-106.
- Galet, P. (1976). *Precis de Viticulture*. Dehan, Montpellier, France.
- Jones, G.V. (2003). Wine grape phenology. In: *Phenology: an integrative environmental science*, 1st edn. Ed. M.D. Schwartz (Kluwer Press: Milwaukee, MA), 523–539.
- Nendel, C. (2010). Grapevine bud break prediction for cool winter climates. *International Journal of Biometeorology*, 54, 231–241.
- Parker, A.K., Cortazar-Atauri, I.G.D., Leeuwen, C.V., & Chuine, I. (2011). General phenological model to characterise the timing of flowering and veraison of *Vitis vinifera* L. *Australian Journal of Grape and Wine Research*, 17, 206–216.
- Santibanez, F., Sierra, H., & Santibanez, P. (2014). Degree day model of table grape (*Vitis vinifera* L.) phenology in Mediterranean temperate climates. *International Journal of Science, Environment*, 3(1), 10-22.
- Van Leeuwen, C., Garnier, C., Agut, C., Baculat, B., Barbeau, G., Besnard, E., Bois, B., Boursiquot, J.M., Chuine, I., Dessup, T., Dufourcq, T., Garcia-Cortazar, I., Marguerit, E., Monamy, C., Koundouras, S., Payan, J.C., Parker, A., Renouf, V., Rodriguez-Lovelle, B., Roby, J.P., Tonietto, J., & Trambouze, W. (2008). Heat requirements for grapevine varieties are essential information to adapt plant material in a changing climate. *Proceedings of the 7th International Terroir Congress, Changins, Switzerland (Agroscope Changins-Wädenswil: Switzerland)*, 222–227.
- Williams, D.W., Williams, L.E., Barnett, W.W., Kelley, K.M., & Mckenry, M.V. (1985). Validation of a model for the growth and development of the Thompson seedless grapevine. I. Vegetative growth and fruit yield. *Am. J. Enol. Vitic.*, 36, 275–282.
- Winkler, A.J., Cook, J.A., Kliewer, W.M., & Lider, L.A. (1962). *General viticulture*. University of California Press, Berkele.

EVALUATION OF SINGLE-CROSS MAIZE HYBRIDS IN WINTER AT RAMPUR, CHITWAN, NEPAL

Priyanka bhandari^{1,*}, Bijay Mahato¹, Ghanashyam Bhandari³, Aayam Poudel¹ and Mahendra prasad Tripathi²

¹ Nepal Polytechnic Institute (NPI), Purbanchal University

² National Maize Research Program (NMRP)/NARC

³ Ginger Research Program (GRP)/NARC

ARTICLE INFO

Keywords:

Food security,
Hybrid maize,
Productivity,
Single cross,
Weather

*Corresponding author:

piru.bhandari2000@gmail.com

ABSTRACT

To Support the development of single-cross maize hybrids in the Nepalese context, seventy-two single-cross maize hybrids were planted using an alpha lattice design with two replications during the winter season of 2023. Research was undertaken to examine and evaluate single-cross maize hybrids' agronomic and yield traits. Data were recorded on various agronomic and yield-attributing traits. The analysis of variance revealed significant differences ($p < 0.005$) for all traits except the ear aspect and the number of kernels per row. The results indicated that the genotype RL373/RML96 had the highest plant height (249 cm), while RL273/CML581 had the highest ear height (145 cm). The longest cob length was observed in RML122/CML581 (19.2 cm), while the highest cob diameter was found in CAL14137/RML17 (4.7 cm). The highest thousand-grain weight (548 g) was recorded in RL273/CML581. Similarly, RML273/CML581 produced the highest grain yield (10,254 kg/ha), followed by RML122/CML581 (9,705 kg/ha), RL278/CML581 (9,004 kg/ha), RL293/RML17 (8,855 kg/ha), and RL273/RML96 (8,517 kg/ha). Correlation analysis suggested that the number of plants per hectare, number of ears per hectare, plant height, ear height, cob diameter, cob length, number of kernels per row, and thousand-grain weight were positively correlated with grain yield. Therefore, RML273/CML581, RML122/CML581, and RL278/CML581 demonstrated superior performance in terms of grain yield and can be utilized in breeding programs for varietal development.

1. INTRODUCTION

Maize (*Zea mays* L., $2n=2x=20$) stands as the second most important staple crop in Nepal after rice, both in terms of area and production. Maize is a monoecious and cross-pollinated crop, which thrives in hot, dry climates, making it highly efficient in energy production. It is a principal food crop of the hilly farmers and a source of animal feed for different feed industries in the Terai region of Nepal (Timsina et al., 2016).

Maize holds a vital position in Nepal's economy, particularly within the agricultural sector, which contributes 25.02% of total

cereal production, 6.88% of Agriculture Gross Domestic Product (AGDP), and 3.15% of Gross Domestic Product (GDP) (Sapkota and Joshi, 2021). The United States leads global production with a 31.54% share, followed by China (23.37%) and Brazil (10.28%) (FAOSTAT, 2024). The total maize cultivation area in Nepal spans 985,565 hectares, yielding 3,106,397 metric tons with an average productivity of 3.15 tons per hectare (MOALD, 2021/2022). Bagmati Province, in particular, plays a crucial role in national production, with 476,432 hectares under cultivation, producing 1,451,755 metric tons at a productivity rate of 3.05 metric tons per hectare (MOALD, 2021/2022). In Chitwan, maize is cultivated over 63,402

hectares, producing 236,145 metric tons with a productivity rate of 3.72 metric tons per hectare (MOALD, 2021/2022).

Hybrid maize technology holds significant potential to increase maize yields in Nepal. Hybrids, which are the first-generation offspring of a cross between parents with contrasting traits, can yield 25-30% more than traditional open-pollinated varieties (OPVs) (Koirala et al., 2021). Hybrid maize development in Nepal has been ongoing since 1999 under the leadership of the National Maize Research Program (NMRP). To date, NMRP has released several hybrid varieties, including Gaurav, Rampur Hybrid-2, Rampur Hybrid-4, and Rampur Hybrid-6. Additionally, Rampur Hybrid-8 and Rampur Hybrid-10 have been registered as heat-stress resilient hybrids, specifically designed for commercial cultivation in the Terai and Inner Terai regions up to 700 meters during the winter season (Timsina et al., 2016).

Despite these advancements, the adoption of hybrid maize in Nepal has been limited, largely due to the country's diverse agro-ecological conditions. Identifying and developing superior hybrid varieties that are well-suited for winter planting in the inner terai regions remains a critical challenge (Tripathi et al., 2016). The maize production scenario in Nepal is further complicated by the increasing demand for maize from the poultry industry. Maize is a vital raw material for

poultry feed and constitutes about 60% of the total feed ingredients (Kandel and Shrestha., 2020). To address these challenges, the NMRP is intensifying efforts to develop new hybrid maize varieties while also evaluating and registering hybrids from multinational seed companies. However, given Nepal's complex agroecological conditions, not all hybrids are suitable for cultivation nationwide. Developing region-specific hybrids that can meet both food and feed demands is essential for enhancing food security, supporting the expanding poultry industry, and reducing dependence on imported maize. Ensuring the availability of superior hybrid varieties and improving productivity in maize cultivation will be crucial for Nepal's agricultural growth and economic resilience in the face of increasing demand.

2. MATERIALS AND METHODS

2.1 Experimental site

The present research was carried out during the winter season of 2023, at the field of the National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. The experimental site was located at a latitude of 27°40'N, a longitude of 84°19'E, and an elevation of 228 meters above mean sea level. Weather parameters were gathered from the weather station of the National Maize Research Program (NMRP), Rampur, Chitwan. Temperature, Relative humidity, and Rainfall during the study are illustrated in Figure 1.

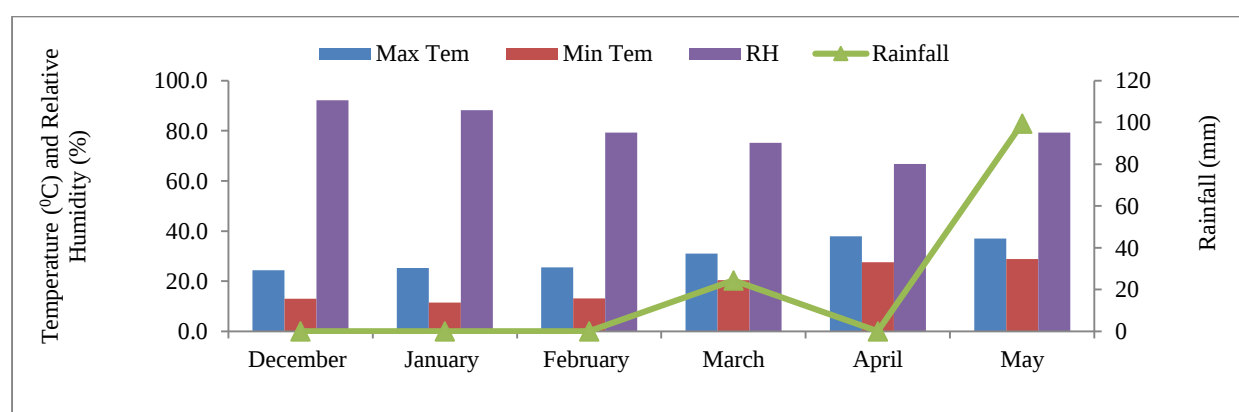


Figure 1. The Graph showing the weather conditions of NMRP during the research period at NMRP, Chitwan (2023).

2.2 Experimental materials

A total of 72 genotypes (RH-10, RH-14, and SULTAN) Check varieties (Table 1) were

tested using an alpha lattice design with two replications.

Table 1. List of tested genotypes in the experiment

S. N.	ENTRY NAME	SN	ENTRY NAME	SN	ENTRY NAME
1	CAH14137/CML581	25	RL279/RML76	49	RML122/CML581
2	CAL14137/RML17	26	RL279/RML96	50	RML122/RML17
3	CML14137/RML76	27	RL290/CML581	51	RML122/RML76
4	CAL14137/RML96	28	RL290/RML17	52	RML145/CML581
5	RL143/CML581	29	RL290/RML76	53	RML145/RML17
6	RL143/RML17	30	RL290/RML96	54	RML145/RML76
7	RML64/RML17	31	RL292/CML581	55	RML145/RML96
8	RL143/RML76	32	RL292/RML17	56	RML191/RML17
9	RL143/RML96	33	RL292/RML76	57	RML191/RML96
10	RL208/CML581	34	RL292/RML96	58	RML32/CML581
11	RL208/RML17	35	RML293/CML581	59	RML32/RML17
12	RL208/RML96	36	RL293/RML17	60	RML32/RML76
13	RL254/CML581	37	RL293/RML76	61	RML132/RML96
14	RL254/RML17	38	RL293/RML96	62	RML46/CML581
15	RL254/RML96	39	RL294/CML581	63	RML46/RML17
16	RL273/CML581	40	RL294/RL17	64	RML46/RML76
17	RL273/RML17	41	RL294/RML76	65	RML46/RML96
18	RL273/RML76	42	RL294/RML96	66	RML64/CML581
19	RL273/RML96	43	RL84/CML581	67	RML64/RML76
20	RL278/CML581	44	RML84/RML17	68	RML64/RML96
21	RL278/RML17	45	RL84/RML76	69	RH10
22	RL278/RML96	46	RL84/RML96	70	RH-16
23	RL279/CML581	47	RL257/RML17	71	CAH1511
24	RL279/RML17	48	RL257/RML76	72	SULTAN

Source: National Maize Research Program (NMRP)

2.3 Experimental design and crop management

The experimental site was located at a latitude of 27°40'N, a longitude of 84°19'E, and an elevation of 228 meters above mean sea level. The experiment was conducted using an alpha lattice design, with a plot size of 3 m² and crop geometry of 60 cm × 25 cm. Each plot was leveled to ensure uniform seed planting conditions in the field. Healthy genotype seeds were selected for sowing, which was carried out manually on December 12, 2023. Seeds were sown at a rate of one seed per hill, at a depth of 4-5 cm. Each row contained 21 seeds, resulting in a total of 42 seeds per plot. Irrigation was applied as needed during critical growth stages, including the knee-length stage, silking stage, and milking/dough stage, using the furrow method. For weed management, a pre-emergence herbicide mixture of Atrazine (2.5 g) and pendimethalin @5 ml per liter of water was used.

2.4 Data collection and analysis

Seventy-two genotypes were observed according to their quantitative and qualitative

characteristics. Additionally, a recording was done by selecting 3 random competitive sample plants from the middle two rows of each plot, then the average was taken as the mean of the treatment. The observations were taken as per the standard norms as per National maize research program (NMRP) which are described below Plant height (cm) Ear height (cm) number of plants, number of ear aspects (1-5), cob length (cm), cob diameter (cm), number of kernel rows, number of kernels per row, thousand-grain weight (g) and grain yield (kg). All these parameters were recorded and analyzed by measuring tapes or scales, vernier caliper, moisture meter, digital weight balance, threshing machine, and seed counter. Similarly, Microsoft Excel, PB tools, and STAR were used for data entry and analysis (Wani et al., 2022). Grain yield (kg/ha) at 12.5% moisture content was calculated using fresh ear weight with the help of the following formula (Kafle et al., 2020)

$$\text{Grain yield (kg/ha)} = \frac{\text{Field weight (kg/ha)} \times (100 - \text{HMP}) \times S \times 1000}{100 - \text{DMP} \times \text{NPA}}$$

Where,
 F.W. = Fresh weight of ear in kg per plot at harvest
 HMP = Grain moisture percentage at harvest
 DMP = Desired moisture percentage, i.e., 12.5%
 NPA = Net harvest plot area, m²
 S = Shelling coefficient, i.e., 0.8

3. RESULTS

The highly significant difference was observed in the number of plants per hectare, the number of ears per hectare, plant height, and ear height, whereas, non-significant difference was observed in ear aspect (Table 2). The result revealed that the mean number of plants per hectare was 71898, which ranged from 63333 to 85000. The highest number of plants per hectare (85000) was found in genotypes RML122/RML17 followed by multinational company hybrid namely SULTAN (check) (81667), CAL14137/RML17 (81607) and the lowest number of plants per hectare was found in genotypes RL290/CML581 (63333) followed by RL273/CML581 (70000). The mean number of ears per hectare was 73500,

ranging from 95000 to 103333. Among them, the highest number of ears per hectare was found in genotypes RL293/RML17, RH16, and RL278/CML581, and the lowest number of ears per hectare was found in genotypes RH-10, RL290/CML581, and SULTAN (check). The mean plant height was 220 cm, ranging from 196 cm to 249 cm, and the highest plant height was found in genotype RL273/RML96, followed by Sultan and RL290/CML581. The shortest plant was found in genotype RH-10, at par with RH-16. The mean ear height was 125 cm, ranging from 87 cm to 145 cm. The longest ear height was found in RL273/CML581, followed by RL273/RML96 and RL290/CML581, whereas the shortest ear height was found in RH-10. Similarly, clean, uniform, large, and well-fitted ears were obtained from genotype RL273/CML581, RL290/CML581 and RL273/RML96. The mean of ear aspect is 2.7 ear aspect was non-significant to grain yield. The broad-sense heritability for number of plants per hectare, number of ears per hectare, plant height, ear height, and ear aspect was 68%, 56%, 66%, 66%, and 31%, respectively

Table 2. Mean comparison of agro-morphological traits and population traits of the top 10% of single-cross maize hybrids at NMRP, Chitwan

Genotypes	No. of plants Per hectare	No. of ears Per hectare	Plant height (cm)	Ear height (cm)	Ear aspect (1-5)
RL273/CML581	68333	90000	238	145	1.5
RML122/CML581	75000	86667	238	133	3.5
RL278/CML581	78333	91667	237	132	3
RL293/RML17	80000	103333	196	117	2.5
RL273/RML96	70000	85000	249	143	2.3
CAL14137/RML17	81607	75000	222	135	2.5
RML122/RML17	85000	85000	225	135	3.3
RL290/CML581	63333	65000	239	142	1.8
RH-10	75000	45000	204	87	3.0
RH16	75000	95000	203	116	3.0
SULTAN	81667	66667	248	126	3.3
Mean	71898	72500	220	125	2.7
SEM	6534.8	9423	9.5	8.1	0.4
F test	***	**	***	***	Ns
LSD _{0.05}	8824	12640	13.01	11.25	0.51
H ²	0.68	0.56	0.66	0.66	0.31

Note: No.=Number, Ha=Hectare, cm=Centimeter, H=Heritability, LSD=Least Standard Deviation, SEM=Standard Error Mean.

*Significant at 5% level, ** significant at 1% level and *** significant at 0.1 percent level.

A highly significant difference was observed for the cob length and grain yield, whereas a significant difference was observed for cob diameter, number of kernel rows, thousand kernel row, and a non-significant difference was observed for number of kernels per row among the genotypes (Table 3). The mean cob length was 15.8cm, which ranged from 14.8 cm to 19.2 cm. The longest cob was found in genotype RML122/CML581, followed by RL290/CML581 and RL273/CML581. The shortest cob was found in genotype RH16, followed by RL293/RML17 and RL273/RML96. Hence, longer cob length directly affects the grain yield. (Turi et al., 2007)The mean cob diameter was 4.4cm, which ranged from 4.2cm to 4.7cm. The highest cob diameter was found in genotype CAL14137/RML17, followed by RML122/CML581, RML122/RML17, and RH-10. The lowest cob diameter was found in genotype RL293/RML17, followed by RL290/CML581. Cob diameter, which is closely linked to grain production, is one of the most important yield factors (Silva et al., 2007). Similarly, the mean number of kernel rows was 13.5, which ranged from 12.8 to 14.4. The maximum number of kernel rows was observed in RL290/CML581, followed by RML122/RML1 and RL273/CML581,

whereas SULTAN shows the minimum number of kernel rows. The mean number of kernels per row was 31, which ranged from 27 to 36. The maximum number of kernels per row was obtained from RML122/CML581 at par RL290/CML581 and followed by RL273/CML581. The minimum number of kernels per row was found in SULTAN, followed by RL278/CML581 and CAL14137/RML17. The mean thousand-grain weight was (397g). The highest thousand-grain weight was obtained in genotypes RL273/CML581 (548g), followed by CAL14137/RML17 (538g), RH-10 (485g), and RL293/RML17 (452g). Similarly, the lowest was found in genotypes RL290/CML581 (349g), RL278/CML581 (361g), and RH16 (362g), respectively. Likewise, the mean grain yield was 6680 kg. The highest grain yield was obtained from RL273/CML581 (10254kg), followed by RML122/CML581 (9705kg), RL278/CML581 (9004kg), RL293/RML17 (8855kg), and RL273/RML96 (8517kg). The minimum grain yield was obtained from RH-10 (4291kg). The broad sense of heritability for cob length, cob diameter, number of kernel rows, number of kernels per row, thousand kernel rows, and gain yield is 64%, 27%, 42%, 2%, 48%, and 67% respectively.

Table 3. Mean comparison of grain yield and yield component traits of the top 10% of single-cross maize hybrids at NMRP, Chitwan

Genotypes	Cob Length (cm)	Cob diameter (cm)	Number of kernel rows	Number of kernels per rows	Thousand kernel rows (g)	Grain Yield (kg)
RL273/CML581	17.3	4.4	14	34	548	10254
RML122/CML581	19.2	4.6	13.4	36	406	9705
RL278/CML581	17.2	4.4	13.2	32	361	9004
RL293/RML17	15.0	4.2	13	30	452	8855
RL273/RML96	15.3	4.5	13.6	30	414	8517
CAL14137/RML17	16.4	4.7	13.4	31	538	8498
RML122/RML17	17.1	4.6	14	31	395	8132
RL290/CML581	19.2	4.4	14.4	36	349	8091

RH-10	16.1	4.6	13.6	33	485	4291
RH16	14.8	4.4	13.8	29	362	8057
SULTAN	15.5	4.5	12.8	27	448	5542
Mean	15.8	4.4	13.5	31	397	6680
SEM	0.71	0.14	0.62	3.59	42.70	1040
F test	***	*	*	ns	**	***
LSD _{0.05}	1.01	0.20	0.88	5.07	58.76	1308
H ²	0.64	0.27	0.42	0.2	0.48	0.67

Note: Ha=Hectare, cm=Centimeter, H=Heritability, g=Gram, kg=Kilo gram, LSD=Least Standard Deviation, SEM=Standard Error Mean.

*Significant at 5% level, ** significant at 1% level, and *** significant at 0.1% level.

The result of correlation analysis shows that the grain yield has a positive and significant correlation with plant height, ear height, number of plants per hectare, number of ears per hectare, cob length, cob diameter, and number of kernels per row (Table 4). Other traits, such as several kernel rows and thousand kernel weights, showed positive correlations with grain yield (Table 4). Similarly, the ear aspect shows significant but negative correlations with grain yield, suggesting that a damaged ear will decrease the performance of plants, which leads to a loss in their yield. This indicates that an increase in this parameter will directly affect the yield of maize. Thousand kernel weight shows no significant relationship with grain

yield. Similarly, Grain yield was also positively correlated with plant height, cob length, and number of kernels per row. The plant height is influenced by competitive environments, light interception, carbon and nutrient capture, and weed competition. Additionally, results show a positive and significant correlation between ear height and the number of ears per hectare. It indicates that an increase in ear height and number of ears positively affects the production and productivity of maize yield. The result of correlation analysis suggests that grain is highly impacted by many parameters; an increase in one parameter directly affects productivity and vice versa.

Table 4. Correlation of maize genotypes with grain yield parameters

Variable	PH	EH	NOP	NOE	EA	CL	CD	NOKR	NOKPR	TGW
Plant height										
Ear height	.741**									
Number of plants	.170*	0.097								
Number of ears	0.057	0.148	.506**							
Ear aspect	-0.092	-0.098	-0.134	-.235**						
Cob length	0.086	0.002	0.029	0.094	.283**					
Cob diameter	0.097	0.060	-0.004	0.129	-.178*	.281**				
Number of kernels row	-0.004	0.099	0.111	0.069	-0.061	0.059	.208**			
Number of kernels per row	-0.050	-0.095	0.045	0.077	-0.136	.308**	.168*	.267**		
Thousand-grain weight	0.024	0.009	-0.062	-0.113	-0.069	0.121	0.115	-.189*	-0.029	
Grain yield	.219**	.236**	.398**	.789**	-.529**	.334**	.344**	0.119	.211*	0.031

*Note: PH= Plant Height, EH= Ear Height, NOP= Number of plants per hectare, NOE= Number of Ear per hectare EA= Ear aspect, CL= Cob Length, CD= Cob Diameter, NOKR=Number of kernel rows, NOKPR=Number of kernels per rows TGW= Thousand kernel weight, GY= Grain yield, *Significant at 5% level of significance and ** significant at 1% level of significance.*

4. DISCUSSIONS

Maize grain yield is a complex trait influenced by various agronomic and morphological factors, with significant differences reported across multiple studies. Significant differences in the number of plants harvested were previously reported by (Abuzar et al., 2011) who also found that grain yield was significantly affected by plant population

density. Similar findings were obtained from (Rai et al., 2022; Gautam et al., 2022) who found significant differences in plant height. Similarly, the findings of the study were also supported by (Dawadi and Sah, 2012), which showed that grain yield was significantly influenced by plant height. Comparable results on ear height were also recorded by (Kandel and Shrestha, 2020). The ear aspect was found to be non-significant in grain yield, which

aligns with the findings of (Kandel and Shrestha, 2020). Sharma et al. (2021) reported that the larger the cob length, the higher the grain yield, indicating that a longer cob length directly affects grain yield. The yield gain was attributed to an increase in the number of kernels per ear (Tandzi and Mutengwa, 2020). the findings of this study on the number of kernels per row are consistent with those of (BK et al. 2018). A study by (Rai et al. 2022) found a positive and significant relation between the number of plants per hectare and cob diameter. Similarly, thousand-grain weight shows a positive correlation with grain yield, and a study by (Reddy et al. 2022) also supports my findings. Similarly, Grain yield was also positively correlated with plant height, cob length, and number of kernels per row in the study of (Sharma et al. 2021). The agronomic traits, like plant height, have a positive correlation as well as a positive direct effect on the grain yield (Kandel and Shrestha, 2020; Joshi et al., 2020). Additionally, results obtained in (Thapa et al. 2022) suggest a

positive and significant correlation between ear height and the number of ears per hectare.

5. CONCLUSION

The study identified significant differences among maize hybrids for key agronomic and yield traits, indicating the potential for selecting superior genotypes. The high-yielding genotypes identified in the experiment were RML273/CML581, RML122/CML581, and RL293/RML17. This study thus revealed that some of the single-cross maize has a high potential; therefore, further research should be conducted across multiple locations.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to the National Maize Research Program (NMRP), Chitwan, Nepal, for providing the research field, materials, and guidance. We also extend our heartfelt thanks to Mrs. Debu Maya Bhandari for her valuable support during the fieldwork.

REFERENCES

- Abuzar, M. R., Sadozai, G. U., Baloch, M. S., Baloch, A. A., Shah, I. H., Javaid, T., & Hussain, N. (2011). Effect of plant population densities on the yield of maize. *The Journal of Animal & Plant Sciences*, 21(4), 692-695.
- Bk A, J Shrestha and R Subedi. 2018. Grain yield and yield attributing traits of maize genotypes under different planting dates. *Malaysian Journal of Sustainable Agriculture*. 2(2). DOI: <https://doi.org/10.26480/mjsa.02.2018.06.08>
- Dawadi D and S Sah. 2012. Growth and Yield of Hybrid Maize (*Zea mays* L.) in relation to Planting Density and Nitrogen Levels during Winter Season in Nepal. *Tropical Agricultural Research*. 23(3). DOI: <https://doi.org/10.4038/tar.v23i3.4659>
- Joshi BK, DK Ayer, D Gauchan and D Jarvis. 2020. Concept and rationale of evolutionary plant breeding and its status in Nepal. *Journal of Agriculture and Forestry University*. DOI: <https://doi.org/10.3126/jafu.v4i1.47023>
- Kafle S, N Adhikari, S Sharma and J Shrestha. 2020. Evaluation of single-cross maize hybrids for flowering and grain yield traits. *Fundamental and Applied Agriculture*. (0). DOI: <https://doi.org/10.5455/faa.130574>
- Kandel BP and K Shrestha. 2020. Performance evaluation of maize hybrids in inner-plains of Nepal. *Heliyon*. 6(12). DOI: <https://doi.org/10.1016/j.heliyon.2020.e05542>
- Koirala K.B, B Nath Adhikari and M Prasad Tripathi. 2021. Maize (*Zea mays* L.) hybrids for Terai ecological belt of Nepal. *Journal of Agricultural Research Advances Research*. (1):21–28.
- Rai K, O Kulung, S Bhandari, HG Singh and Mahendra Tripathi. 2022. Evaluation of single cross maize hybrids during the spring season in Khairahani, Chitwan, Nepal. *Journal of Agriculture and Applied Biology*. 3(2). DOI: <https://doi.org/10.11594/jaab.03.02.08>
- Sapkota M and NP Joshi. 2021. Factors Associated with the Technical Efficiency of Maize Seed Production in the Mid-Hills of Nepal: Empirical Analysis. *International Journal of Agronomy*. 2021. DOI: <https://doi.org/10.1155/2021/5542024>
- Sharma H.P., J Upadhyaya and J Shrestha. 2021. Analysis of correlation and agro-morphological traits in single cross hybrids of maize. *Russian Journal of Agricultural and Socio-Economic Sciences*. 117(9):143–149. DOI: <https://doi.org/10.18551/rjoas.2021-09.16>
- Sharma Hari Prasad, A Journals and J Shrestha. 2021. Single-cross maize hybrids with mid and better parent heterosis in growth and yield attributing traits. *Azarian Journal of Agriculture Azarian J. Agric*. 8:92–99. DOI: <https://doi.org/10.52547/azarinj.057>
- Tandzi LN and CS Mutengwa. 2020. Estimation of Maize (*Zea mays* L.) Yield Per Harvest Area: Appropriate methods. *Agronomy*. DOI: <https://doi.org/10.3390/agronomy10010029>
- Thapa S, S Rawal and S Adhikari. 2022. Varietal evaluation of hybrid maize in the summer and winter seasons in the Terai region of Nepal. *Heliyon*. 8(11). DOI: <https://doi.org/10.1016/j.heliyon.2022.e11619>
- Timsina KP, YN Ghimire and J Lamichhane. 2016. Maize production in mid hills of Nepal: from food to feed security. *Journal of Maize Research and Development*. 2(1). DOI: <https://doi.org/10.3126/jmrd.v2i1.16212>
- Tripathi MP, J Shrestha and DB Gurung. 2016. Performance evaluation of commercial maize hybrids across diverse Terai environments during the winter season in Nepal. *Journal of Maize Research and Development*. 2(1). DOI: <https://doi.org/10.3126/jmrd.v2i1.16210>



Government of Nepal
Ministry of Agriculture and Livestock Development
Singhadurbar, Kathmandu
July, 2025