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EDITORIAL

Agriculture faces multiple challenges in the present time, including climate change, environmental degradation, and rapid demographic and socio-economic shifts. Together, these factors threaten the sustainability of agri-food systems. Research and innovation are critical in addressing these challenges, and evidence-based, reliable information is crucial for policy formulation and developing practical solutions. Scientific journals play a vital role in agricultural development and environmental sustainability by providing new knowledge, innovative ideas, and practical solutions. Research outcomes published in peer-reviewed journals expand scientific understanding, inform policies, guide development programs, and support the adoption of improved technologies and sustainable farming practices. Ultimately, this enables researchers, policymakers, extension professionals, and practitioners to learn from one another, exchange experiences, and work collaboratively to address common challenges.

For countries like Nepal, where agriculture remains the backbone of the economy and environmental resources are closely linked to people's livelihoods, scientific publications in these areas are particularly significant. They provide an opportunity to document local innovations, indigenous knowledge, and research findings that might otherwise remain inaccessible to the wider scientific community. Realizing this importance, the Ministry of Agriculture, Forests and Environment has been publishing The Journal of Agriculture and Environment for the past 26 years.

In this issue of the journal, we have covered a wide range of areas, including soil management, insect pest management, agricultural resource utilization, nutrition security, innovation adoption, and dairy sector development. We hope the articles published in this edition will inspire further research, provide practical solutions, and encourage informed decisions that will contribute to the overall development of the agricultural sector, protect the environment, and support sustainable development in Nepal.

The Editorial Board would like to thank all contributing authors for their valuable submissions. We also express our gratitude to the reviewers for providing expert evaluations, which made the timely publication of this issue possible. Additionally, in my capacity as Editor-in-Chief, I acknowledge the efforts of the entire editorial team, whose dedicated work ensured the successful release of this issue.

Dr. Ram Krishna Shrestha
Editor in chief

Guidelines of author

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Access, Utilization Pattern and Impact of Agricultural Credit on Farm Income: Evidence From Vegetable Farmers in Thakre Rural Municipality, Nepal

Hari Krishna Panta[1], Niruta Shrestha[1]*, Rudra Bahadur Shrestha[2] and Milan Bhattarai[1]

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ABSTRACT

This study assesses farmers' access to credit, their utilization patterns, and the impact on farm income. Data were collected in 2024 by interviewing 150 randomly selected farmers from Thakre rural municipality of Dhading and analyzed using descriptive statistics, an independent samples t-test, and a weighted priority index. About 67% of sampled households accessed credits, of which only 47% used the funds exclusively for agricultural activities. Of the 67% who borrowed, 44% accessed formal credit sources, implying that the remaining 56% relied entirely on informal channels. The independent t-test shows that credit receivers have a significantly higher annual farm income (NRs. 536,231/HH) than that of non-receivers (NRs. 372,071/HH) at a highly significant level (p = 0.0001). Easier access to formal credit will substitute costly informal credit to enhance farm productivity and income. Therefore, implementing effective regulatory frameworks and strict monitoring is crucial to remove structural and procedural barriers, thereby enhancing proper credit access and utilization.

1. INTRODUCTION

In Nepal, agriculture influences the socio-economic dynamics of rural communities significantly. This sector contributes about 24.03% to the national Gross Domestic Product (GDP) (MoF, 2026). Despite its importance, Nepal's agricultural sector continues to lag in productivity, production, export volume, diversity, and product quality (Bhawan, 2018). In today's world, agricultural credit is critical for farmers to access new agricultural technologies. While timely access to production inputs such as seeds, fertilizer, and implements enhances production and productivity (Hussain, 2019), most smallholders face binding capital constraints that limit their initial purchasing power for high-quality production resources, causing a persistent drag on localized farming efficiency (Lamichhane, 2021). Agricultural credit is crucial for agricultural modernization and rural economic development (Khan *et al*., 2011).

Recognizing the need to invest in agriculture, Nepal Rastra Bank (NRB) introduced Priority Sector Lending Program (PSLP) in 2017 that mandates formal institutions like banks and finance companies to allocate 10% of their loan to the agricultural sector at a subsidized interest rate of 5% (Upadhyay *et al*., 2020).The NRB's Unified Directive 2020 mandated that commercial banks allocate at least 11%, 13%, and 15% of total credit in the agriculture sector in 2020/21, 2021/22, and 2022/23, respectively (Pandey, 2022). Other BFIs have also been directed to invest in agriculture as a priority sector (NRB, 2020). Since 1991/92, NRB has mandated that banks and other financial organizations to lend the “deprived sector” to uplift the socio-economic conditions of society's most vulnerable populations (NRB, 2008). As of mid-March 2022/23, banks and financial institutions have disbursed NRs. 411.27 billion in agricultural loans. As of this, the largest percentage of loans disbursed 38.7% have been utilized for agricultural and associated services, followed by 37.2% for livestock and related services, 21.9% for crop farming-related services, and 2.1% for other related sectors (MoF, 2023). To ease financial constraints and promote commercialization, Nepal Rastra Bank implemented Interest Subsidy on Subsidized Loan Integrated Procedure in 2018. This framework provides a 5% interest subsidy on commercial agriculture and livestock loans up to NRs. 50 million, significantly lowering borrowing costs for farmers(NRB, 2018). By emphasizing project-based collateral and group guarantees, the policy expands formal credit access for smallholders lacking conventional land assets, aiming to optimize loan utilization toward productive farm investments like infrastructure and mechanization.

Different types of formal and informal sources are available to provide credit facilities to farmers. NRB regulates banks and financial institutions (BFIs), MFIs, and cooperatives as the formal sector. The informal sector includes farmers' groups, women's groups, personal and professional money lenders, relatives, and others (Rimal, 2015). Regardless of institutions established, several bottlenecks prevent farmers' access to credit, resulting in the sluggish growth of agriculture. High transaction costs, administrative hurdles, collateral requirements, high interest rates, restricted credit procedures and standards, a poor repayment ratio, and poor loan utilization skills all reduce credit access. Data from NSCA (2021/22) also stated that the agricultural loan recipients have dropped from 22% to 12% from 2011 to 2021 (NSO, 2021). Despite extending the accessibility and growth of official channels across the country, the use of friends and family to get loans has more than quadrupled, from 5% to 13% during the same period(IFC, 2023).

Rimal (2015) investigated the impact of agricultural credit from commercial banks on GDP growth, finding that agricultural lending exerts a favorable and significant effect on agricultural GDP. Similarly, a study report NRB (2014) from the Dhangadhi Banking Development and Research Unit revealed that all the farmers who used the loan facility attained a better level of technical efficiency (82% on average), whereas farmers who did not use the credit facility had a lower level (63% on average) in the study area. Access to sufficient credit greatly enhances household welfare, food security, and poverty reduction. Recent empirical work on smallholders in Nepal indicates that expanding access to formal financial windows plays an immediate role in transforming traditional production setups, enabling low-income growers to purchase high-yielding crop inputs and expand their localized cultivation scale (Mishra, 2021).

In view of the aforementioned problems, the following research questions served as the foundation for this study: a) what are the current credit access patterns and credit utilization practices; b) what is the relationship between credit access and farm income; and c) what are the constraints faced by farmers in accessing formal credit? Therefore, this study aims to investigate credit access and use pattern, as well as their effect on farm income. Study findings will generate valuable information serving financial institutions to offer more focused interventions to increase loan availability and effective use to enhance production and income.

2. MATERIALS AND METHODS

2.1 Study area

The Dhading district was purposively selected for this study as it is a premier hub for commercial vegetable production in Nepal, supplying approximately 30% of the Kathmandu Valley's total vegetable demand (MoALD, 2021). Within the district, Thakre Rural Municipality was selected as the primary research site, as it represents a key vegetable-producing pocket. This municipality spans a total area of 96.41 square km across 11 wards and is located at a distance of 32.5 km from Kathmandu with a total population of 32,374 (NPHC, 2021).

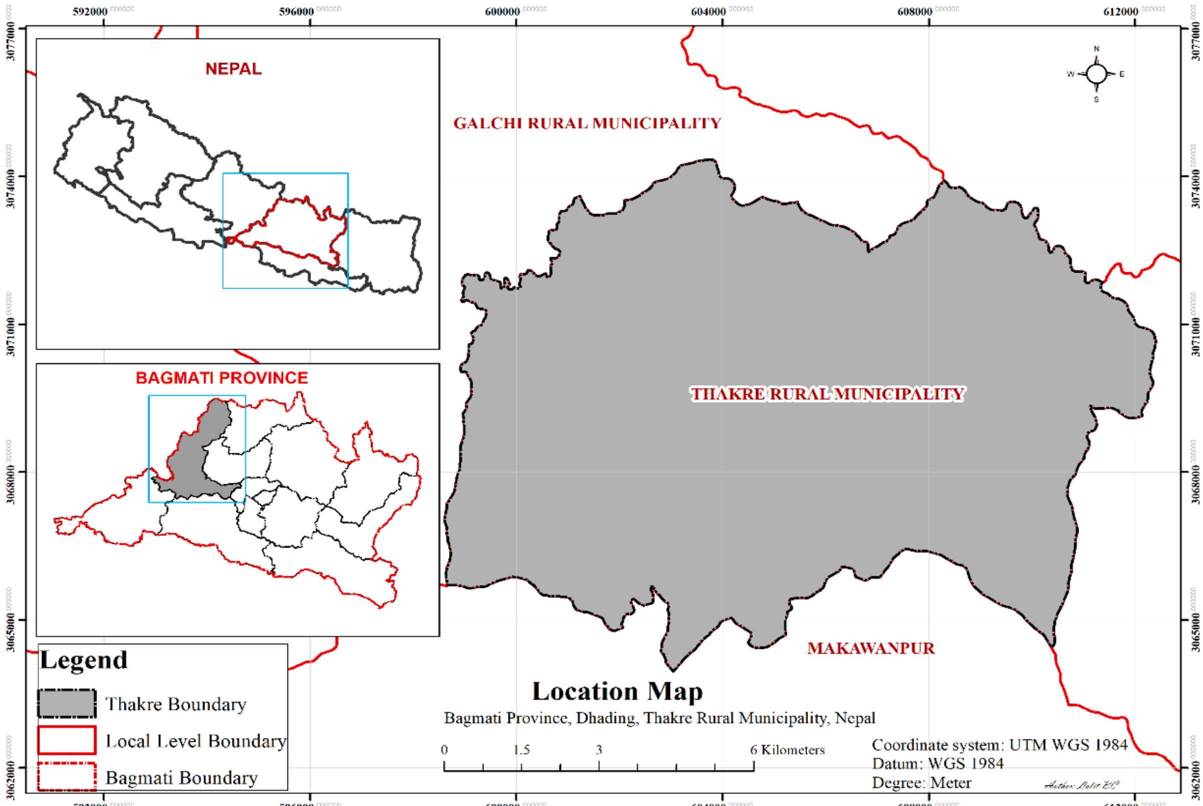

Figure 1. Map showing the study area

2.2 Sampling process

A multi-stage (four-stage) sampling technique was employed to select 150 farmers. Thakre Rural Municipality was purposively chosen, followed by a random selection of five wards (3, 5, 8, 9, and 11) of the municipality. From these, five communities were identified, and 30 vegetable farmers were randomly sampled from each. Additionally, three credit department officials from selected commercial banks and other financial institutions were selected purposively. The sample size (n=150) of farmers was determined using Taro Yamane's formula (Yamane, 1967) at the critical value 0.08.

2.3 Data analysis

Data were analyzed using descriptive and inferential statistical tools. Descriptive statistics summarized demographic and socioeconomic characteristics, while inferential statistics, particularly the t-test, were used to determine the effect of credit access to farm income by comparing mean annual farm income between credit users and non-users. To analyze the constraints in accessing the formal credit, weighted indexes were calculated based on the major challenges faced by the credit non-users in accessing such credit. Farmers' perceptions of different difficulties were ranked by using the five-point level of extent comprising very high, high, moderate, partial, and low in an ordinal scale value of 5, 4, 3, 2, and 1, respectively. The priority index for each was computed using the following formula.

$$I_{imp} = \Sigma(Si \times fi) / N$$

Where,

I_{imp} = Scaling index

Si = Weight assigned to each response

fi = Frequency of the responses to a particular problem

N = Total number of respondents

3. RESULTS AND DISCUSSION

3.1 Household characteristics

The characteristics include socio-economic profile of the household head, such as age, gender, education, occupation, and household characteristics, such as household size, total operational landholdings, annual family income, and so on. Such factors were analyzed to understand the demographic drivers of agricultural credit access and its use pattern in the study area. The descriptive statistics for socio-demographic variables (continuous) are summarized in Table 1. The average age of the 150 household heads was found to be 44.46, with a range of 28 to 75 years and a standard deviation of 10.44. The result indicates that middle-aged members of households served as household heads. Average family size was 4.7 (±1.73), ranging between 1 and 11. Household heads' average experience in farming was found to be 32 (±1.73) years. The total operational landholding, on average, was 0.48 hectare (ha) (i.e., 9.53 ropani, where 1 ha = 20 ropani) spreading between a minimum of 0.5 ropani and a maximum of 92 ropani. The average annual farm income was NRs. 443206.67 that ranged from NRs. 50000 to 2000000. Accessibility to financial services also varied, with the distance to the nearest Bank or Financial Institutions (BFIs) averaging 6.29 km, ranging from a convenient 2 km to a more remote 14 km.

Table 1. Summary statistics of household characteristics

Variable	Mean	Standard deviation	Minimum	Maximum
Age of the household head (years)	44.46	10.44	28	75
Household size (number)	4.79	1.73	1	11
Farming experience (years)	32	13.83	3	60
Operational land holdings (ropani)	9.53	9.64	.5	92
Annual farm income (NRs.)	443206.67	261883.51	50000	2000000
Distance from BFIs (km)	6.29	2.40	2	14

As shown in Table 2, the majority of household heads were male (72.67%), while female heads accounted for 27.33%. This gender distribution suggests that resource ownership and household decision-making remain largely male-dominated within the local vegetable production sector. Education is a critical driver for adopting modern agricultural technologies as it exposes farmers to new ideas and concepts. In the study, the education level of the farmers was categorized into 6 groups: Never attended school, Non-formal, Primary, Secondary, Bachelor's, and Master's degree. The study found that 36% of household heads had only a primary-level education, followed closely by 32% with secondary-level schooling. Higher education was rare, with only 2% and 1.33% holding Bachelor’s and Master’s degree, respectively. This prevalence of lower formal education levels may influence the speed at which new agricultural technologies are integrated.

Agriculture (vegetable farming) was the main economic activity with 132 (88%) household heads practicing it as their primary occupation, while the remaining 18 (12%) engage in other occupations like salaried jobs, businessmen, and retired workers as their main occupation. Among the sampled households, at least one member from 36.67% of the households have been residing in foreign countries. Therefore, the remittances serve as a vital financial cushion, significantly enhancing the timely repayment of agricultural loans.

While 37.33% of the farmers are adopting the commercial farming system, the majority of farmers (62.67%) are still practicing the subsistence farming system. Around 93.33% of the household heads and their family are food self-sufficient and do not have to obtain credit to fulfill their food sufficiency needs year-round, while 6.67% of them obtain credit from both the formal and informal sources to meet basic food needs. A significant gap exists in technical support: only 18.67% of farmers have regular contact with agriculture extension workers. Overall, 57.33% households (at least one member) maintain memberships in farmer groups. The low level of extension services likely contributes to the limited adoption of advanced technologies and intensive farming systems.

Table 2. Count of categorical variables describing the socio-economic characteristics of the households

Variables	Descriptions	Frequency	Percentage
Gender of household head	Female	41	27.33
	Male	109	72.67
Education level	Never attended school	37	24.67
	Non-formal	6	4
	Primary	54	36
	Secondary	48	32
	Bachelor's	3	2
	Master's	2	1.33
Occupation	Agriculture	132	88
	Other than agriculture	18	12
Remittance	No	95	63.33
	Yes	55	36.67
Nature of production	Subsistence	94	62.67
	Commercial	56	37.33
Food sufficiency	No	10	6.67
	Yes	140	93.33
Contact to extension agents	No	122	81.33
	Yes	28	18.67
Group membership	No	64	42.67
	Yes	86	57.33

3.2 Access to credit

The study found that a majority (67%) of farmers in the study area accessed credit for their farming operations. This access allows farmers to leverage capital for essential inputs, adopt modern technologies, and improve overall productivity. Furthermore, credit provides the financial flexibility required to manage cash flows, enabling farm expansion or mechanization that might otherwise be unaffordable. In contrast, 33% of households lacked access to any form of credit, limiting their ability to modernize or scale their agricultural activities

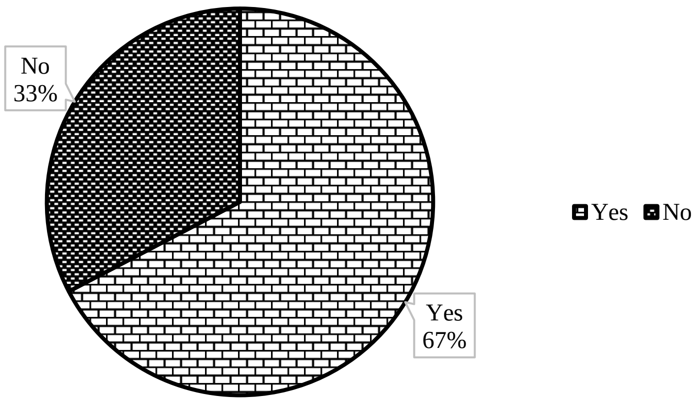

Figure 2. Household credit access

In the study area, farmers had access to various credit sources, categorized broadly into formal and informal sources. The study revealed that of the 67% who borrowed, 44% accessed formal credit sources, meaning more than half (56%) of the farmers were unable to secure loans from institutional lenders. This indicates a heavy reliance on informal networks or a total lack of structured financial support for a significant portion of the farming community.

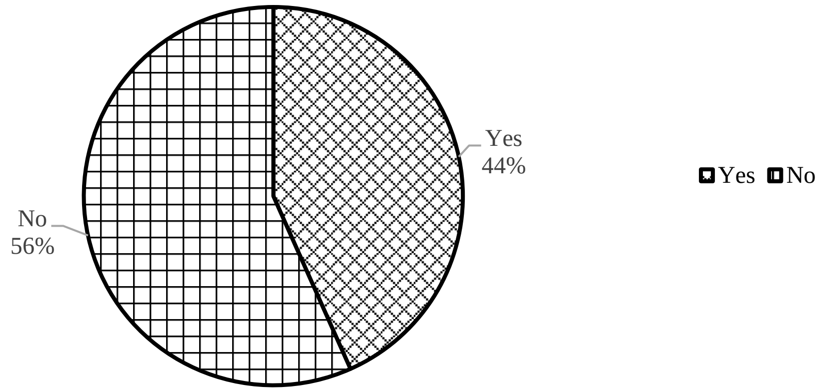

Figure 3. Sampled households (%)with access to formal credit

Result as shown in Table 3 indicates that the majority of farmers in the study area do not have access to formal credit, though those who obtain from formal channels benefit from a more structured and reliable borrowing environment with more favorable terms, such as subsidized interest rates. Approximately 10% of respondents had access to both formal and informal channels to meet their capital needs. Study reveals a significant disparity on borrowing costs between institutions: Microfinance Institutions (MFIs) recorded the highest annual interest rates, averaging 17% due to the risks and costs of serving fewer number of underserved populations with limited collateral. However, Commercial Banks and Financial Institutions (BFIs) served the largest population and offered a lower average rate of 11.7%. As expected, the rate of interest and the population served by the cooperatives were found intermediate between banks and the micro-finance companies.

Table 3. Sources of credit accessed by the households in the study area

Sources of credit	Frequency	Average interest rate charged (%)
Formal		
Bank	40 (26.67)	11.7
Cooperative	24 (16.00)	13.62
Micro-finance	2 (1.33)	17
Sub-total	66 (44.00)	
Informal		
Friends and relatives	33 (22.00)	
Input suppliers	8 (5.33)	
Village lenders	8 (5.33)	
Sub-total	49 (32.67)	
Both formal and informal	15(10)	

Figures in parentheses indicate the percent of households

3.3 Pattern of credit use

The study reveals that nearly half of the credit users (47%) used the credit exclusively for agricultural purposes, while 41% applied the funds to a mix of agricultural and non-agricultural needs. Only 12% directed their credit solely toward non-agricultural uses. Notably, 100% of credit users reported a positive impact on their agricultural productivity and household food security, citing an enhanced ability to meet essential production requirements. This aligns with findings by Siyoum *et al*. (2012)who noted that credit programs empower rural farmers to invest in vital agricultural supplies and focus on farm management by reducing the immediate need for off-farm income-generating activities.

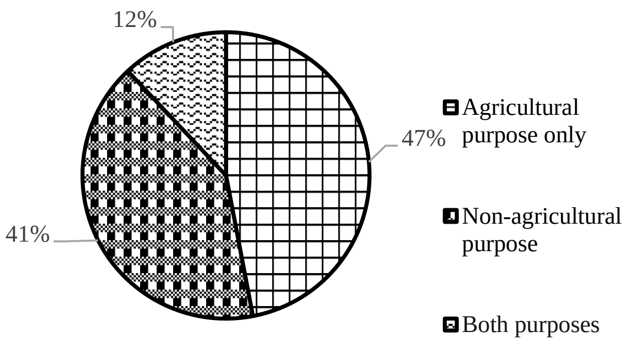

Figure 4. Utilization of accessed credit by the household

"Within the agricultural sector, credit allocation was distributed across both variable inputs and capital investments, as illustrated in Figure 5. The largest share was utilized for purchasing fertilizers and pesticides (23.53%), followed closely by payments for farm labor (21.57%). Beyond these immediate production expenses, a substantial portion of the credit was directed toward structural modernization and capital assets: construction of plastic tunnels for vegetable cultivation accounted for 17.65%, while the purchase of agricultural land comprised 15.69%. Mechanization and livestock expansion also represented notable shares, with 11.76% spent on custom hiring or purchasing agricultural machinery, and 9.80% allocated to buying livestock or poultry. This distribution demonstrates that while farmers prioritize chemical inputs and labor to sustain immediate seasonal yields, they also make significant mid-to-long-term investments in agricultural infrastructure and land expansion.

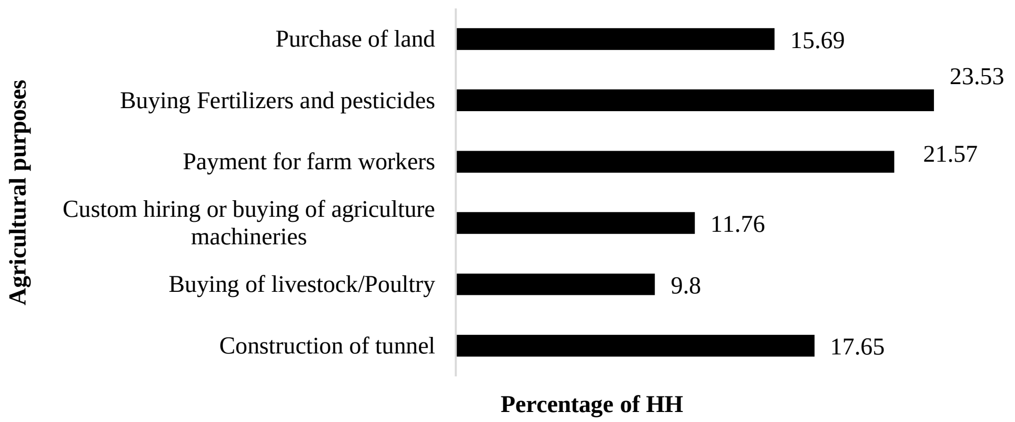

Figure 5. Allocation of credit for specific agricultural purposes

When credit was diverted to non-agricultural sectors, it was predominantly used for fixed household investments and family advancement rather than minor daily expenses, as shown in Figure 6. The leading non-agricultural utilization was house construction, accounting for 26.83% of the responses, followed closely by personal expenses at 24.39%. Notably, financing family members for study abroad constituted a major share at 19.51%, reflecting a significant household strategy to secure future remittance inflows. Funding for education and school fees comprised 14.63%. Conversely, the smallest allocations were shared equally between basic household consumption requirements (7.32%) and the repayment of prior debts (7.32%). This hierarchy suggests that when credit is diverted away from farming, it is primarily directed toward long-term asset creation and human capital development.

This phenomenon of credit diversion is a rational household coping and economic diversification strategy. Vegetable farming in Thakre Rural Municipality is characterized by high seasonal production risks, weather dependencies, and market price volatility. Because agricultural yields are highly unpredictable, farming households frequently divert portions of their loans toward securing stable, non-farm income streams - such as international migration for remittance - to mitigate future production shocks. Furthermore, formal credit lines often carry rigid, immediate repayment timelines that do not align well with seasonal crop harvesting cycles. When local credit options lack flexible restructuring terms for unexpected crop failures, making large investments in volatile open-field vegetable cultivation becomes financially unviable. Consequently, farmers strategically reallocate borrowed capital toward fixed household infrastructure or family education, which offer more reliable, long-term livelihood security than immediate farm reinvestment.

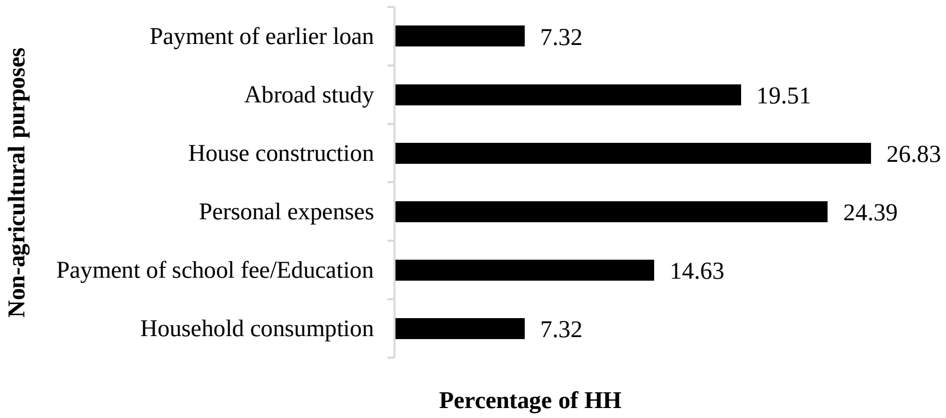

Figure 6. Allocation of credit for non-agricultural purposes

3.4 Effect of credit on annual farm income

The comparative analysis of mean annual farm income between credit recipients and non-recipients is presented in Table 4. The results demonstrate that households with credit access achieved a significantly higher mean annual farm income (NRs. 536,230.8/HH) compared to those without credit access (NRs. 372,070.6/HH). The calculated t-value of 3.9903 confirms that this income disparity is statistically significant at the 1% level ($p<0.01$), underscoring the vital role of credit in enhancing household financial well-being. Various other socio-economic variables also affect farm income. However, credit access acts as a primary catalyst because investment leverage via borrowed capital yields a greater operational impact than relying on limited household equity alone. The high efficiency of borrowed credit ensures its complete and productive utilization. This triggers a clear economic progression where increased investment leads to higher crop productivity, which directly expands overall farm revenue. The finding is in line with Chandio *et al.* (2017) who observed that credit-receiving households experience twice as much income compared to those reliant solely on their own limited capital. Higher income of the credit receiver was attributed to commercialization, efficiency, and higher productivity.

Table 4. Mean comparison of annual farm income between the credit recipients and credit non-recipients

Variable	Credit receiver	Credit non-receiver	Mean difference	t-value	P-value
Mean annual farm income (NRs.)	536230.8	372070.6	164160.2	3.9903***	0.0001

This is supported by national macroeconomic evaluations in Nepal which confirm a long-run co-integrating relationship between commercial bank credit flows and agricultural GDP expansion, highlighting institutional credit as a strategic driver of input intensification (Acharya & Duwal, 2024). Sidhu *et al*. (2008) identified a positive link between the usage of factors of production and credit in Punjab. Furthermore, Upadhyay et al. (2020) found that binding credit constraints heavily restrict a household's capacity to optimize resource allocation, leading to lower agricultural productivity and suppressed farm household performance. Supporting these findings, NRB (2014) reported that institutional credit acts as a vital tool to relax cash constraints, thereby significantly enhancing the production efficiency and overall output of the farming sector. Rahman *et al*. (2014) emphasized that agricultural credit is a primary determinant of enhancing farm productivity, concluding that the timely provision of adequate credit enables the purchase of high-yielding variety (HYV) seeds, fertilizers, and pesticides.

3.5 Constraints in accessing formal credit

The major constraints faced by farmers in accessing formal credit were evaluated using a Weighted Constraint Index, as presented in Table 5. The primary hurdle identified by farmers was the lack of personal connections with bank officials (Rank 1), highlighting a prominent social network barrier. Most credit-constrained farmers reported that an existing personal relationship inside the financial institution was practically a prerequisite to expedite loan applications and secure approval. Following this social barrier, lengthy paperwork was ranked as the second major constraint, indicating rigid bureaucratic hurdles. Distinct from the network barrier, long physical distance from BFIs was identified as a separate geographical constraint, ranking third, which increases transactional costs and travel time for remote farmers. Complex transaction procedures, lack of education, insufficient collateral, and rigid repayment schedules further restrict credit acquisition. These distinct structural, procedural, and geographical barriers must be systematically addressed to enhance formal credit access and utilization.

Table 5. Index value of constraints in accessing the formal credit

Constraints	Index value	Rank
Insufficient collaterals/ landholdings	0.37	6
Lack of education	0.42	5
Lengthy paper works	0.68	2
Lack of personal connection with bank officials	0.73	1
Long distance from BFIs	0.62	3
Complex transaction procedure	0.57	4
Need for extended loan repayment in case of financial setbacks	0.29	7

4. CONCLUSION

Agricultural credit is a definitive driver of economic resilience and income growth for vegetable growers in Thakre Rural Municipality, as an independent t-test confirmed that credit recipients earned a significantly higher mean annual farm income than non-recipients. However, a critical institutional access gap remains, forcing a large portion of the population to rely entirely on high-cost informal channels. Credit utilization patterns reveal that while seasonal inputs like fertilizers, pesticides, and labor dominate immediate farm budgets, farmers make substantial capital commitments toward plastic tunnel construction and land purchase. When diverted to non-agricultural sectors, capital is primarily channeled into long-term family assets like house construction and financing study abroad.

Furthermore, accessing institutional finance is severely hindered by distinct structural and physical constraints. The foremost barrier is a prominent social network distance, specifically the lack of personal connections with bank officials to expedite loan processing, which operates independently of geographical barriers like long physical distances from banking institutions. To bridge these gaps, local authorities and financial institutions must expand institutional proximity by establishing government-owned bank branches in commercial vegetable pockets, streamline bureaucratic procedures to remove connection-based advantages, enforce strict agricultural lending quotas with subsidized interest rates, and implement robust monitoring mechanisms to ensure credit tracks directly into productive farm modernization.

ACKNOWLEDGEMENTS

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REFERENCES

Acharya, S., & Duwal, S. (2024). Effect of agricultural credit on the growth of agricultural GDP in Nepal. *Journal of Econometric and Economic Studies, 2*(1), 45–58. https://www.nepjol.info/index.php/jems/article/view/74567

Bhawan, H. (2018). *Inter-provincial dependency for agricultural development*.Department of agriculture, 9, 8-11.

Chandio, A. A., Jiang, Y., Wei, F., Rehman, A., & Liu, D. (2017). Famers' access to credit: Does collateral matter or cash flow matter? - Evidence from Sindh, Pakistan.*Cogent Economics & Finance*, *5*(1), Article 1369383.https://doi.org/10.1080/23322039.2017.1369383

Hussain, M. R., Qayyum, M., & Hussain, M. E. (2019). Effect of seven steps approach on simplex method to optimize the mathematical manipulation. *International Journal of Recent Technology and Engineering*.https://doi.org/10.14445/22315381/ijett-v67i8p208

IFC. (2023). *Nepal Financial Inclusion Report 2023*. IFC Communications, 2121 Pennsylvania Avenue, N.W., Washington, D.C.4,33.

Khan, N., Muhammad Shafi, M., Shah, M., Islam, Z., Arif, M., Javed, R., & Shah, N. (2011). Review of past literature on agriculture credit in rural area of Pakistan. *Sarhad Journal of Agriculture, 27(1), 103–110*.https://doi.org/ 10.56976/jsom.v1i2.5

Lamichhane, B. D. (2021). Agricultural credit: A powerful tool for rural youth self-employment. *Journal of Development Review*, *6*(1), 1–13.

Mishra, B. P. (2021). Factors affecting use of formal agricultural credit among smallholder farmers in Western Nepal. *International Journal of Social Sciences and Management*, *8*(4), 457–462.

MoALD. (2021). *Statistical information on Nepalese agriculture (2020/21)*. Government of Nepal.

MoF. (2023). *Economic survey 2022-23*. Department of Economic Affairs, Economic division, Government of Nepal. 59.

MoF. (2026). *Economic survey 2025–26*. Government of Nepal.

NPC.(2023). *The Fifteenth Plan (Fiscal year 2019/20-2023/24).*National Planning Commission, Government of Nepal, Singha durbar, Kathmandu, Nepal.

NPHC.(2021). Statistical information on Nepalese population and housing (2021). Publications of Nepal in data portal, Government of Nepal.31.

NRB. (2008). *Micro-financing towards empowerment of disadvantaged groups in Nepal: Innovations and practices*.Micro Finance Department, Nepal Rastra Bank.

NRB. (2018). *Integrated procedural directive for interest subsidy on concessional loans, 2075*. Microfinance Department, Government of Nepal.

NRB. (2020). *Unified directives for A, B, and C class banks and financial institutions*. Nepal Rastra Bank.

NSO. (2021). National sample census of agriculture(2021/22). National Statistics Office, Government of Nepal.9.

Pandey, A. (2022). Credit and financial access in Nepalese agriculture: Prospects and challenges. *Journal of Institute of Agriculture and Animal Science*,6, 56–70.

Rahman, S. u., Hussain, A., & Muhammad, T. (2014). Impact of agricultural credit on agricultural productivity in Pakistan: An empirical analysis. *International Journal of Advanced Research in Management and Social Sciences,* 3(4), 112–125. https://doi.org/10.3390/agriculture10050143

Rimal, N. S. (2015). Agricultural credit flow of commercial banks and impact on agricultural production in Nepal.*Scholars Journal of Arts , Humanities and Social Sciences*, 21, 9-16.

Upadhyay, N., Gairhe, S., Acharya, Y., & Ghimire, Y. N. (2020). Credit's use performance and its determinants on farm household : A case of Chitwan district of Nepal.*Nepalese Journal of Agricultural Sciences*, *3*, 140–149.

Yamane, T. (1967). Statistics:An introductory analysis (2nd ed.). Harper and Row.

EFFECT OF POTASSIUM DOSES AND MOISTURE REGIMES ON GROWTH AND YIELD OF AFRICAN MARIGOLD IN LAMJUNG, NEPAL

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ABSTRACT

Marigold is a popular ornamental plant widely grown in Nepal. However, the optimal potassium (K) dose and moisture level for maximizing its growth and yield under the agro-climatic conditions of Lamjung have not been clearly established. To identify their effect on marigold plants, the experiment was conducted at the horticultural farm of Institute of Agriculture and Animal Science, Lamjung Campus, from July to November 2023. The study was laid out under a two-factor factorial Randomized Complete Block Design (RCBD) with four K levels (40, 80, 120, and 160 kg/ha) and two moisture levels (60% and 100% of fieldcapacity (FC)), comprising eight treatments replicated three times. Other essential nutrients were applied uniformly across all treatments. Application of 120 kg/ha K significantly increased ($p \leq 0.05$) plant height, number of primary and secondary branches, canopy spread, earlier flower initiation, days to 50% flowering, number of flower heads per plant, flower diameter, flower weight per plant and flower yield. All parameters showed significantly higher values at 100% of FC. The interaction of 120 kg/ha K with 100% of FC significantly improved most attributes. The study suggests that applying 120 kg/ha K, with 100% of FC, favors the growth and yield of marigold.

1. INTRODUCTION

Marigold (*Tagetes spp*.), commonly known as 'Sayapatri' in Nepali, is a popular and vibrant ornamental and medicinal plant widely cultivated in Nepal and worldwide. It is an annual, erect, hermaphrodite herbaceous plant with green stems and compound leaves (Zahara et al., 2024). It is popular in Nepal due to its large-sized flowers used for garland-making during Hindu religious ceremonies, rituals, and festivals celebrated in Nepal, like Dashain and Tihar, easy culture, and wider adaptability. It has additional applications in traditional medicine and as a natural pest repellent in agriculture (Bakshi & Ghosh, 2022). Among the essential nutrients, potassium (K) is referred to as the third major macronutrient, playing essential roles in photosynthesis, osmoregulation, stomatal movement, enzyme activation, protein synthesis, energy transfer, phloem transport, cation-anion balance, and stress resistance (Hasanuzzaman et al., 2018). Similarly, water is a primary component of plant physiology and soil water supports plant growth by providing moisture supply and transporting essential nutrients. Irrigation benefits croplands by cooling the soil and atmosphere to create a more favorable environment for plant growth (FAO, 2014). The pairing of appropriate K doses with moisture levels may create a synergistic effect, amplifying their benefits to foster the growth and yield of African marigold.

The agriculture sector engages around 66% of the total population in Nepal (FAO, 2024). Out of the total GDP of the country, agriculture contributes 24.12% (MoALD, 2023). With this, floriculture contributes only 0.0558% of total agricultural GDP, which is too low even after having the suitable agro-climatic conditions required for flower cultivation. Marigold flowers are cultivated commercially in around 157 hectares of land in 32 districts across the country (Himalayan News Service, 2020). However, most Nepalese farmers follow the chemical fertilizer recommendation of 200:80:80 kg/ha NPK (Floriculture Association Nepal, 2018) for marigold plants, which may not be optimum for all soils, climates, and varieties. Potassium deficiency exhibits stunted growth and yellowing in their leaf margins, showing phenomena like poor root systems, lodging, and yield reductions of crops (Khalil et al., 2022). A lack of K fertilizer increases plant susceptibility to various diseases and pest infestation and makes plants vulnerable to damage under various stress conditions (Hasanuzzaman et al., 2018). On the other hand, drought stress in plants may result in leaf rolling, stunning plants, leaf yellowing, scorching and permanent wilting (Kumar et al., 2023). If excessive moisture conditions persist for long time, they can lead anaerobic respiration and may produce toxic effects on plants and also affects the photosynthesis of plants (Chen et al., 2022). A field trial was required to determine the amount of potassium and moisture regimes required for any given climate in the study area. Therefore, this research trial aimed to study the influence of different potassium and moisture regimes on the growth and yield of African marigold, and to determine the optimal K and moisture levels to achieve the maximum production.

2. MATERIALS AND METHODS

2.1. Experimental site

The study was conducted in the horticultural farm of the Institute of Agriculture and Animal Science, Lamjung Campus, Sundarbazar-07, Lamjung, Nepal, from late July 2023 to mid-November 2023. This location is situated at 28°7’31” north latitude and 84°25’4” east longitude with an elevation of 991 meters above sea level. Lamjung district has diverse climatic and soil conditions. The annual average temperature is recorded from a minimum of 14.1 °C to a maximum of 26.7 °C and the annual precipitation is recorded as 2944.23 mm. Relative humidity ranges from 50% in May to 100% in December and January. According to the test and analysis of the homogenous soil sample of our experimental plot was done in the Soil and Fertilizer Testing Laboratory, Gandaki province, Nepal. The initial soil pH was 6 (slightly acidic), soil organic matter was 2.80% (medium), nitrogen content was 0.14% (medium), phosphorus content (P_2O_5) was 124.67 kg/ha (very high) and potassium content (K_2O) was 250.48 kg/ha (medium). The average level of coarse fragment intensity in our experimental area was about 18.70%.

2.2. Experimental design

The experiment was conducted in two-factor factorial Randomized Complete Block Design (RCBD) with four doses of Potassium i.e., K1 (40 kg/ha), K2 (80 kg/ha), K3 (120 kg/ha), K4 (160 kg/ha) and two moisture regimes i.e. W0 (60% of FC) and W1 (100% of FC) comprising a total of eight treatments (Table 1). Each of the eight treatments was replicated three times, creating 24 individual plots, with a dimension of 1.6 m x 0.9 m for each individual plot. Spacing between each plot and the distance between the replications was 0.5 m.

Table 1: Details of treatment combination

Treatments	Potassium Doses	Moisture Regimes
K1W1 (T1)	40 kg/ha	100% of FC
K2W1 (T2)	80 kg/ha (RDF)	100% of FC
K3W1 (T3)	120 kg/ha	100% of FC
K4W1 (T4)	160 kg/ha	100% of FC
K1W0 (T5)	40 kg/ha	60% of FC
K2W0 (T6)	80 kg/ha (RDF)	60% of FC
K3W0 (T7)	120 kg/ha	60% of FC
K4W0 (T8)	160 kg/ha	60% of FC

Note: RDF = Recommended dose of fertilizer

2.3. Cultivation practices

Seeds to be planted were collected by importing from Karma Groups of Companies, Kathmandu, Nepal. The germination percentage of seed was 85% and a purity of 99%. Seeds were carefully selected and sown at a depth of 0.5 cm in a 1:1 mixture of cocopeat and vermicompost. After 25 days, the seedlings were ready for transplanting. The experimental field was ploughed and leveled manually a week before transplanting. The field plots were prepared using measuring tapes, pegs and ropes. Well-decomposed farmyard manure (FYM) at 20 t/ha (i.e., 5.1 kg/plot) was integrated into the soil during initial land preparation. Since the experiment was conducted in RCBD, the treatments for each plot were selected randomly through the lottery method. Fertilizers and water were applied after calculation. According to the Floriculture Association Nepal (2018), the fertilizer recommendation for marigold plant is 200:80:80 kg/ha NPK. Half dose of recommended nitrogen and full dose of phosphorus and potassium were applied as a basal application. The remaining half dose of the nitrogen was split into two doses (¼ dose at 30 DAP and ¼ dose at 50 DAP). 25 g of DAP and 43g of Urea were applied per plot as a basal dose. 9.6 g /plot, 19.2 g/plot, 28.8 g/plot and 38.4 g/ plot MOP were applied as 40 kg/ha K, 80 kg/ha K, 120 kg/ha K and 160 kg/ha K respectively. The K treatments were selected to encompass levels below, near, and above the recommended dose in order to evaluate the crop response across a wide range of potassium supply. For moisture regimes, FC was calculated from the gravimetric method. 16.29 L/plot and 27.15 L/ plot water as 60% of FC and 100% of FC were irrigated at intervals of 10 days. Twenty-five days old seedlings were transplanted in the raised bed of the experimental plot. Twelve plants were planted per plot with four rows and three columns, maintaining row-to-row and plant-to-plant spacing of 40cm×30cm. Light irrigation was applied right after transplantation. All intercultural operations, such as staking, weeding, hoeing and plant protection materials were consistently performed when required. Irrigation was administered accordingly. Flowers were manually harvested when fully opened. Flowers from five randomly selected plants were harvested separately to collect experimental data.

2.4. Data collection

The observations on different parameters such as plant height, stem diameter, number of primary and secondary branches, plant canopy spread, days to flower initiation, diameter of flower, flower fresh weight, flower numbers and flower yield per hectare were recorded. Data were collected randomly from five plants per plot. Data required for plant height, stem diameter, number of primary and secondary branches, and plant canopy spread were recorded at 25, 40, and 55 days after transplanting (DAT), whereas the remaining data were taken after 60 DAT at an interval of 10 days. For data collection of days to flower initiation, the number of days from transplanting was counted until the first visible flower bud appeared and for the 50% of bud emerges, dates were recorded on the days when 50% of the plant in the plot showed flower bud initiation.

2.5. Statistical analysis

Data was entered and organized using Microsoft Excel. The effects of potassium doses and moisture regimes on the studied variables were first subjected to the Shapiro-Wilk test to determine the normal distribution and analyzed through two-way Analysis of Variance (two-way ANOVA) to identify the significance of the results using the statistical software R version 4.4.0 (package: Agricolae). For mean comparison, the Least Significant Difference (LSD) test was employed to find significant mean differences between treatments at a significance level of 5%. Data visualization was also done using Microsoft Excel

3. RESULTS AND DISCUSSION

3.1. Plant height

Potassium doses and soil moisture regimes significantly influenced plant height (Table 2 and Figure 1). The application of potassium levels gave significant ($p \leq 0.001$) differences for plant height. Application of 120 kg/ha K produced the highest plant height (36.66 cm, 61.61 cm and 81.27 cm at 25, 40, and 55 DAT, respectively), followed by 160 kg/ha K whereas, 40 kg/ha K resulted in the lowest plant height. Similarly, 100% of FC exhibited significantly greater heights at all growth stages compared to 60% FC. K doses and soil moisture regimes interaction also showed a significant effect on plant height (highest at the interaction of 120 kg/ha K under 100% of FC). Since K plays the vital role in the activation of enzymes, cell expansion, photosynthesis, nitrogen use, and water balance, it favors stem elongation for plant height (Hasanuzzaman et al., 2018). On the other hand, adequate water supply helps in maintaining cell turgor, supporting translocation of photosynthates and regulating plant hormones, which can enhance vegetative growth (Kudoyarova et al., 2015).

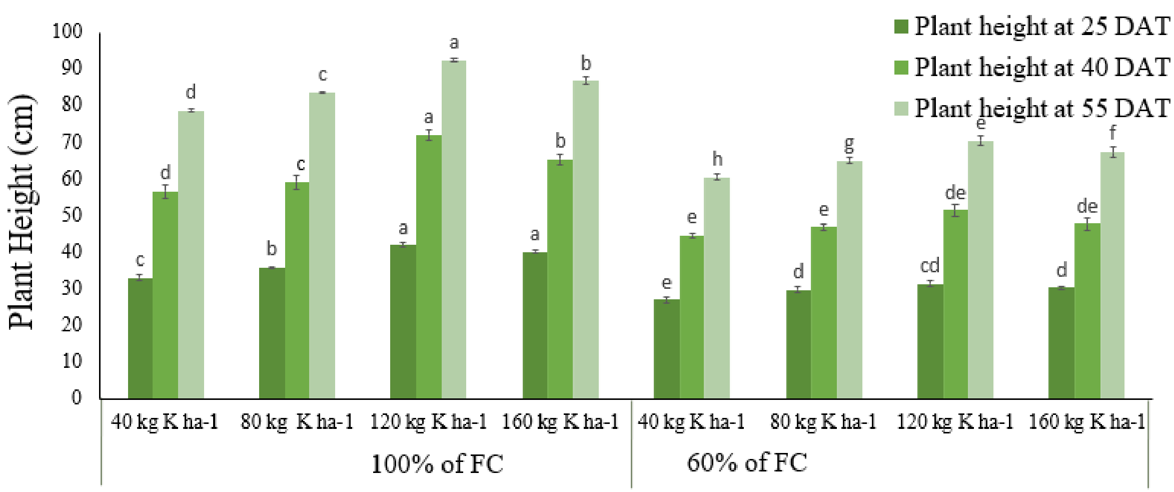

Figure 1: Effect of potassium doses and moisture regimes interaction on plant height

3.2. Stem diameter

Stem diameter increased significantly ($p \leq 0.001$) as K doses increased from 40 kg/ha to 160 kg/ha. The stem diameter was the largest at 160 kg/ha K(0.91 cm), followed by 120 kg/ha K and the smallest at 40 kg/ha. Kanai et al. (2011) suggested that increased potassium enhances stem diameter as it improves water uptake, photosynthesis and anatomical characteristics of the stem. Moisture regimes also significantly affected stem diameter. Plants grown under 100% of FC had significantly larger stem diameters (0.88 cm) than those under 60% of FC (Table 2). Also, plants at 100% FC fully absorb water, which increases the pressure that helps the cells to expand and divide, resulting in thicker stems as new cells develop in the cambial layer (Meng et al., 2017). But the interaction effect of potassium doses and moisture regimes was found to be non-significant.

Table 2: Effect of potassium doses and moisture on plant height and stem diameter of marigold at different days after transplanting.

Treatment	PH25 (cm)	PH40 (cm)	PH55 (cm)	SD25 (cm)	SD40 (cm)	SD55 (cm)
K doses (kg/ha)						
40	29.91[d]	50.53[c]	69.40[d]	0.40[c]	0.53[b]	0.79[c]
80	32.75[c]	52.95[c]	74.12[c]	0.45[b]	0.61[b]	0.81[c]
120	36.66[a]	61.61[a]	81.27[a]	0.48[a]	0.70[a]	0.85[b]
160	35.16[b]	56.95[b]	76.93[b]	0.50[a]	0.78[a]	0.91[a]
LSD (0.05)	1.411	3.391	1.107	0.026	0.831	0.036
SEM (±)	0.116	0.279	0.091	0.002	0.006	0.002
Significance	***	***	***	***	***	***
Moisture regimes						
60% of FC	29.56[b]	47.56[b]	65.66[b]	0.36[b]	0.61[b]	0.80[b]
100% of FC	37.68[a]	63.23[a]	85.20[a]	0.55[a]	0.70[a]	0.88[a]
LSD (0.05)	0.998	2.397	0.783	0.018	0.058	0.025
SEM (±)	0.164	0.395	0.129	0.003	0.009	0.004
Significance	***	***	***	***	**	***
Interaction						
LSD (0.05)	1.996	4.795	1.566	0.037	0.117	0.051
SEM (±)	0.082	0.197	0.064	0.001	0.004	0.002
Significance	**	*	**	.		
CV, %	3.39	4.94	1.185	4.649	10.156	3.467
Grand Mean	33.62	55.4	75.43	0.46	0.66	0.84

Note: PH25: Plant height at 25 DAT, PH40: Plant height at 40 DAT, PH55: Plant height at 55 DAT, SD25: Stem diameter at 25 DAT, SD40: Stem diameter at 40 DAT, SD55: Stem diameter at 55 DAT, LSD: Least Significant Difference, SE m = Standard error of mean, CV: Coefficient of variation, '***', '**', '*', '.' and ' ' indicates significant at 0.001, 0.01, 0.05, 0.1 and 1 probability level respectively and value with same letters on column are not significantly different at 5% DMRT.

3.3. Primary and secondary branches number

The number of primary and secondary branches varied significantly with the individual and interactive effects of potassium doses and moisture regimes. The highest number of primary and secondary branches was recorded at 120 kg/ha K and the lowest ones were again observed at the 40 kg/ha dose. Plants under 100% of FC produced significantly higher number of primary branches at 55 DAT (25.43) and secondary branches at 55 DAT (16.67) compared to those under 60% of FC (Table 3). According to Silva et al. (2021), an increase in potassium doses improves CO_2 assimilation, water use efficiency, and root branching patterns in plants. And sufficient moisture supports an increase in the number of branches, by improving physiological processes such as chlorophyll content, leaf area, and overall biomass production (Wadleigh & Ayers, 1945).

3.4. Plant canopy spread

The significant differences were observed in the individual effects of potassium and moisture on plant canopy; however, they did not show significant effects for their interaction (Table 3). The plant canopy spreads were significantly larger at 120 kg/ha K (59.11 cm). Potassium plays a pivotal role in promoting the production and movement of growth hormones like auxins, which promote lateral branching and leaf development. As a result, plants can capture more sunlight, which enhances their ability to photosynthesize (Xie et al., 2020). Similar findings were supported by Hasanuzzaman et al. (2018). The plants applied with 100% of FC had significantly larger canopy spreads (27.01 cm, 42.59 cm and 57.93 cm) than the other one. Through sufficient moisture, the plant tissues hydrate better. This promotes cell expansion and root development, which supports increased nutrient uptake, further driving shoot growth and canopy spread (Banik et al., 2024).

Table 3: Effect of potassium doses and moisture on number of primary branches, secondary branches and plant canopy spread of marigold at different days after transplanting

Treatment	PB25	PB40	PB55	SB40	SB55	PC25 (cm)	PC40 (cm)	PC55 (cm)
K doses (kg/ha)								
40	5.16^{c}	19.33^{c}	21.30^{c}	8.58^{c}	14.45^{d}	21.50^{c}	37.12^{c}	51.96^{c}
80	5.65^{b}	20.96^{b}	22.61^{b}	9.00^{b}	15.21^{c}	23.75^{bc}	39.71^{b}	54.65^{bc}
120	6.58^{a}	22.53^{a}	25.38^{a}	9.53^{a}	16.78^{a}	28.08^{a}	42.80^{a}	59.11^{a}
160	6.43^{a}	22.26^{a}	23.35^{b}	9.13^{b}	15.91^{b}	24.48^{b}	41.55^{a}	56.00^{b}
LSD (0.05)	0.231	0.495	0.763	0.161	0.276	2.652	1.688	2.743
SEM (±)	0.019	0.041	0.062	0.013	0.022	0.218	0.139	0.226
Significance	***	***	***	***	***	***	***	***
Moisture Regimes								
60% of FC	5.15^{b}	19.98^{b}	20.89^{b}	8.60^{b}	14.5^{b}	21.89^{b}	38.00^{b}	52.93^{b}
100% of FC	6.76^{a}	22.56^{a}	25.43^{a}	9.51^{a}	16.67^{a}	27.01^{a}	42.59^{a}	57.93^{a}
LSD (0.05)	0.163	0.350	0.539	0.114	0.195	1.875	1.194	1.940
SEM (±)	0.027	0.057	0.089	0.018	0.032	0.309	0.196	0.319
Significance	***	***	***	***	***	***	***	***
Interaction								
LSD (0.05)	0.370	0.700	1.079	0.228	0.391	3.751	2.388	3.880
SEM (±)	0.013	0.028	0.044	0.009	0.016	0.154	0.098	0.159
Significance	**	**	*	***	*			
CV, %	3.139	1.880	2.661	1.438	1.434	8.76	3.384	3.99
Grand Mean	5.95	21.27	23.16	9.06	15.59	24.45	40.29	55.43

Note: PB25: Number of primary branches at 25 DAT, PB40: Number of primary branches at 40 DAT, PB55: Number of primary branches at 55 DAT, SB40: Number of secondary branches at 40 DAT, SB55: Number of secondary branches at 55 DAT, PC25: Plant canopy spread at 25 DAT, PC40: Plant canopy spread at 40 DAT and PC55: Plant canopy spread at 40 DAT.

3.5. Days to early flower initiation

There was a significant influence of potassium and soil moisture regimes on the days to flower initiation. Application of 120 kg/ha K showed the earliest flowering (28.05 days) and 50% flower initiation (36.00 days), followed by 80 kg/ha. Similarly, plants treated with 100% of FC resulted in significantly earlier flowering (30.58 days) and reached 50% flower initiation sooner (39.83 days) than those at 60% of FC. The interaction of 120 kg/ha K with 100% FC significantly accelerated flowering (28.00 days) and resulted in earlier days to 50% flower initiation (Table 4). This might be due to plant canopy spread at 55 DAT potassium-mediated enzymes being activated along with optimal cellular hydration, which together accelerate meristematic activity and floral primordia development (Singh & Rao, 2005).

3.6. Flower diameter

The flower diameter was also significantly influenced by different levels of potassium and moisture. Significantly, 120 kg/ha K recorded the larger diameter of the flower (6.54 cm), followed by 80 kg/ha (6.19 cm), whereas the smaller flowers were found at 40 kg/ha K. Similarly, plants grown at 100% of FC produced flowers with a larger diameter than those grown at 60%. The interaction between them also resulted in a significant effect ($p \leq 0.05$) (Table 4).

3.7. Number of flowers

Plants treated with 120 kg/ha K produced significantly higher number of flowers (30.45), followed closely by 160 kg/ha K and the lowest were observed at 40 kg/ha K. Plants grown under 100% of FC significantly outperformed those under 60% of FC again, with statistically significant differences. There were significant interactions ($p < 0.05$) between potassium doses and moisture regimes for the number of flowers per plant (Table 4 and Figure 2). A similar result was found by Sanghamitra et al. (2015), who concluded that higher potassium levels are directly proportional to the number of flowers in marigold plants. This is because potassium improves nutrient uptake, helps in photosynthesis, and carbohydrate transport to flower buds. It also plays a key role in regulating enzymes and hormones like auxins that promote flowering, resulting in an increased number of blooms (Teja et al., 2017). The increased soil moisture leads to more efficient nutrient transport and higher turgor pressure, which stimulates bud formation and results in an increase in the number of flowers (Martin, 1940).

3.8. Flower fresh weight and yield

The potassium dose of 120 kg/ha recorded significantly higher flower weight (8.83 gm) and yield (11.11 t/ha), which were statistically similar to those of 80 kg/ha. Similarly, the lowest flower weight and yield was found at 40 kg/ha K. 100% of FC produced a significantly higher flower weight (6.27 gm) and yield (6.27 t/ha) than those under 60% of FC. A similar result by Massoud et al. (2014), which showed that irrigating marigold plants resulted in maximum fresh and dry weights, while less irrigated marigold plants produced the lowest weight. The interaction effect was also significant, with 120 kg/ha K and 100% of FC producing the maximum flower fresh weight (11.67 gm) and yield (11.52 t/ha) (Table 4). Potassium enhances water uptake and retention in marigold cells while proper moisture ensures optimal nutrient transport, together leading to increased flower fresh weight through better cell expansion and metabolic functions (Singh & Rao, 2005).

Table 4: Effect of potassium doses and moisture on yield attributes of marigold at different days after transplanting

Treatment	**DFI**	**DFI_{50}**	**FH60**	**FH70**	**FW (gm)**	**FD (cm)**	**Yield (t/ha)**
K doses (kg/ha)							
40	34.33^{b}	45.00^{c}	15.45^{c}	15.46^{d}	5.30^{c}	5.42^{d}	9.03^{c}
80	33.30^{b}	42.50^{b}	23.30^{a}	26.06^{b}	8.08^{ab}	6.19^{b}	10.3^{ab}
120	28.50^{a}	36.00^{a}	23.97^{a}	30.45^{a}	8.83^{a}	6.54^{a}	11.11^{a}
160	34.66^{b}	44.33^{c}	20.60^{b}	23.16^{c}	6.76^{bc}	5.76^{c}	9.98^{bc}
LSD (0.05)	1.62	1.98	1.72	1.67	1.72	0.33	0.35

SEM (±)	0.13	0.16	0.14	0.13	0.14	0.27	0.11
Significance	*	**	*	**	**	***	**
Moisture regimes							
60% of FC	34.33^{b}	44.08^{b}	19.6^{b}	22.43^{b}	5.80^{b}	6.27^{b}	8.60^{b}
100% of FC	30.58^{a}	39.83^{a}	22.06^{a}	25.14^{a}	8.68^{a}	5.68^{a}	10.80^{a}
LSD (0.05)	1.14	1.40	1.22	1.18	1.21	0.23	0.22
SEM (±)	0.18	0.23	0.20	0.19	0.20	0.37	0.16
Significance	*	**	*	**	**	***	**
Interaction							
LSD (0.05)	2.29	2.80	2.44	2.36	2.43	0.47	0.81
SEM (±)	0.75	0.92	0.80	0.78	0.80	0.55	0.61
Significance	**	*	*	*	*	*	*
CV, %	4.04	3.82	6.69	5.68	19.17	4.49	3.20
Grand Mean	32.4	41.95	20.84	23.78	7.24	5.98	9.85

Note: DFI: Days to flower initiation, DFI_{50}: 50% of bud emergence, FH60: Flower heads/plant at 60 DAT, FH70: Flower heads/plant at 70 DAT, FW: Flower fresh weight and FD: Flower diameter

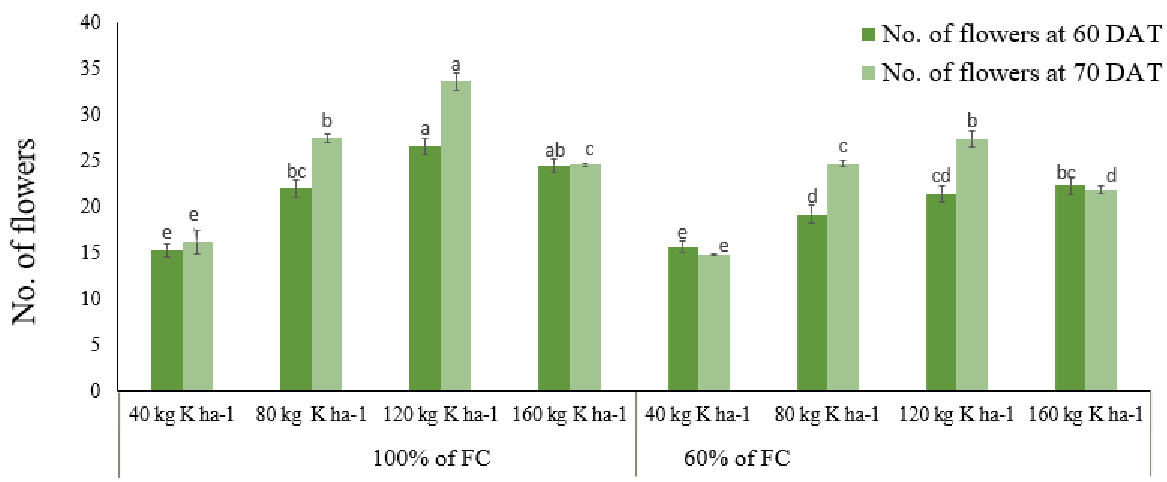

Figure 2: Effect of potassium doses and moisture regimes interaction on the number of flowers

4. CONCLUSION

Based on the study, it was found that potassium doses and soil moisture regimes had significant and consistent effects on the growth, flowering, and yield attributes of African marigold. The application of 120 kg/ha K significantly increased all the parameter, while 160 kg/ha K showed comparable but not consistently superior effects but was able to give significantly larger stem diameter. And 40 kg/ha K resulted in inferior growth and yield attributes. All the measured parameters were significantly higher at 100% of FC. Similarly, the synergistic effects of 120 kg/ha K under 100% of FC had a significant effect on overall parameters. Thus, it can be concluded that the application of 120 kg/ha K with 100% of FC results in better marigold flower production. However, further multi-seasonal and multi-locational trials of the experiment are required before making broad recommendations to farmers.

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REFERENCES

Bakshi, L., & Ghosh, R. (2022). Marigold biopesticide as an alternative to conventional chemical pesticides. *Journal of Advanced Scientific Research*, *13*(05), 26-33. https://doi.org/10.55218/JASR.202213503

Banik, B., Korav, S., Guin, A., & Unjia, D. (2024). Impact of Drip Irrigation on Crop Growth, Yield, Water Productivity, and Weed Dynamics: A Review. *International Journal of Environment and Climate Change*, *14*(4), 739–749. https://doi.org/10.9734/IJECC/2024/V14I44154

Chen, R., Liu, L., & Liu, X. (2022). The Negative Impact of Excessive Moisture Contributes to the Seasonal Dynamics of Photosynthesis in Amazon Moist Forests. *Earth's Future*, *10*(1), e2021EF002306. https://doi.org/10.1029/2021EF002306

FAO. (2014). The practice of irrigation. https://www.fao.org/4/t0231e/t0231e03.htm

FAO. (2024). *Nepal at a glance | FAO in Nepal | Food and Agriculture Organization of the United Nations*. https://www.fao.org/nepal/fao-in-nepal/nepal-at-a-glance/en/

Floriculture Association Nepal. (2018). *Marigold Flower Cultivation Technology*. 16.

Hasanuzzaman, M., Bhuyan, M. H. M. B., Nahar, K., Hossain, M. S., Al Mahmud, J., Hossen, M. S., Masud, A. A. C., Moumita, & Fujita, M. (2018). Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy*, *8*(3), 31. https://doi.org/10.3390/AGRONOMY8030031

Himalayan News Service. (2020). *Domestic production to meet flower demand - The Himalayan Times.* https://thehimalayantimes.com/business/domestic-production-to-meet-flower-demand

Kanai, S., Moghaieb, R. E., El-Shemy, H. A., Panigrahi, R., Mohapatra, P. K., Ito, J., Nguyen, N. T., Saneoka, H., & Fujita, K. (2011). Potassium deficiency affects water status and photosynthetic rate of the vegetative sink in green house tomato prior to its effects on source activity. *Plant Science*, *180*(2), 368–374. https://doi.org/10.1016/J.PLANTSCI.2010.10.011

Khalil, R., Elsayed, N., Khan, T. A., & Yusuf, M. (2022). Potassium: a potent modulator of plant responses under changing environment. In *Role of Potassium in Abiotic Stress* (pp. 221-247). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-16-4461-0_11

Kudoyarova, G. R., Dodd, I. C., Veselov, D. S., Rothwell, S. A., & Yu. Veselov, S. (2015). Common and specific responses to availability of mineral nutrients and water. *Journal of Experimental Botany*, *66*(8), 2133–2144. https://doi.org/10.1093/jxb/erv017

Kumar, A., Dhansu, P., & Mann, A. (Eds.). (2023). *Salinity and drought tolerance in plants: physiological perspectives* (pp. 387-417). Singapore:: Springer. https://doi.org/10.1007/978-981-99-4669-3

Martin, E. V. (1940). Effect of Soil Moisture on Growth and Transpiration in Helianthus Annuus. *Plant Physiology*, *15*(3), 449–466. https://doi.org/10.1104/PP.15.3.449

Massoud, H. Y., Sharef El-Deen, M. N., Yousef, R. M. M., & Megahed, M. S. (2014). Effect of water requirement and organic fertilization on growth and yield of marigold (Calendula officinales L.) PLANTS UNDER SANDY SOIL CONDITIONS. *Journal of Plant Production*, *5*(11), 1849-1865. doi 10.21608/jpp.2014.64734

Meng, Z., Duan, A., Chen, D., Dassanayake, K. B., Wang, X., Liu, Z., Liu, H., & Gao, S. (2017). Suitable indicators using stem diameter variation-derived indices to monitor the water status of greenhouse tomato plants. *PLOS ONE*, *12*(2), e0171423. https://doi.org/10.1371/JOURNAL.PONE.0171423

MoALD. (2023). Statistical Information on Nepalese Agriculture 2022/23, Ministry of Agriculture and Livestock Development, Government of Nepal. Kathmandu.

Sanghamitra, M., Vijaya Bhaskar, V., Dorajee Rao, A. V.D., & Subbaramamma, P. (2015). Effect of different sources and levels of potassium on yield and carotenoids content of African marigold (Tagetes erecta linn.) cv. Maxima Yellow. *Plant Archives*, *15*(2), 633–636.

Silva, D. M. R., Santos, J. C. C. D., Sab, M. P. V., & Silva, M. D. A. (2021). Morpho-physiological and nutritional responses of safflower as a function of potassium doses. *Journal of Plant Nutrition*, *44*(13), 1903-1915. https://doi.org/10.1080/01904167.2021.1881550

Singh, M., & Rao, G. (2005). Effects of nitrogen, potassium and soil moisture regime on growth, herbage, oil yield and nutrient uptake of South American marigold (Tagetes minuta L.) in a semi-arid tropical climate. *The Journal of Horticultural Science and Biotechnology*, *80*(4), 488-492. https://doi.org/10.1080/14620316.2005.11511965

Teja, P. R., Bhaskar, V. V., Dorajeerao, A. V. D., & Subbaramamma, P. (2017). Effect of graded levels of nitrogen and potassium on growth and flower yield of annual chrysanthemum (Chrysanthemum coronarium L.).

Wadleigh, C. H., & Ayers, A. D. (1945). Growth and Biochemical Composition of Bean Plants as Conditioned By Soil Moisture Tension and Salt Concentration. *Plant Physiology*, *20*(1), 106–132. https://doi.org/10.1104/PP.20.1.106

Xie, K., Lu, Z., Pan, Y., Gao, L., Hu, P., Wang, M., & Guo, S. (2020). Leaf photosynthesis is mediated by the coordination of nitrogen and potassium: The importance of anatomical-determined mesophyll conductance to CO2 and carboxylation capacity. *Plant Science*, *290*, 110267. https://doi.org/10.1016/J.PLANTSCI.2019.110267

Zahara, Meutia, Vera Nazhira Arifin, and Syarifah Farissi Hamama. "A Brief Review of Efficacious Plants in the World: Tagetes (Marigold)." *Journal of Tropical Biodiversity & Biotechnology* 9.2 (2024). https://doi.org/10.22146/jtbb.85079

EVALUATING THE APPLICATION OF NEPALESE FOOD COMPOSITION DATABASE FOR ADDRESSING IRON DEFICIENCY ANEMIA

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ABSTRACT

Iron deficiency anemia (IDA) remains a persistent public health challenge in Nepal, affecting 43% of children under five and up to 47.6% of pregnant women. This study evaluates the quality and applicability of the Nepalese Food Composition Table (NFCT) and the Nepal Agricultural Research Council (NARC) database for addressing the IDA burden. Using a qualitative design, the methodology comprised 12 semi-structured Key Informant Interviews with stakeholders from government, academia, and the private sector, supplemented by a literature review and a comparative technical review against the Indian Food Composition Tables (IFCT). Results show that NFCT 2017, despite covering 387 food items, lacks analytical sensitivity, carries an estimated error margin of ±10%, and omits iron bioavailability data. NARC 2024 is more statistically structured but limited by geographic bias and a lack of animal-source and processed-food data. IFCT 2017, by contrast, shows stronger analytical precision, broader geographic coverage, and bioavailable-iron profiling. These gaps constrain dietary assessment and nutrition-sensitive policy planning in Nepal. The study recommends a multi-sectoral approach to strengthen laboratory infrastructure, adopt standardized FAO/INFOODS methodologies, and integrate food composition data digitally, supporting the Multi-Sector Nutrition Plan III and a shift from supplementation toward sustainable food-based strategies.

1. INTRODUCTION

Iron deficiency anemia (IDA) in Nepal

Micronutrient deficiencies, especially IDA, continue to be a persistent public health problem in Nepal, affecting cognitive development in children and adolescents and physiological health in women of reproductive age. Despite decades of targeted interventions, the burden of anemia in Nepal remains among the highest in the South Asian region. The 2022 Nepal Demographic and Health Survey (NDHS) reports a national prevalence of 43% among children under five and 46% to 47.6% among pregnant women (MoHP, 2023). Iron deficiency is thought to account for roughly half of all anemia cases (Sherpa et al., 2026). High anemia prevalence reflects both low intake of iron-rich foods and poor iron utilization by the body.

Food composition database (FCD)

FCDs are the building blocks of nutrition science; they are used to measure food consumption and translate it into nutrient intake. Globally, organizations such as FAO/INFOODS have made significant efforts to harmonize, standardize, and improve access to this data (Charrondiere et al., 2020; Ortenzi et al., 2021). Nevertheless, gaps remain in food composition data, particularly regarding the relevance and usefulness of such data for developing-country contexts.

FCD in nutrition planning

FCDs play a critical role in nutrition planning and program decision-making. High-quality, standardized databases enable accurate nutrient intake estimates and help identify population-level deficiencies for targeted interventions (Ahuja et al., 2020; Charrondiere et al., 2022). However, the limited coverage of micronutrients in these databases constrains the development of effective nutrition strategies (Beal et al., 2021). Improved data quality and harmonization strengthen dietary assessment accuracy, which is essential for sound policymaking, while the inclusion of indigenous biodiversity in datasets makes strategies more culturally relevant and better suited to local dietary needs (Stadlmayr et al., 2020).

FCD in research and nutrition programs

FCD is central to nutritional epidemiology as the analytical tool that converts food consumption data into nutrient profiles for population-level health assessments. High-quality FCD is essential for translating findings into effective micronutrient programs; weak FCD coverage of iron and vitamin A constrains program design in developing countries (Charrondiere et al., 2022). Differences in analytical methods and documentation across studies also make findings difficult to compare and less reliable (González-Domínguez et al., 2021; Ortenzi et al., 2021).

FCD in dietary guidelines

FCD is critical for converting nutrient goals into dietary recommendations and remains a vital tool for public health interventions. Gaps in this data reduce the accuracy of intake measurement and weaken the evidence base for dietary recommendations (Micha et al., 2021). Global studies emphasize harmonized, high-quality FCD as a prerequisite for effective, evidence-based food and nutrition guidelines (Charrondiere et al., 2022), and evidence supports incorporating indigenous foods to improve dietary adequacy modelling and cultural relevance (Stadlmayr et al., 2020).

Dietary assessment tools and FCD

Combining FCDs with dietary assessment instruments such as food frequency questionnaires, 24-hour recalls, and digital applications is central to modern nutritional epidemiology. Digital tools have improved the efficiency and accessibility of dietary assessment, but FCD quality remains the key determinant of accuracy (Cade et al., 2021; Kirkpatrick et al., 2020). Newer tools, including mobile and image-based systems, depend on real-time access to comprehensive FCDs to calculate nutrient intake (Illner et al., 2021). Cross-platform integration remains challenging, however, due to inconsistent food classification and a lack of standardized food descriptors (Westenbrink et al., 2021), and limited food matching reduces accuracy across different dietary contexts (Bradley et al., 2020).

Data quality evaluation for FCD

FCD is reliable only when established quality criteria, particularly those recommended by FAO/INFOODS, are followed. Key criteria include sampling representativeness, validated analytical methods, sound nutrient profiles, and complete metadata documentation (Charrondiere, 2020). Where these are inconsistent, data quality and comparability suffer (Ortenzi et al., 2021), limiting the usefulness of FCDs for research and policy applications (Greenfield & Southgate, 2021; Kumari et al., 2023). Poor analytical validation can also introduce errors in nutrient values, particularly for micronutrients (Beal et al., 2021).

This study assessed the quality of iron-content data in Nepal's food composition tables and the NARC database in relation to the national IDA burden. Specifically, it evaluated the comprehensiveness, methodological quality, and contextual relevance of existing food composition data; identified gaps in micronutrient profiling; and explored how existing data could inform nutrition policy, dietary assessment, and nutrition-based interventions. A comparative technical review of the Nepalese and Indian food composition tables was conducted using secondary data.

2. METHODOLOGY

This study used a qualitative research design combined with a literature review. Primary qualitative data were collected through 12 semi-structured Key Informant Interviews (KIIs) with stakeholders from government, academia, development partners, and the private sector, focusing on institutional roles in IDA prevention and management and on programmatic opportunities for applying FCD. A review of nutrition policy documents identified gaps and opportunities for FCD application in IDA prevention and management in Nepal. Findings were validated through expert consultation with nutrition and food composition specialists.

3. RESULTS AND DISCUSSIONS

Food composition database of Nepal

Systematic FCD collection in Nepal began more than six decades ago with the establishment of the Department of Food in 1961, which later evolved into the Department of Food Technology and Quality Control (DFTQC) (DFTQC, 2017; Ojha et al., 2024). Over time, Nepal's food composition tables have improved, strengthening their role in nutritional research, dietary assessment, and policy formulation. The Nepalese Food Composition Table (NFCT) 2017 is the country's most extensive national table, covering 387 food items across major food groups, including a substantial number of plant-based iron sources. Its nutrient profile includes proximate composition, three minerals (iron, calcium, and phosphorus), and four vitamins (carotene, vitamin C, riboflavin, thiamin, and niacin) (DFTQC, 2017).

NFCT 2017 follows a product-based approach and uses standardized AOAC laboratory protocols, but its analytical methods lack sensitivity, producing less precise micronutrient values. This yields an estimated error margin of ±10% when sampling from local markets, compounded by environmental variability, which limits confidence in nutrient estimates. The table also lacks data on iron bioavailability. Figure 1 shows the distribution of food items across the eight NFCT groups.

The recently launched NARC FCD 2024 represents a shift toward a more structured, statistically grounded approach. It covers 100 food products using structured sampling and standardized AOAC and ASTM protocols (Ojha et al., 2024), but its scope remains narrow: it focuses primarily on plant foods, omits animal-source and processed foods, and is further limited by geographic sampling bias across over- and under-sampled regions.

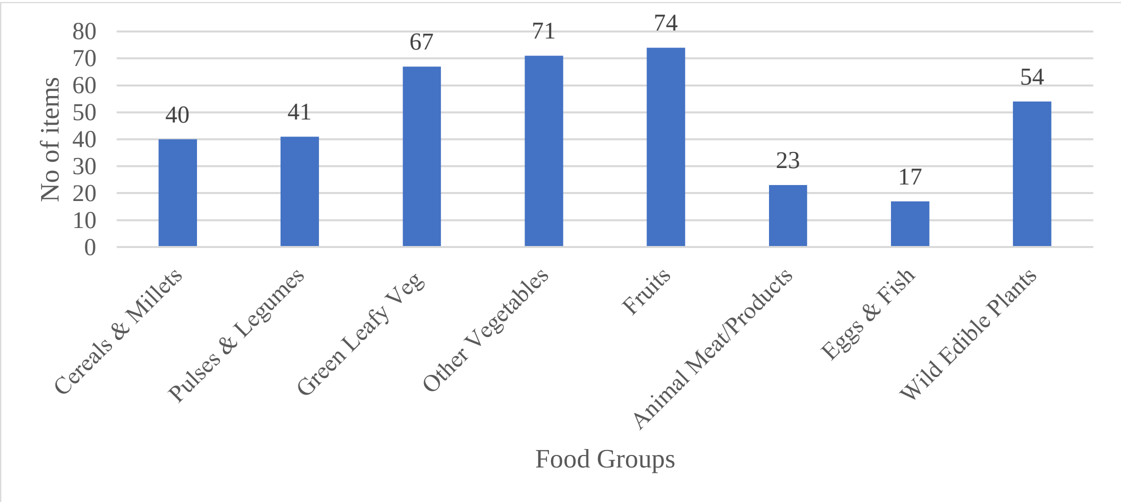

Figure 1. Coverage of food items in NFCT 2017.

By comparison, the Indian Food Composition Tables (IFCT) 2017 represent a well-established system developed since 1937 and updated over subsequent decades (Longvah et al., 2017). IFCT 2017 covers 533 food items across 20 plant- and animal-based food groups, supporting more comprehensive assessment of both total and bioavailable iron intake. Figure 2 shows the distribution of food items across the thirteen IFCT groups.

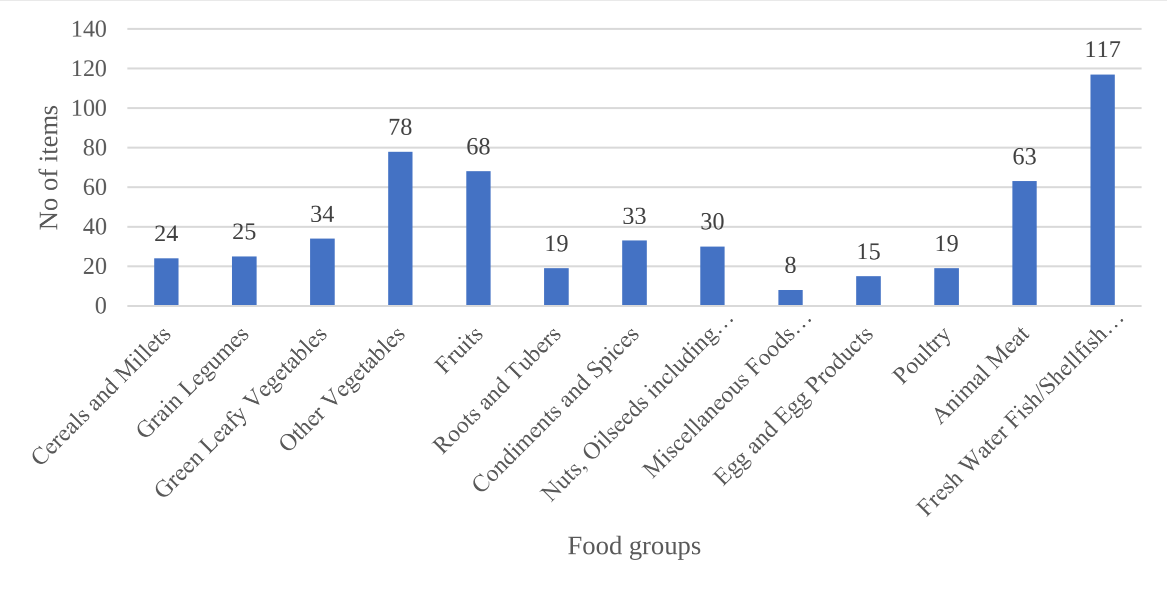

Figure 2. Coverage of food items in IFCT 2017.

Both countries show strong coverage of plant foods, reflecting national dietary patterns dominated by cereals, legumes, and green leafy vegetables. India's IFCT, however, has substantially stronger representation of animal-source foods, allowing better estimation of bioavailable iron intake than Nepal's database. India also shows clear superiority in analytical precision and consistency: its use of certified reference materials and probability-based sampling produces more reliable, comparable data (Longvah et al., 2017), whereas Nepal's limited laboratory capacity yields less accurate and less reproducible results, reflecting underlying differences in technical infrastructure and investment. Geographic representativeness is another key gap: IFCT draws on nationally representative sampling across diverse agro-ecological zones, while Nepal's datasets carry regional bias, particularly under-representing remote and ecologically distinct areas, which limits their usefulness for national-level dietary evaluation and policymaking. Both countries also share difficulty in measuring iron bioavailability, a gap that limits understanding of the physiological significance of nutrient composition data.

Both systems struggle to capture the full diversity of indigenous foods, ethnic dishes, and processed foods, though Nepal's gaps are deeper, particularly in indigenous biodiversity and micronutrient completeness. Both databases point to the need for food-based solutions that support traditional, nutrient-dense food crops; underutilized foods are recognized as potential iron sources in both countries, labelled as pseudocereals in Nepal and as millets in India.

Utilization of FCD in IDA prevention

In Nepal, DFTQC, under the Ministry of Agriculture and Livestock Development, leads FCD development and management. KII findings point to multiple opportunities for applying FCD within ongoing nutrition programs across ministries, development partners, and professional sectors, particularly in promoting locally available foods as a sustainable, food-based strategy for anemia prevention. However, inadequate data on iron-rich foods continues to constrain program planning and policy use, directly limiting the design of effective Social and Behavioral Change (SBC) programs for IDA prevention.

Weak FCD coverage limits efforts to promote dietary diversity locally, restricts the integration of indigenous and iron-rich foods into programs, and weakens evidence-based dietary counseling. It also reduces the effectiveness of nutrition labelling, limits promotion of iron-rich foods within Food-Based Dietary Guidelines (FBDGs), and weakens SBC approaches targeting IDA prevention. Table 1 summarizes KII findings on institutional roles and programmatic opportunities for using FCD in IDA prevention.

Table 1: Institutional role and strategic opportunities for utilizing FCD in IDA prevention

S.N.	Agency	Role (in IDA Prevention and Management)	Opportunities
1	National Planning Commission	Coordinates national nutrition programs across federal, provincial, and local levels	Promote programs encouraging consumption of iron-rich foods
2	Ministry of Agriculture and Livestock Development	Plans and implements nutrition-sensitive agriculture; develops food balance sheets; develops and promotes FBDGs	Strengthen nutrition-sensitive agriculture planning; promotes food-based strategies focused on iron nutrition; address iron in FBDGs
3	Ministry of Health and Population	Distributes Iron-Folic Acid (IFA) supplements to adolescents and pregnant women; implements school health programs	Promote dietary diversity with iron-rich foods; supports development of iron-rich school meal recipes; enables gradual transition from supplementation to food-based approaches
4	Ministry of Education, Science and Technology	Designs school curricula; implements school meal programs	Integrate iron-rich food concepts into curricula; incorporate iron-rich foods in school meals
5	Ministry of Federal Affairs and General Administration	Plan and implement nutrition programs at provincial and local levels	Support design and dissemination of SBC messages
6	Provincial Ministries (Agriculture, Health)	Plan agriculture and nutrition-specific programs	Promote nutrition-sensitive agriculture; integrates SBC messages into health education
7	Local Governments	Implements agriculture and health programs at local level	Strengthen delivery of effective SBC programs
8	Academia (Universities)	Designs and updates curricula; conducts research and development	Incorporate food composition data into academic curricula
9	Food Industries	Nutrition labelling for consumer education	Enhance consumer education through labelling; develop iron-rich processed foods; promote indigenous iron-rich foods in niche markets
10	Hospitals (Clinicians and Dietitians)	Dietary recommendations	Educate vulnerable groups, including children, adolescents, and pregnant women

S.N.	Agency	Role (in IDA Prevention and Management)	Opportunities
11	Development Partners (e.g., World Food Programme, UNICEF)	Support food fortification; manages severe and moderate acute malnutrition (SAM, MAM); promotes nutrition-sensitive agriculture	Food-based program planning; promote dietary diversity across health and agriculture SBC programs
12	Consumer Associations	Deliver SBC messages to the general public	Promote consumption of iron-rich foods; discourage unnecessary iron supplementation

Note. IDA = Iron Deficiency Anemia; IFA = Iron-Folic Acid; SBC = Social and Behavior Change; FBDGs = Food-Based Dietary Guidelines; SAM = Severe Acute Malnutrition; MAM = Moderate Acute Malnutrition.

4. CONCLUSION

Nepal's food and nutrition literacy lags significantly, driven by an incomplete Food Composition Database (FCD) that covers basic nutrients for less than half of commonly consumed foods. Crucial data on traditional foods, anti-nutritional factors, and plant-iron bioavailability remain unrecorded—a major gap given Nepal's predominantly plant-based diet.While recent initiatives like NARC 2024 mark progress, DFTQC still faces severe analytical and coverage constraints. To modernize Nepal's FCD system, a coordinated multi-sectoral approach is required;

Standardization & Digital Integration: Conduct primary nutrient testing via FAO/INFOODS standards and digitize FCD data for seamless use in dietary assessment tools.

Institutional Capacity: Build partnerships with universities, upgrade laboratory infrastructure, and establish continuous updating mechanisms.

Policy Alignment: Integrate updated FCD data directly into national health strategies, specifically supporting Nepal's Multi-Sector Nutrition Plan III (2023–2030) target to reduce anemia among women and children by 10%.

Strengthening FCD shifts technical data into a practical asset for evidence-based dietary guidelines and national nutrition policy.

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REFERENCES

Ahuja, J. K. C., Li, Y., & Haytowitz, D. B. (2020). USDA food and nutrient database for dietary studies: Update and applications. *Journal of Food Composition and Analysis, 87*, 103386. https://doi.org/10.1016/j.jfca.2019.103386

Beal, T., Massiot, E., Arsenault, J. E., Smith, M. R., & Hijmans, R. J. (2021). Global gaps in food composition data for critical nutrients. *BMJ Global Health*, *6*(7), e006113. https://doi.org/10.1136/bmjgh-2021-006113

Bradley, J., Simpson, E., Poliakov, I., et al. (2020). Measurement of dietary intake using technology. *Public Health Nutrition, 23*(14), 2530–2540.

Cade, J. E., Warthon-Medina, M., Albar, S., et al. (2021). DIET@NET: Best practice guidelines for dietary assessment. *BMC Medicine, 19*, 202.

Charrondiere, U. R., Stadlmayr, B., Rittenschober, D., et al. (2020). FAO/INFOODS food composition database for biodiversity. *Journal of Food Composition and Analysis, 89*, 103470.

Charrondiere, U. R., Stadlmayr, B., & Burlingame, B. (2022). The role of food composition data in nutrition policy and research. *Frontiers in Nutrition, 9*, 889910.

Department of Food Technology and Quality Control. (2017). *Food composition table for Nepal 2017.* Government of Nepal, Ministry of Agriculture and Cooperatives.

González-Domínguez, R., Castellano-Escuder, P., Carmona-Pontaque, F., et al. (2021). Advances in food composition databases. *Nutrients, 13*(5), 1739.

Greenfield, H., & Southgate, D. A. T. (2021). Food composition data: Production and use. *Food Chemistry, 342*, 128275.

Illner, A. K., Freisling, H., Boeing, H., Huybrechts, I., Crispim, S. P., & Slimani, N. (2021). Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. *International Journal of Epidemiology, 50*(2), 604–620. https://doi.org/10.1093/ije/dyaa258

Kirkpatrick, S. I., Baranowski, T., Subar, A. F., Tooze, J. A., & Frongillo, E. A. (2020). Dietary assessment using digital tools. *Annual Review of Nutrition, 40*, 327–348.

Kumari, M., Ahmad, S., & Sharma, R. (2023). Integration of food composition databases in South Asia. *Food Policy, 114*, 102392.

Longvah, T., Ananthan, R., Bhaskarachary, K., & Venkaiah, K. (2017). *Indian food composition tables.* National Institute of Nutrition, Indian Council of Medical Research.

Micha, R., Coates, J., Leclercq, C., Charrondiere, U. R., & Mozaffarian, D. (2021). Dietary data quality and global guidelines. *The Lancet Planetary Health, 5*(6), e426–e436.

Ministry of Health and Population [MoHP], New ERA, & ICF. (2023). *Nepal Demographic and Health Survey 2022.* MoHP.

National Planning Commission [NPC]. (2023). *Synopsis of Multi-Sector Nutrition Plan III (2023–2030).* Government of Nepal.

Ojha, P., Karki, R., Sharma, B., et al. (2024). *Nepal food composition database.* National Food Research Centre, Nepal Agricultural Research Council.

Ortenzi, F., Beal, T., & Fanzo, J. (2021). Data quality and harmonization challenges. *Nutrients, 13*(7), 2406.

Sherpa, M., Rai, P., Trital, D., et al. (2026). Iron deficiency anemia: A major public health challenge in Nepal .Research Square. https://doi.org/10.21203/rs.3.rs-8633488/v1

Stadlmayr, B., Mwakaboko, A. E., & Charrondiere, U. R. (2020). Nutrient composition of indigenous foods. *Journal of Food Composition and Analysis, 87*, 103381.

Westenbrink, S., Roe, M., Oseredczuk, M., Castanheira, I., & Finglas, P. (2021). Food composition databases and tools: Interoperability for dietary assessment in Europe. *European Journal of Clinical Nutrition, 75*(2), 265–272. https://doi.org/10.1038/s41430-020-00787-0

FALL ARMYWORM, *Spodoptera frugiperda* (J.E. Smith) DAMAGE SEVERITY ON MAIZE CROPS IN FARMERS' FIELD CONDITIONS IN KATHMANDU VALLEY

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ABSTRACT

Maize, a major staple crop that is essential for Nepal's food security and rural livelihoods, is increasingly threatened by the invasive fall armyworm (Spodoptera frugiperda J.E. Smith), which causes substantial yield losses while farmers' heavy reliance on indiscriminate pesticide use and limited knowledge of sustainable management practices obstruct effective control. Field survey was carried out in six major maize-growing areas of Kathmandu valley- Kathmandu, Bhaktapur and Lalitpur districts to assess the fall armyworm, Spodoptera frugiperda (J.E. Smith) incidence, severity and farmers' management practices during maize growing season in 2024. Semi-structured questionnaires were used for farmer interview , and damage assessment in the field was recorded using a score ranging from 1 to 9 scale based on the reference damage on the scaling of the leaf lesions, scraping of leaf surfaces and visual observations of the damage symptoms. Data analysis and result interpretation were carried out using MS Excel 2016 and SPSS version 29.0.2.0. Results indicated that maize crop damage incidence and severity varied significantly ($p<0.05$) with $p<0.001$ at vegetative and $p=0.005$ reproductive stages. Damage severity was highest in V11 stage during vegetative stage and dough (R4) stage during reproductive stage of maize crop. Similarly, in relation to temperature, the damage was more at temperature range of 25°C to 27°C. The highest infestation (91%) was observed in Kathmandu compared to other two districts. The survey indicates that maize farmers have to focus on agro-ecological adoption approaches like chemical, cultural, physical/mechanical, IPM, biological, and botanical measures for the management of this pest.

1.INTRODUCTION

Internally displaced persons (IDPs) are Maize (*Zea mays* L.) is a versatile crop grown across a wide range of agro-climatic zones. It thrives from 58°N to 40°S and at altitudes from sea level to 3,000 m, from the sea level with annual rainfall requirements that span roughly 250–5,000 mm (CIMMYT 2023,; FAO 2023). Globally, maize is cultivated in more than 160 countries on about 197 million hectares, contributing nearly 1.2 billion tons of grain and accounting for around 35–36% of total global cereal production (FAO, 2023; OECD-FAO, 2023). The United States remains the largest maize producer, contributing about one-third of global production (FAO, 2023; Solaimalai et al., 2020).

The crop is widely cultivated in Nepal, particularly in the mid-hills and Terai regions. However, it is predominantly grown in the hills, where farm sizes are generally smaller compared to the Terai (Gairhe et al., 2021). Globally, maize ranks among the top cereal crops in terms of production and trade, alongside wheat and rice (Erenstein et al., 2022). Moreover, the contribution of cereal crops in national GDP of Nepal accounted about 8.24% in the fiscal year 2020/21 (MoALD, 2020/21). It ranks the second after rice with contribution of GDP 6.83% in the fiscal year 2020/21 In Nepal, maize is cultivated over an area of approximately 0.98 million hectares, with a total production of around 3.0 million tonnes and an average productivity of about 3.15 t/ha (MoALD, 2022/23); far lower than the global yield of 5.71 Mt/ha(FAO 2023; MoALD 2022/23)

In the hills, more than 86% of the maize produced is used for human use, and 80% of the Terai produced is used as animal feed, with the remaining 10% being used in industries and human consumption (Timsina et al., 2016). Furthermore, in the hills and mid-hills, 60% of the grain produced is used for animal feed, 25% for human use, and 3% for seed and the remaining 12% is marketed (Ghimire et al., 2019). The amount of maize consumed per person per day in Nepal was calculated 98 g/person/day (KC et al., 2015; Ranum & Pe, 2014). This crop can grow during both short- and long-day periods and is photo-insensitive (Coles et al., 2010). Maize contains nearly 72% starch, 10% protein, and 4% fat. Its caloric density is 365 kcal/100g (Ranum and Pe, 2014).

A review was made on the notorious insect pest fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) which has potential to cause maize yield losses of 20-25% (Badhai et al., 2020). For the pest to be established, the temperature during pre-monsoon, monsoon and post monsoon is highly favorable. According to reports, *S. frugiperda* larvae can consume 353 different plant species, but in Nepal, the pest poses a serious threat, particularly to the maize crop due to the country's moderate climate, vegetation, staggered and scattered maize planting, all of which make it ideal for the pest to establish itself (Sah et al., 2020). Despite its widespread occurrence, it is mostly found in areas with very low frost cover, a minimum annual temperature of 18–26 °C, and 500–700 mm of rainfall (Early et al., 2018). Given the economic and food security importance of maize and the increasing threat posed by *S. frugiperda*, there is a pressing need for effective and context-specific pest management strategies. This study aimed to assess the incidence and severity of *S. frugiperda* infestation and to document farmers' existing management practices. Specifically, the objectives were to: (i) determine the prevalence and distribution of *S. frugiperda* across selected sites, (ii) evaluate the level of infestation and crop damage in farmers' fields, and (iii) analyze the pest management strategies adopted by farmers to control this pest.

2.MATERIALS AND METHODS

2.1 Study area

Survey and field-based studies were conducted in selected municipalities of the Kathmandu valley, representing the major maize-growing areas with a history of fall armyworm occurrence. Kathmandu, Lalitpur and Bhaktapur districts were purposively selected because maize is widely cultivated in these districts under diverse agro-ecological conditions, making them suitable for assessing FAW incidence, severity and farmers management practices. Within the selected municipalities, farm sites were chosen using simple random sampling to ensure unbiased representation. Field damage assessmens were conducted in Tarakeshwar Municipality (Kathmandu), Khumaltar(Lalitpur),and Madhyapur Thimi (Bhaktapur) For the farmer survey, five municipalities were selected: Tarakeshwar and tokha in Kathmandu, Mahalaxmi in Lalitpur, and suryabinayak and Madhyapur Thimi in Bhaktapur (Figure-1)

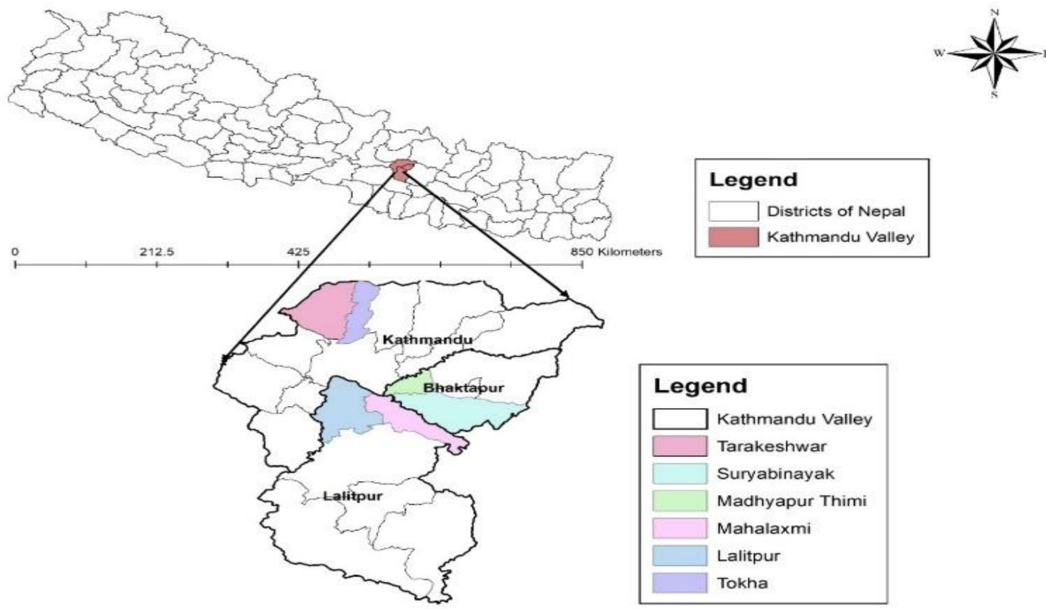

Figure 1: Map of study area

2.2 Questionnaire survey

The survey was conducted across five municipalities in the Kathmandu Valley, encompassing Kathmandu, Bhaktapur, and Lalitpur districts. Respondents were selected from maize-growing households with the assistance of municipal agriculture offices and local farmer groups, and only farmers who cultivated maize during the 2024 season were included in the survey. A simple random sampling approach was then used to select respondents from the prepared list of eligible maize growers. A total of 90 maize-growing farmers were selected, with 15–20 respondents sampled from each municipality. Specifically, 40 respondents were selected from Kathmandu district (20 each from Tarakeshwar and Tokha municipalities), 20 respondents from Mahalaxmi municipality in Lalitpur district, and 30 respondents from Bhaktapur district (15 each from Suryabinayak and Madhyapur Thimi municipalities).

Data were collected using a semi structured questionnaire comprising both closed- and open-ended questions. Closed-ended questions were employed to obtain information on pest identification, the prevalence status of *Spodoptera frugiperda*, and infestation levels across different maize growth stages. In addition, semi-structured open-ended questions were used to gather detailed information on fertilizer application practices, pest management strategies, and farmers' perceptions of crop damage.

Table 1. Number of farmers across municipality and total number of maize growers in each municipality

Area/District	Municipalities	Number of Respondents	Estimated Maize Growers (HH)
Kathmandu	Tarakeshwar	20	~800 – 1,200
	Tokha	20	~500 – 900
Lalitpur	Mahalaxmi	20	~600 – 1,000
Bhaktapur	Suryabinayak	15	~400 – 700
	Madhyapur Thimi	15	~300 – 600
Total		90	

Source: Field Survey and Estimated maize growers s (CBS,2021)

2.3 Data recording

Data on *S. frugiperda* infestation patterns and damage severity in maize were collected from June to August 2024. Observations included different growth stages of the crop, taking into account the prevailing weather conditions during each sampling period. Data were recorded on a weekly basis using a standardized scoring sheet (Davis et al., 1992; Ni et al., 2011).

In total, 14 farms across the three districts were included in the study, with 10 plants randomly selected from each field for observation. During the vegetative stage, field scouting followed a "W" sampling pattern, where damage levels were systematically observed and recorded. During the reproductive stage, data were collected using a ladder sampling pattern (Prasanna et al., 2021).

Table 2. Damage scoring by sampling of farmers maize growing fields

Score	Description/Symptoms
1	Healthy plant/ No damage/Visible Symptoms
2	Few short/pin sizes holes/scraping on a few leaves (1-2)
3	Short/pin size holes/scraping on several leaves (3-4)
4	Short/pin size holes/scraping on several leaves (5–6) and a few long elongated lesions (1–3 Nos) up to 2.0 cm in length present on whorl and or adjacent fully opened leaves
5	Several holes with elongated lesions (4–5 Nos) up to 4.0 cm in length and uniform/ irregularly shaped holes present on whorl and or adjacent fully opened leaves
6	Several leaves with elongated lesions (6–7 Nos) up to 6.0 cm in length and uniform/ irregular shaped holes present on whorl and adjacent fully opened leaves
7	Several long lesions (>7 Nos) up to 10 cm in length and uniform/irregular shaped holes common on one-half of the leaves present on whorl and adjacent fully opened leaves
8	Several long lesions >10 cm in length and uniform/irregular shaped holes common on one half to two-thirds of leaves present on whorl and adjacent fully opened leaves
9	Complete defoliation of whorl of the plant

Source: (Davis et al., 1992; Ni et al., 2011)

2.4 Damage severity at different crop stages

Data was recorded observing the visual damage symptoms and infestation pattern on the leaves of 10 maize plants from each farmer's maize field. Damage score was given varying from 1 to 9 following the reference table of damage score (Davis et al., 1992; Ni et al., 2011). Data was recorded for ten weeks maintaining the weekly interval in the fields chosen for study. For the damage severity evaluation, average field damage score was calculated district wise (Table 2)

2.5 Level of maize crop damage

Damage level and its severity were determined following the 1 to 9 rating scale (Davis et al., 1992; Ni et al., 2011) where the higher ratings were based on the length of the lesions on the leaf. The damage rating varied from 1 (healthy plant/no damage/visible symptoms) to 9 (complete defoliation of whorl of the plant). For each plant, the stage of the plant was determined during both vegetative and reproductive stages. The plants were selected following the pattern recommended during field scouting (Prasanna et al., 2021). The infestation patterns by *S. frugiperda* were identified based on the visual observation and scored scale measurement of the lesions, and damage severity**.**

2.6 Primary data

The primary data encompass quantitative data that was collected through field research in various municipalities of Kathmandu valley. The quantitative information was concerned with *S. frugiperda* infestation patterns and damage levels in maize fields. The qualitative data for the study was collected through a household survey. Various maize growing farming sites were selected for the study with the consultation of Agriculture Knowledge Center (AKC), Lalitpur and Plant Quarantine and Pesticide Management Center (PQPMC), Hariharbhawan, Lalitpur.

2.7 Secondary data

Data related to the study was collected from related publications on *S. frugiperda* infestation patterns and damage severity in maize crops. Various books, journals, research papers, proceedings, annual publications of different institutions from internet and other sources were used as sources of secondary data for the study.

2.8 Statistical analysis

The data collected from the field scouting was first recorded in MS Excel 2016 and analyzed using software SPSS version 29.0.2.0 (20). The collected data for respective study parameters were classified according to the required values, like mean and standard error. One-way analysis of variance (ANOVA) was used to check the significant differences between the groups. Data on temperature was accessed from the online source. The coefficient of determination (R^2) was determined to analyze the variance caused by temperature to the field damage level.

3. RESULTS AND DISCUSSION

3.1 Information about fall armyworm and their damage in maize

As shown in figure 2, 72% of the respondents were able to identify fall armyworm (*Spodoptera frugiperda*), whereas 28% were unable to identify the pest. This finding is consistent with Kumela et al. (2019), who reported that the majority (99%) of farmers in Ethiopia were aware of *S. frugiperda*. Likewise, Poudel et al. (2023) reported that 59.3% of farmers in Baitadi, Nepal, were able to identify *S. frugiperda* based on visual observation, which is broadly comparable to the findings of the present study

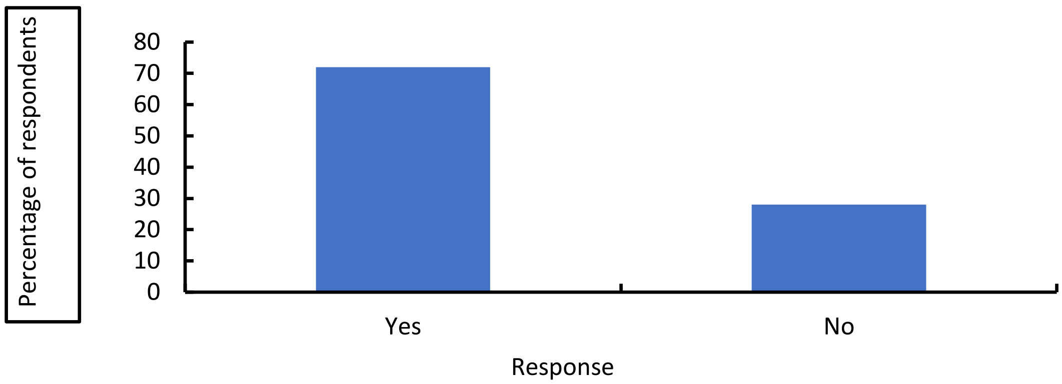

Figure 2 Identification of the fall armyworm, S. frugiperda by maize farmers

3.2 Fall armyworm prevalence in farmers' fields:

Based on two-way interaction between the farmers and the interviewers, it was found that 3% of the respondents had no prevalence of fall armyworm their fields. Three-fourth of the respondents (75%) experienced a moderate level of infestation, indicating a widespread but manageable presence of the pest. Meanwhile, 22% of the respondents reported a high level of infestation in their maize fields, suggesting significant pest pressure in those areas. These findings, as illustrated in Figure 3, highlight that *S. frugiperda* infestation is prevalent across most surveyed fields, with varying degrees of severity.

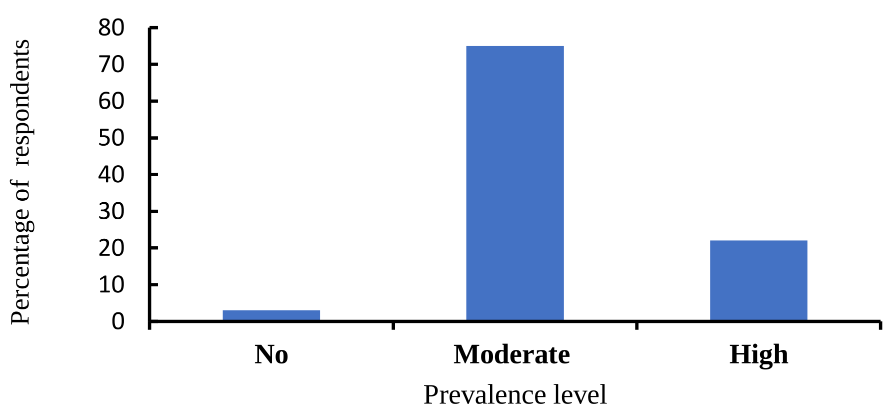

Figure 3. Prevalence status of FAW

3.3 Fall armyworm prevalence at different stages of maize growth

Based on the responses of the farmers and their field experience, farmers reported that *S. frugiperda* damage occurs from seedling stage to the tasseling and silking stages (Figure 4). Infestation was most frequently reported at the knee height stage (40%), followed by the tasseling and silking stages(27%), seedling stage (13%), milking stage (11%), and maturity stage (9%). This finding aligns with the result of Poudel et al. (2023), that highlights that compared to all other pests, *S. frugiperda* causes the most serious damage at vegetative growth stage, tasseling stage, and physiological maturity stage of maize development.

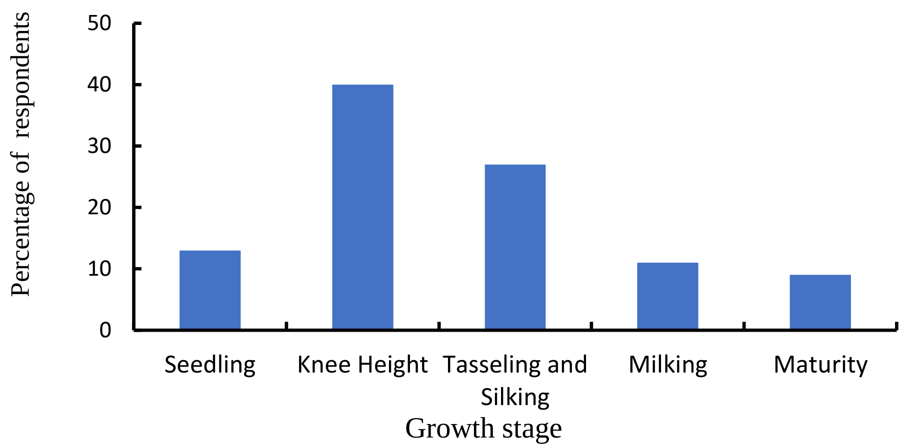

Figure 4. Prevalence status based on growth stage

3.4 *Fall armyworm damage in 2024 year*

During the survey, data relating to damage caused by *S. frugiperda* in previous year was also evaluated using closed ended questionnaire. Figure 5, depicted that 31% of the responded believed <10% damage, 47% optioned 10-30% damage, 13% indicated 30-60% damage and remaining 9% viewed >60% damage in 2024. Here, majority of the farmers responded with 10-30% damage which is similar with the findings of Kansiime et al. (2019) where majority of farmers reported with major pest damage level of (10-40%).

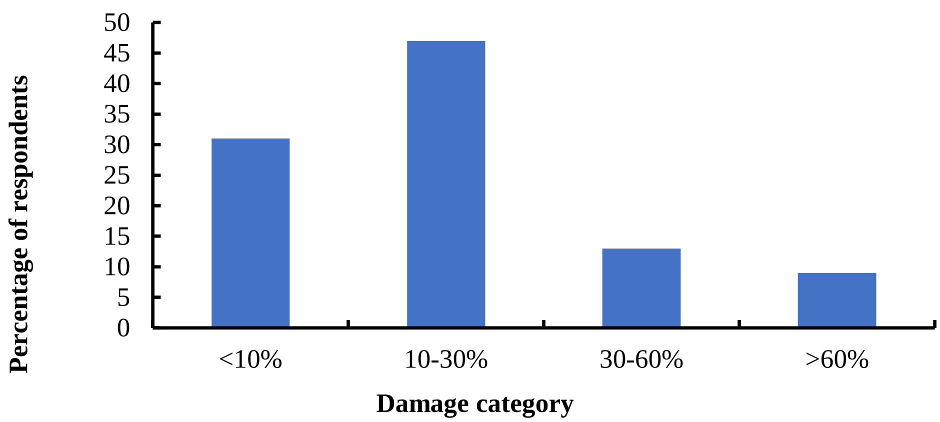

Figure 5. Damage caused by FAW in 2024 year

3.5 *Farmers' practices of fall armyworm management*

The survey revealed that most maize farmers in the Kathmandu valley cultivated maize primarily for household consumption. The majority of farmers were unfamiliar with biological control and integrated pest management (IPM) approaches and relied predominantly on chemical pesticides for pest management. A smaller proportion of farmers adopted cultural practices, including timely weeding, hoeing, and irrigation, as part of their crop management. Overall, 67% of farmers relied on chemical control methods, followed by cultural practices (13%), physical/mechanical methods (7%), IPM (6%), biological control (4%), and botanical measures (3%) (Figure 6).

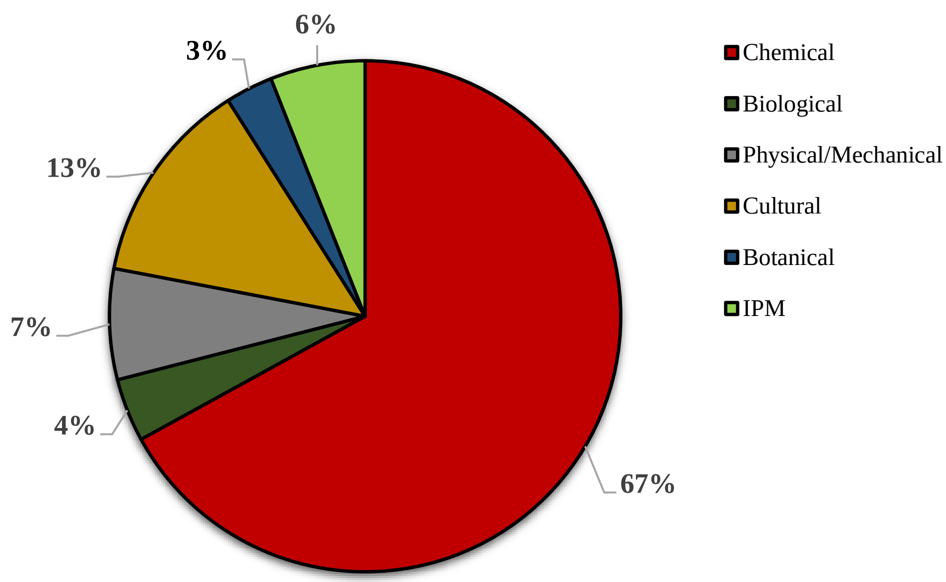

Figure 6. Management practices adopted by farmers

According to Bista et al. (2020), intercropping maize in strips with pigeon pea, cowpea, cassava etc. or other repellant crops aid in reducing the infestation level and reproductive activities in *S. frugiperda*. Yurina et al. (2023) reported that compared to a non-IPM plot, the IPM adopted for fall armyworm in maize was more productive economically beneficial and ecologically friendly.

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3.6 Farmers' source of technical advice

Study showed farmers relying on advice from agro-vets for management of *S. frugiperda* (Figure 7). It was found that 39% of the respondents depended on agro-vets, 22% on mobile apps/digital services, 19% on other maize growers, 17% on media (radio, television, newspaper) and only 3% on the technicians. Bhandari et al. (2021), reported that very few households received extension services regarding fall armyworm and related preventative measures.

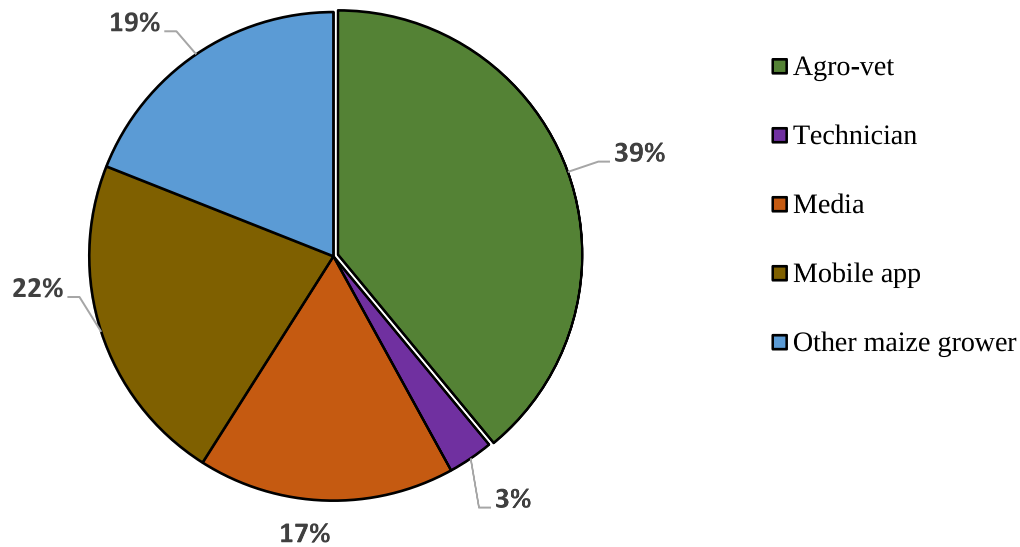

Figure 7. Source of technical advice for pest control

3.7 Maize crop damage severity

Table 3 presents the one-way Analysis of Variance (ANOVA) results comparing average damage score across vegetative growth stages, which differed significantly ($p < 0.05$) at different vegetative growth stages of maize crop.

Table 3. ANOVA table for average field score at vegetative stage o maize crop

Source of variation	Sum of squares	df	Mean square	F	p-value
Between Groups	58.750	13	4.519	48.919	<0.001
Within Groups	2.587	28	0.092		
Total	61.336	41			

Source: Field Research, 2024

Figure 8 presents the results of the one-way Analysis of Variance (ANOVA) comparing the mean damage scores across different vegetative growth stages of maize. The analysis revealed significant differences among vegetative stages ($p < 0.05$), indicating that the level of crop damage varied significantly throughout maize development. Post-hoc mean separation using Tukey's HSD test was performed, and the corresponding grouping letters are shown above the error bars in Figure 8. Vegetative stages sharing the same letter are not significantly different, whereas stages with different letters differ significantly at the 5% significance level. The average damage scores across the three study districts are illustrated in Figure 8. Damage increased progressively with crop growth stage, reaching its highest value at the V11 stage, followed by V12 and VT (tasseling stage). In contrast, the V3 stage recorded the lowest average damage score. The Tukey HSD groupings further indicate that the later vegetative stages generally experienced significantly greater damage than the early vegetative stages. This trend suggests that maize plants become increasingly susceptible to pest injury as they advance through vegetative development.

These findings are consistent with those reported by Omar (2023), who noted that larvae can infest maize throughout the crop growth cycle, causing characteristic leaf-feeding damage accompanied by sawdust-like frass and subsequently damaging reproductive structures. As pest populations build up over time, damage severity tends to increase during the later vegetative stages, potentially resulting in substantial yield losses. Consequently, effective pest monitoring and management should be emphasized during the mid- to late-vegetative growth stages of maize.

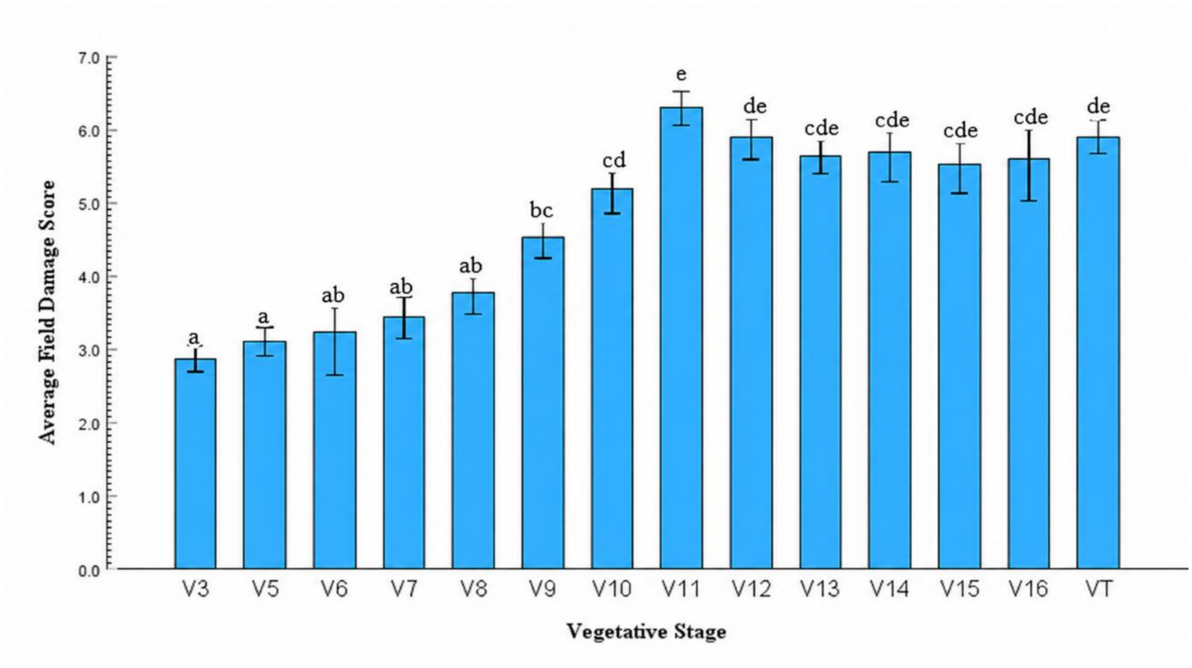

Figure 8- Damage level in vegetative stage

3.8 Damage severity in reproductive stage of maize crops

The ANOVA Table 3 shows the average maize plant damage score at different reproductive stages. There was significant effect in the change of average damage score in relation to the reproductive stage of plant ($p < 0.05$). In the ANOVA table, p-value is lesser than the typical alpha value (0.05) i.e. (Table 4). This suggested that the average field damage score and reproductive stage of plant have statistically significant difference.

Table 4. ANOVA table for average field score at reproductive stage of maize crop

Source of variation	Sum of squares	df	Mean square	F	p-value
Between Groups	8.143	4	2.036	7.151	0.005
Within Groups	2.847	10	0.285		
Total	10.989	14			

Source: Field Research, 2024

Similarly, Figure 9 shows the average field damage scores across different reproductive stages of the crop- Silk, Blister, Milk, Dough and Dent. The highest average damage score was found in the Dough (R4) stage followed by Milk (R3) and Dent (R5) stage. While the lowest average damage was found in the Silk (R1) stage.

Results of Table 3 and 4, are in line with the findings of Mutyambai et al. (2022), who stated that maize damage levels varied significantly ($p<0.05$) across cropping systems, production systems, soil types, and weeding patterns, where young maize plants were more infected and damaged compared to tasseling and mature plant

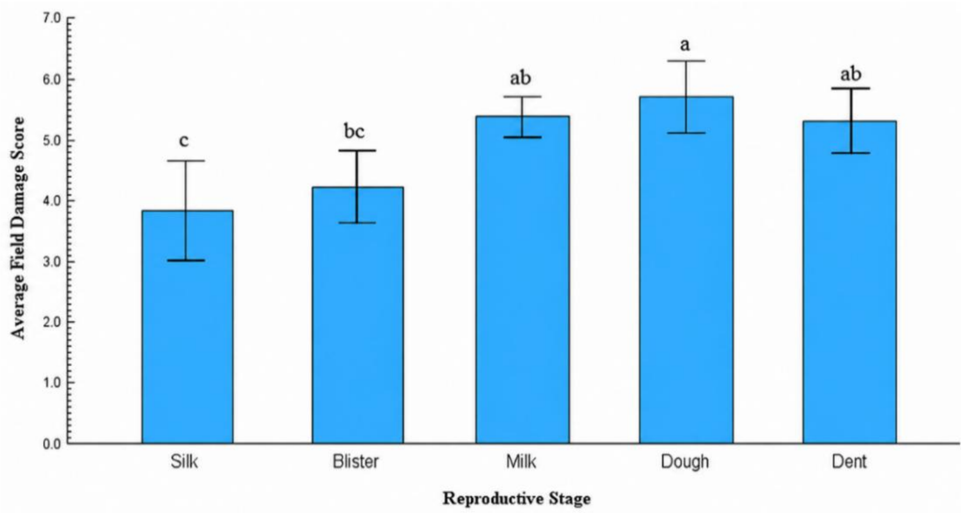

Figure 9: Damage level in reproductive stage

3.9 Fall armyworm infestation level in Lalitpur, Kathmandu and Bhaktapur districts

Infestation level across all three districts were determined from the affected area of land and average damage percentage. The highest average damage percentage was recorded in Kathmandu followed by Bhaktapur and the lowest in Lalitpur district. Data relating to infestation level highlighting affected area of land and average damage percentage in Lalitpur is represented in Table 5.

Table. 5. Comparison of infestation level, affected area, and average damage of Fall armyworm in three districts of Kathmandu valley

District	Infestation level	Affected area (Ropani)	Average damage (%)	Comments
Bhaktapur	Low	0.88	22	Low infestation, well managed
	Medium	1.04	26	Moderate infestation
	High	1.70	34	Severe infestation observed
Kathmandu	Low	0.96	24	Low infestation, well managed
	Medium	1.74	29	Moderate infestation
	High	2.66	38	Severe infestation observed
Lalitpur	Low	0.42	21	Low infestation, well managed
	Medium	0.72	24	Moderate infestation
	High	1.24	31	Severe infestation observed

Source: Field Survey, 2024

Table 5 shows the average maize damage caused by *S. frugiperda* under low, medium, and high infestation levels in the three districts of Kathmandu Valley. Across all districts, crop damage increased as infestation severity increased, demonstrating a clear relationship between *S. frugiperda* infestation intensity and maize damage. Among the three districts, Kathmandu experienced the highest level of crop damage at every infestation category. Average damage increased from 24% under low infestation to 29% under medium infestation, reaching 38% under high infestation. These findings indicate that maize fields in Kathmandu were more severely affected by *S. frugiperda* than those in the other districts, which may be associated with higher pest pressure, environmental conditions favorable for *S. frugiperda* development, or differences in crop management and pest control practices.

Bhaktapur recorded moderate levels of crop damage, with average damage rising from 22% under low infestation to 26% under medium infestation and 34% under high infestation. Although the damage was consistently lower than in Kathmandu, the steady increase across infestation levels indicates that *S. frugiperda* remains an important production constraint for maize farmers in the district. In comparison, Lalitpur showed the lowest average crop damage across all infestation categories. Damage increased from 21% under low infestation to 24% under medium infestation and 31% under high infestation. The relatively lower damage observed in Lalitpur may reflect lower infestation pressure, more effective field management practices, or environmental conditions that limited *S. frugiperda* population development.

Overall, the results reveal a consistent pattern of increasing maize damage with increasing *S. frugiperda* infestation severity in all three districts. Kathmandu was the most severely affected district, whereas Lalitpur experienced comparatively lower damage. These findings highlight the need for district-specific integrated pest management (IPM) strategies, particularly in Kathmandu, where enhanced monitoring, early detection, and timely implementation of sustainable control measures could help reduce *S. frugiperda* infestations and minimize yield losses.

3.10 Fall armyworm damage severity in relation to temperature

Figure 10 illustrates the relationship between mean damage scores and mean temperatures across different week intervals from May 27th to July 29th in Lalitpur district. Throughout the period, mean damage scores exhibit a general upward trend, starting from around 4 at the end of May and gradually increasing to nearly 6 by the end of July. In contrast, the mean temperature, represented by a line plot, remains relatively stable, fluctuating slightly around 25°C in Lalitpur.

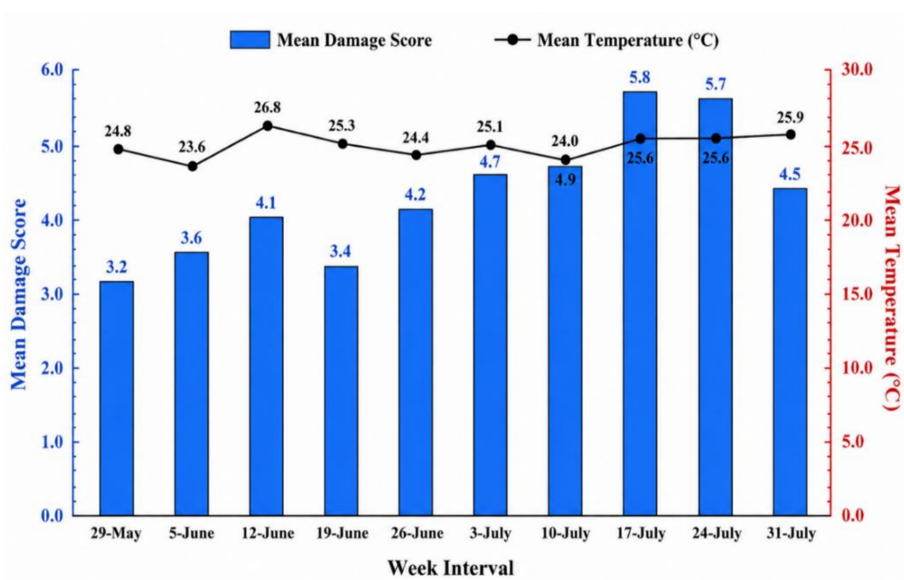

Figure 10. Average damage score vs mean temperature on weekly interval for Lalitpur district

Figure 11 illustrates the relationship between mean damage scores and mean temperatures across different week intervals from May 29th to July 31st in Kathmandu district. Throughout the period, mean damage scores exhibit a general upward trend starting from around 4 from first week of June to gradually increasing to nearly 6 by the last week of July. In contrast, the mean temperature represented by a line plot, have gradual increment in temperature from first week of June at temperature around 25.5°C. Furthermore, the mean temperature fluctuates over time with its value ranging from 20 to 25°C in Kathmandu.

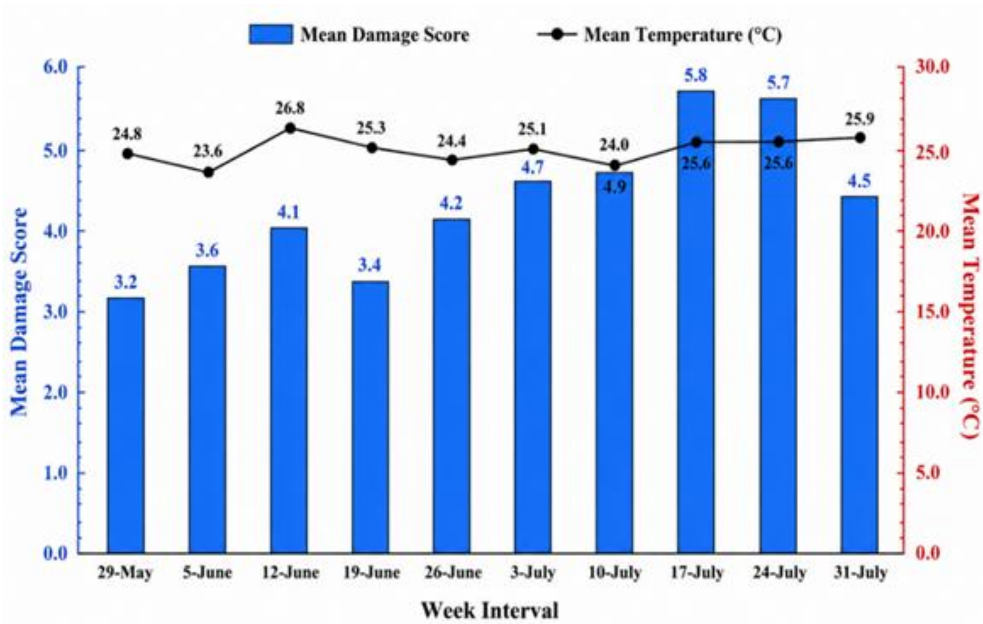

Figure 11- Average damage score vs mean temperature on weekly interval for Kathmandu

Figure 12 illustrates the relationship between mean damage scores and mean temperature across different week intervals from May 27th to July 29th. Throughout the period, the mean field damage scores exhibit alternatively increasing and decreasing trend from end of May to the first week of July. Similarly, the mean damage score exhibits increasing value from start of July and gradually increases in the mid-July and depicts decreasing trend by the end of July. In contrast, the mean temperature represented by a line plot remains relatively stable fluctuating around 25°C in Bhaktapur district.

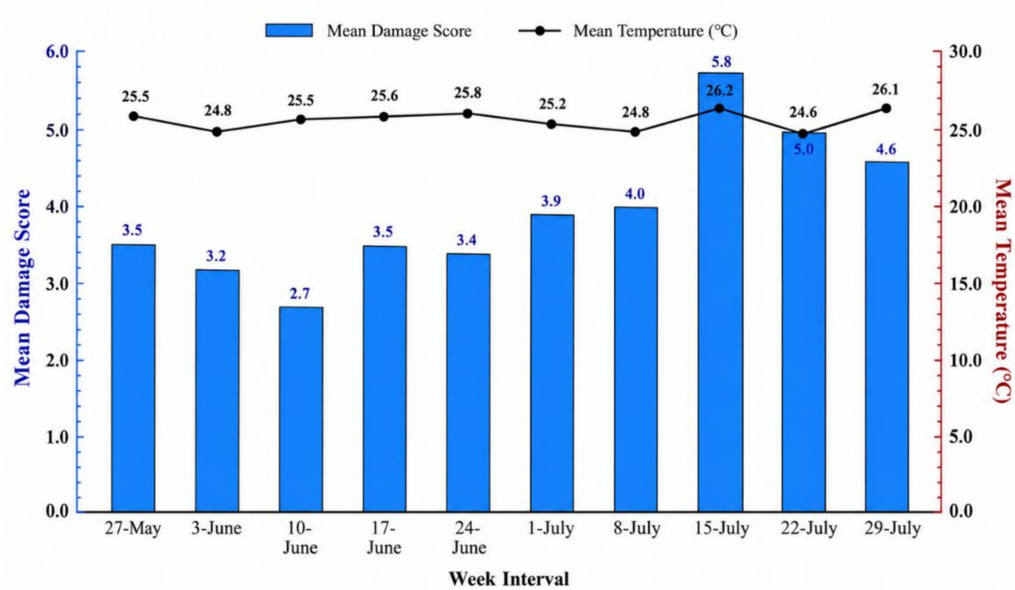

Figure 12. Average damage score vs mean temperature on weekly interval for Bhaktapur

Despite these temperature fluctuations, the increase in damage scores appears consistent, indicating that while temperature may have some influence, other factors are likely contributing to the rising damage. The correlation between damage and temperature stability suggests the need for closer examination of environmental or management practices during this period to better understand the causes of increasing crop damage. In this study, infestation pattern of *S. frugiperda* in relation to temperature remain parallel to the findings of Du Plessis et al. (2020), who reported that larval development is the highest between 26°C and 30°C. The time required for *S. frugiperda* development is significantly shorter at 31°C than it is at lower temperature but lower temperatures are still sufficient for the pest to finish its development stage (Díaz-lvarez et al., 2021). This might be the reason that even at lower temperature of 25 to 26°C infestation level is high. Likewise, findings of Haroli et al. (2023) concluded maximum temperature positively correlated in rainy season and negatively correlated in summer. Overall, the graph of three districts have an increasing trend in the average damage score level on the month of July due to the fact that low rainfall act as an additive for increase in mean damage score (Haroli et al., 2023). Similarly, He et al. (2019) reported that the mean temperature of 19 to 30 °C was optimal for *S. frugiperda* growth and development, which peaked at 29 °C. This aligns with the findings of the highest average damage score level recorded in Kathmandu and Bhaktapur in relation to temperature.

The analysis of correlation of average temperature on average damage score was conducted across three districts which have been depicted in **Table 6**.

Table 6. Coefficient of determination across three surveyed districts

District	Coefficient of determination (R^2)
Lalitpur	0.203
Kathmandu	0.241
Bhaktapur	0.196

Source: Field research, 2024

The coefficient of determination (R^2) values obtained across the three surveyed districts—Kathmandu (0.241), Lalitpur (0.203), and Bhaktapur (0.196)—indicate that mean temperature explains approximately 19–25% of the variation in fall armyworm (*Spodoptera frugiperda*) damage in maize. This suggests that while temperature plays a significant role in influencing pest incidence and severity, a large proportion of the variation is governed by other factors.

The relatively moderate R^2 values observed in this study are consistent with previous findings that highlight temperature as an important but not exclusive driver of fall armyworm population dynamics. For instance, Haroli et al. (2023) reported that temperature significantly influences larval development, feeding activity, and infestation intensity, but emphasized that its effect is often moderated by environmental and agronomic conditions. Similarly, Prasanna et al. (2018) and Day et al. (2017) noted that *S. frugiperda* performance is highly sensitive to temperature ranges, with optimal development occurring under warm conditions; however, pest outbreaks are also strongly affected by rainfall patterns, humidity, and host plant availability.

4. CONCLUSION

Fall armyworm is an invasive and destructive pest native to tropical and sub-tropical regions of the world. High infestation level of *S. frugiperda* was in the farms located in Tarakeshwar municipality. The survey conducted to know the perception of the farmers and management practices adopted in the maize growing areas gave a valuable insight about the factors responsible for the *S. frugiperda* damage incidence in those areas. Temperature fluctuation influenced the incidence severity and damage levels in the maize fields. Damage severity level analyzed considering the crop growth stage showed that there was significant effect in the damage levels with respect to the crop growth stages. Knee-height followed by tasseling and silking stage tend to have more damage score levels compared to other late whorl stages of the crop. Similarly, milking and dough stage showed more damage levels in comparison to other stages. Overall, the temperature threshold for *S. frugiperda* incidence severity determined in this study would aid in predicting the distribution and incidence level. Further study about the infestation pattern and damage levels against *S. frugiperda* is imperative.

REFERENCES

Badhai, S., Gupta, A.K., and Koiri, B. (2020). Integrated management of fall armyworm (*Spodoptera frugiperda*) in maize crop. *Reviews in Food and Agriculture*, 1(1), 27-29.

Bhandari, S., Bhattarai, R., Pandey, K.R., and Adhikari, S. (2021). Assessment of infestation of *Spodoptera frugiperda* (J.E. Smith) on maize and its implemented management practices with their efficacy in Kailali, Nepal. *Malaysian Journal of Sustainable Agriculture*, 5(1), 10-15.

Bista, S., Thapa, M. K., and Khanal, S. (2020). Fall armyworm: Menace to Nepalese farming and the integrated management approaches. *International Journal of Environment, Agriculture and Biotechnology*, 5(4), 1011-1018.

Central Bureau of Statistics (CBS). (2021). National agricultural census 2021. Government of Nepal.

CIMMYT. (2023). Maize and its global importance. International Maize and Wheat Improvement Center. https://www.cimmyt.org

Coles, N. D., McMullen, M.D., Balint-Kurti, P.J., R. C., and Holland, J.B. (2010). Genetic control of photoperiod sensitivity in maize revealed by joint multiple population analysis. *Genetics*, 184 (3), 799-812.

Davis, F.M., Sen-Seong, N.G. and Williams, W.P. (1992). Visual rating scales for screening whorl-stage corn for resistance to fall armyworm. Technical Bulletin, Mississippi Agricultural and Forestry Experiment Station, USA. p. 186.

Díaz-lvarez, E.A., Martínez-Zavaleta, J.P., López-Santiz, E.E., Barrera, E.D.L., Larsen, J., and Del-Val, E., (2021). Climate change can trigger fall armyworm outbreaks: A developmental response experiment with two Mexican maize landraces. *International Journal of Pest Management*, 69(2), 184-192.

Du Plessis, H., Schlemmer, M.L. and Van den Berg, J. (2020). The effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Insects*, 11(4), 228.

Early, R., González-Moreno, P., Murphy, S.T. and Day, R. (2018). Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. *BioRxiv*, p.391847. Available at: 10.3897/neobiota.40.28165.

Erenstein O, Jaleta, M., Sonder, K., Mottaleb, K., and Prasanna, B.M. (2022). Global maize production, consumption, and trade: trends and R&D implications. *Food Security*, 14(5), 1295-1319. Available at: https://doi.org/10.1007/s12571-022-01288-7.

FAO. (2023). FAOSTAT statistical database. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat

Gairhe, S., Timsina, K.P., Ghimire, Y.N., Lamichhane, J., Subedi, S. and Shrestha, J. (2021). Production and distribution system of maize seed in Nepal. *Heliyon*, 7(4).?

Ghimire, Y.N., Timsina, K., Devkota, D., and Poudel, H.K. (2019). Status of maize production, marketing, and prospects in Nepal. In Proceedings of the 13th Asian Maize Conference and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Asian Maize Conference, Ludhiana, India.

Haroli, M., Ramanathan, S.P., Dheebakaran, G.A., Geethalakshmi, V., Kennedy, J.S., and Duraisamy, M.R. (2023). Studies on the relationship of weather on fall armyworm damage in maize (*Zea mays* L.) under different growing environments. *Journal of Applied & Natural Science*, *15*(2), 709–715. https://doi.org/10.31018/jans.v15i2.4522

He, L.M., Ge, S.S., Chen, Y.C., Wu, Q.L., Jiang, Y.Y., and Wu, K.M. (2019). The developmental threshold temperature, effective accumulated temperature and prediction model of developmental duration of fall armyworm, *Spodoptera frugiperda*. *Plant Protection*, *45*(5), p.18e26.

Kansiime, M.K., Mugambi, I., Rwomushana, I., Nunda, W., Lamontagne-Godwin, J., Rware, H., Phiri, N.A., Chipabika, G., Ndlovu, M., and Day, R. (2019). Farmer perception of fall armyworm (*Spodoptera frugiderda* J.E. Smith) and farm-level management practices in Zambia. *Pest Management Science*, 75(10), 2840-2850.

KC, G., Karki, T.B., Shrestha, J. and Achhami, B.B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, 1(1), 1-9. Available at: 10.5281/zenodo.34257.

Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L. and Tefera, T., (2019). Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *International Journal of Pest Management*, 65(1), 1-9.

MoALD. (2023). Statistical information on Nepalese agriculture 2022/23. Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. (2020/21). Statistical information on Nepalese agriculture. Ministry of Agriculture and Livestock Development, Agri-Business Promotion and Statistics Division. Singha Durbar, Kathmandu, Nepal.

Mutyambai, D.M., Niassy, S., Calatayud, P.A. and Subramanian, S. (2022). Agronomic factors influencing fall armyworm (*Spodoptera frugiperda*) infestation and damage and its co-occurrence with stemborers in maize cropping systems in Kenya. *Insects*, 13(3), 266.

Ni, X., Chen, Y., Hibbard, B.E., Wilson, J.P., Williams, W.P., Buntin, G.D., and Li, X. . (2011). Foliar resistance to fall armyworm in corn germplasm lines confers resistance to root and ear-feeding insects. *Florida Entomologist*, 94(4), 971-981.

OECD/FAO. (2023). OECD-FAO agricultural outlook 2023–2032. OECD Publishing. https://doi.org/10.1787/08801ab7-en

Omar, H. (2023). Damage symptoms, development, and reproductive performance of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on fodder maize and cob. *Academia Biology*, *1*(1), 1-10.

Prasanna, B.M., Cairns, J.E., Zaidi, P.H., Beyene, Y., Makumbi, D., Gowda, M., Magorokosho, C., Zaman-Allah, M., Olsen, M., Das, A., and Worku, M. (2021). Beat the stress: Breeding for climate resilience in maize for the tropical rainfed environments. *Theoretical and Applied Genetics*, 134(6), 1729-1752.

Poudel, A., Upadhayay, B., Rokaya, P., Chand, S., and Regmi, B. (2023). Farmer's Knowledge on Maize Pests, Their Management, and Cultivation Practices in Baitadi. *In proceedings of the International Congresses of Turkish Science and Technology Publishing*, 414-425.

Ranum, P., Peña-Rosas, J.P. and Garcia-Casal, M.N., (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, 1312(1), 105-112.

Sah, L.P., Lamichhaney, D., KC, H.B., Acharya, M.C., Humagain, S.P., Bhandari, G. and 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.

Solaimalai, A., Anantharaju, P., Irulandi, S. and Theradimani, M. (2020). Maize crop: Improvement, production, protection, and post-harvest technology. *CRC Press* [Accessed: July 2024].

Yurina, N., Syahrawati, M., Arneti, A. and Busniah, M. (2023). The environmentally IPM package for controlling fall armyworm (*Spodoptera frugiperda*) in maize field. *Journal of Plant Protection*, 7(1), 55-64.

MARKET TREND ANALYSIS (2019-2024) OF MIXED CHEMICAL FERTILIZERS AND MICRONUTRIENT PRODUCTS IN KATHMANDU VALLEY

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ABSTRACT

In Nepal agricultural input market is observed growing basically in micronutrient fertilizers. There is no trend analysis for such inputs in recent years and thus hinders evidence-based policy making. This research was carried out to assess five-year trend analysis comparing product categories, formulation types, countries of origin, and registration status between 2019 and 2024 in Kathmandu valley. Further the objective of the study is to classify product categories and minimum nutrient specifications for policy makers. Baseline market survey was done in 2019 and documented 78 such products across the Kathmandu Valley. Again, market survey was done in 2024, and we found 218 products—a 2.9-fold increase in five years. Of 218 products surveyed across 15 agrovets in Kathmandu, Lalitpur, and Bhaktapur districts, only two (0.9%) products were found registered in Fertilizer Control Order with valid government approval. This shows the market of such product is exponentially growing.

1. INTRODUCTION

Chemical fertilizers are indispensable inputs in modern agriculture. In Nepal, their use dates to 1952, and the Government currently subsidizes and distributes the three major macronutrient fertilizers—urea (N), diammonium phosphate (DAP, P), and muriate of potash (MOP, K)—to meet approximately 60% of the country's annual active fertilizer demand (Vista et al., 2022; MoALD, 2022). While the NPK subsidy system has been relatively well-governed under the Fertilizer Control Order 2055 (1999), the private sector has increasingly filled market demand for specialty inputs: liquid fertilizers (LF), mixed micronutrient fertilizers (MN), plant growth regulators (PGR), enzymes, hormones, vitamins, and soil conditioners.

The global micronutrient fertilizer market, valued at USD 3.8 billion in 2022, is expanding at a compound annual growth rate (CAGR) of approximately 6.8–6.9%, driven by increasing soil depletion, high-value horticulture, and precision agriculture adoption (Business Research Company, 2024; Mordor Intelligence, 2025). Asia-Pacific accounts for nearly 45% of global micronutrient fertilizer consumption, with South Asian countries—including India and Nepal—contributing significantly to this demand (Coherent MI, 2023). In Nepal specifically, deficiencies of boron (B) and zinc (Zn) are well-documented: B deficiency affects 80–90% of agricultural soils, while Zn deficiency affects 20–50% of cultivated lands, with higher prevalence in the rice-growing Terai belt (Andersen, 2007; Shrestha et al., 2020a, 2020b). These deficiencies, if unaddressed, limit crop yields, impair nutritional quality of food, and contribute to hidden hunger (Bevis et al., 2023).

Despite clear agronomic need and rapidly growing market demand, Nepal's regulatory framework for specialty fertilizer inputs remains underdeveloped. The Fertilizer Control Order 2055 (1999) was drafted to regulate conventional solid NPK fertilizers and makes no specific provision for liquid formulations, mixed micronutrient products, PGRs, or soil conditioners. This legal vacuum has allowed hundreds of products of uncertain composition, quality, and efficacy to proliferate in the Nepali market without oversight. Earlier work by Vista and Shrestha (2019) documented 78 such products in the Kathmandu Valley market; the present (2023–2024) survey found the number had risen to 218, with only two approved by the Government.

This research was done to assess trend analysis comparing product categories, formulation types, countries of origin, and registration status between 2019 and 2024; and to proposed product classification categories and minimum nutrient specifications. Its contribution is threefold: it provides the first longitudinal market trend data comparing specialty agricultural inputs in Nepal over a five-year period (2019–2024); it synthesizes international minimum nutrient specifications relevant to Nepal's context; and it proposes a concrete classification framework and labeling standards for policy makers.

2. MATERIALS AND METHODS

2.1 Comparative market survey (2019 and 2023–2024)

A baseline market survey was conducted in 2019 by Vista and Shrestha (2019), documenting 78 specialty agricultural input products across the Kathmandu Valley. The present team conducted a follow-up survey in 2023–2024, visiting 15 agrovets across three districts: Kathmandu (5 agrovets, primarily in Kalimati), Lalitpur (5 agrovets), and Bhaktapur (5 agrovets). The two surveys used comparable methodologies, enabling longitudinal trend comparison.

For each product, we recorded: product name, product category (Liquid Fertilizer, Micronutrient, Soil Conditioner, Plant Growth Regulator, enzyme, hormone, vitamin), formulation type (liquid, granule, powder), country or district of origin, manufacturer name, package sizes, declared chemical composition and nutrient content, expiry period, registration status, application rate and method, recommended crops, application frequency, retail price per unit, and customer satisfaction rating. Data were entered into structured spreadsheets for each product and aggregated for analysis.

2.2 Manufacturing facility visits

We visited six manufacturing facilities in Bhaktapur, Bara, and Parsa districts. Semi-structured interviews explored production processes, raw material sourcing, blending practices, quality control, and marketing channels.

2.3 Review of international specifications

We reviewed minimum nutrient content standards for mixed liquid and solid fertilizers from India's Fertilizer (Control) Order 1985 (as amended through 2024), supplemented by standards from the EU (Regulation 2019/1009), Canada's CFIA micronutrient requirements (T-4-129), and the US EPA. The India FCO 1985 was treated as the primary reference given Nepal's geographic proximity, shared agro-ecology, and trade relationships.

2.4 Data analysis

Market data from both surveys were analyzed using descriptive statistics. Proportions were calculated for product category, formulation type, and country of origin to facilitate trend comparisons for the 2019–2024 period. Recommendations were developed through reviews, and informed by the survey data and international review.

3. RESULTS AND DISCUSSION

3.1 Five year market trend: 2019-2024

3.1.1 Overall market expansion

The most striking finding is the sheer scale of market growth. Between 2019 and 2024, the total number of specialty agricultural input products circulating in the Kathmandu Valley market increased from 78 to 218, a 2.9-fold increase in approximately five years (Table 1). This rapid proliferation mirrors global trends: the micronutrient fertilizer market has grown at a CAGR of ~6.8% globally, with developing-country markets in Asia seeing accelerated growth as awareness of soil micronutrient deficiencies improves and commercial horticulture expands (Business Research Company, 2024). Nepal's peri-urban and commercial farm belt surrounding the Kathmandu Valley—characterized by intensive vegetable cultivation with high nutrient demands—appears to be a primary driver of this demand.

Table 1. Comparative market status of specialty agricultural input products in the Kathmandu Valley, 2019 vs. 2024.

Indicator	2019	2024	Change
Total products documented	78	218	+2.9×
Number of districts/agrovets	3 districts/40 agrovets	3districts / 40 agrovets	—
Micronutrient products	35 (43%)	>131 (>60%)	+40%
PGR / Enzyme / Hormone products	35 (45%)	reduced share	↓
Soil conditioners	8 (10%)	present	—
Liquid formulation share	~67%	87% (189/218)	+20%
Powder formulations	Included	18 (8%)	—
Granule formulations	Included	11 (5%)	—
Products made in Nepal (% share)	67%	60.5%	−6.5%
No. of source countries	3	≥6	+2×
Government-approved products	7 of 35 (20%)	2 of 218 (0.9%)	↓↓
Products lacking nutrient label	0	40 (18%)	—

3.1.2 Shift in product categories

Micronutrient products dominated both surveys but increased their share from approximately 43% in 2019 to over 60% in 2024 among surveyed fertilizer baskets. This shift reflects the growing adoption of zinc, boron, calcium, and iron supplements in Nepal's intensifying crop production systems, consistent with trends documented in high-value vegetable rotations where micronutrient removal rates are substantially higher than under traditional cereal systems (Shrestha et al., 2020a). The relative share of PGR/enzyme/hormone products declined proportionately, though their absolute number may have remained stable or grown.

A notable emergence in the 2024 survey was IFFCO Nano Urea—a nanotechnology-based liquid nitrogen fertilizer approved under India's FCO 1985 in 2021 and Nepal's FCO in 2022—marking the entry of nano-fertilizer technology into Nepal's specialty input market.

3.1.3 Formulation trends

Liquid formulations dominated in both surveys and increased their share from approximately 67% in 2019 to 87% (189/218 products) in 2024. This is consistent with global specialty fertilizer trends, where water-soluble and liquid formulations are experiencing the fastest growth owing to their compatibility with fertigation and foliar application, faster plant uptake, and perceived greater efficacy by farmers (Fortune Business Insights, 2023). Powder formulations accounted for 8% (18 products) and granules for 5% (11 products) in the 2024 survey.

3.1.4 Country of origin and domestic manufacturing

In 2019, Nepal-manufactured products constituted 67% of the market (53/78); by 2024, this share had declined to 60.5% (132/218) while the number of source countries nearly doubled—from 3 to at least 6. Products from India, China, the United States, Japan, the Netherlands, and Thailand were all represented in the 2024 survey, reflecting increasingly globalized supply chains for specialty agricultural inputs.

Facility visits revealed that most 'Nepali-manufactured' products are, in practice, repackaging or blending operations: raw materials or concentrated formulations are imported from India and China, then diluted, mixed, bottled, and labeled in Nepal. This is economically rational—raw material import tariffs are lower than finished-product tariffs—but also means that product quality depends entirely on unregulated domestic operations. However, several genuinely manufacturing-capable facilities in Bhaktapur and Bara were found to employ in-house chemists and possessed the technical capacity to produce quality-controlled formulations.

3.1.5 Registration status

The most alarming finding, consistent across both surveys, is the near-total absence of regulatory compliance. In 2019, only 7 of 35 micronutrient products (20%) had registration; by 2024, only 2 of 218 total products (0.9%) were government approved. This deterioration in the approval rate—despite the absolute number of approved products remaining roughly stable—reflects the explosive market growth outpacing regulatory capacity. Of the 218 products, 40 (18%) did not even declare the names or quantities of nutrients on their labels, representing a basic consumer protection failure.

The root cause is structural: the FCO 2055 provides no registration pathway for these product categories. Without a legal framework, Ministry of Agriculture and Livestock Development (MoALD) cannot grant registration, enforce standards, or penalize non-compliance. Importers and manufacturers have accordingly operated in a regulatory void, with documented adverse outcomes including products of unknown composition reaching farmers, potential phytotoxicity risks, and inability of farmers to verify product claims.

3.2 International minimum nutrient specifications

To inform proposed specifications for Nepal, the team reviewed minimum nutrient content standards from India's FCO 1985 as the primary reference, given its direct applicability to Nepal's agro-ecological and trade context.

The global consensus on micronutrient fertilizer specifications emphasizes: (i) minimum content thresholds to ensure agronomic efficacy; (ii) maximum content limits to prevent phytotoxicity; (iii) physical quality parameters (pH, viscosity, density, solubility); and (iv) mandatory pre-market laboratory certification from accredited laboratories (CFIA, 2020; EU 2019/1009; Alloway, 2008). Canada's CFIA T-4-129 specifically requires all micronutrient fertilizers to adhere to standards on content, compositional criteria, contaminant levels, and upper tolerances before being placed on the market (CFIA, 2020). These principles encouraged the research team to propose nutrient specifications for Nepal.

3.3 Proposed product classification and minimum nutrient specifications

Based on the survey findings and international review, the research team proposes the following classification system and minimum nutrient content requirements for registration under the Fertilizer Control Order 2055. Table 2 presents specifications for liquid formulations; Table 3 presents specifications for solid (granule/powder/tablet) formulations.

Table 2. Proposed minimum nutrient content requirements for liquid mixed chemical fertilizers (proposed for inclusion in FCO 2055).

SN	Formulation	Cat.	Category Description	Min. Nutrient Content (% w/v)
1	Liquid	A	Primary nutrients ($N:P_2O_5$: K_2O, sole or mixture)	20%
		B	Primary nutrients + secondary nutrients	15% primary + 5% secondary
		C	Primary nutrients + micronutrients	15% primary + 5% micronutrients
		D	Primary + secondary + micronutrients	15% primary + 5% secondary + 4% MN
		E	Secondary nutrients (mixture)	15% secondary
		F	Secondary nutrients + micronutrients	12% secondary + 4% micronutrients
		G	Micronutrients (sole or mixtures)	12% micronutrients

Note: Primary nutrients = N, P, K; Secondary nutrients = Ca, Mg, S; Micronutrients = Zn, B, Mn, Cu, Fe, Mo, Cl, Ni. N = total nitrogen (% w/v); P = total phosphorus as P_2O_5 (% w/v); K = potash as K_2O (% w/v).

Table 3. Proposed minimum nutrient content requirements for solid mixed fertilizers (granules/powder/tablets) for registration under FCO 2055**.**

SN	Formulation	Cat.	Category Description	Min. Nutrient Content (% w/w)
2	Soil (granules/ powder/ tablet)	A	Primary nutrients + micronutrients	10% primary + 5% micronutrients
		B	Primary nutrients + secondary nutrients	10% primary + 6% secondary
		C	Primary + secondary + micronutrients	10% primary + 6% secondary + 4% MN
		D	Secondary nutrients (mixture)	12% secondary
		E	Secondary nutrients + micronutrients	8% secondary + 4% micronutrients
		F	Micronutrients (sole or mixtures)	10% micronutrients

Note: For solid formulations, minimum content is expressed as % by weight (w/w).

3.4 Proposed mandatory labeling requirements

Labeling is the primary consumer protection mechanism for specialty fertilizer products. Based on international best practices (India FCO 1985; EU 2019/1009; CFIA T-4-129) and the market survey findings—in which 18% of products lacked any nutrient information—the research team proposes the following as mandatory label requirements for all registered mixed liquid fertilizers and micronutrient products in Nepal:

- Product trade name
- Names and concentrations of all active nutritional constituents (% w/v for liquids; % w/w for solids)
- Targeted crop(s)
- Method, dose, timing, and frequency of application
- Product registration number (Government of Nepal)
- Manufacturer name, address, and (for imports) distributor name and address
- Production date (manufacture date)
- Expiry date / shelf life
- Net quantity or volume
- Maximum retail price (MRP) per unit
- Toxic/hazardous elements (if any) and relevant safety warnings
- Storage and handling precautions

Labels must be in Nepali (Devanagari script) or English. The team also recommends that products containing chemical nutrients must not be labeled or marketed as 'biofertilizers' or 'organic fertilizers', as this constitutes misleading consumer communication.

3.5 Discussion: Regulatory implications

The five-year market trend data presented here reveal a loophole in regulatory system. The near-total collapse in the approved-product rate—from 20% of micronutrient products in 2019 to 0.9% of all specialty products in 2024—is not a reflection of worsening product quality per se, but of market growth dramatically outpacing legal frameworks. This pattern is not unique to Nepal: Paudel and Crago (2018) have documented how fertilizer subsidy policies in Nepal crowded out private sector importers of primary NPK but inadvertently opened space for an unregulated specialty input market. Amgain et al. (2017) similarly noted the absence of effective governance for organic and biofertilizer inputs. With the federalization, the Government has authorized provincial government for market inspection and weak market inspection is one reason for this unregistered products trading.

The domestic manufacturing sector, while currently operating informally, should be viewed as an asset rather than a liability. Facility visits confirmed that several companies possess genuine formulation capability with in-house chemistry expertise. A well-designed registration system with clear specifications could incentivize these companies to formalize, invest in quality assurance, and expand—creating a domestic specialty fertilizer industry that reduces import dependence over time.

4. CONCLUSION

Nepal's specialty agricultural input market has expanded nearly threefold in five years, growing from 78 to 218 products in the Kathmandu Valley between 2019 and 2024. Micronutrient fertilizers now constitute the dominant category (>60% of products), liquid formulations account for 87% of the market, and source countries have multiplied from 3 to at least 6. Yet regulatory oversight has deteriorated markedly: only 0.9% of surveyed products carry government approval, compared to 20% of the narrower micronutrient category in 2019, and 18% of products lack basic nutrient content information on their labels.

This paper has presented a longitudinal market trend analysis of specialty agricultural inputs in Nepal alongside internationally benchmarked product specifications. The proposed classification framework—seven liquid fertilizer categories and six solid fertilizer categories with defined minimum nutrient content thresholds—provides policy makers an evidence-based, actionable foundation for bringing this rapidly growing market segment under legal governance.

RECOMMENDATIONS

4.1 Amendment of Fertilizer Control Order 2055

The most urgent action required is amendment of the Fertilizer Control Order 2055 to explicitly include mixed chemical liquid fertilizers, mixed micronutrient fertilizers, and related specialty inputs within its scope. The amendment should incorporate the classification system and minimum nutrient specifications proposed in Tables 2 and 3.

4.2 Registration system activation

Upon amendment, MoALD should issue a transition period of six months during which existing products in the market must submit registration applications. Applications should require: laboratory analysis reports from accredited laboratories confirming compliance with minimum specifications; manufacturer authorization documents from country of origin; complete label drafts; and safety data sheets for products with hazardous constituents.

4.3 Strengthening analytical laboratory capacity

Nepal's Central Agricultural Laboratory (CAL) and NARC/NSSRC laboratories should be prioritized for investment in multi-element analysis capability—particularly inductively coupled plasma optical emission spectrometry (ICP-OES)—to enable efficient pre-market and post-market testing of micronutrient products. Accreditation to selected private laboratories having standard infrastructure and facilities should also be pursued to distribute the testing burden.

4.4 Market enforcement

Post-enactment, the Department of Agriculture's fertilizer inspection personnel should be empowered and resourced to conduct regular market surveillance, with provisions for product seizure, importer suspension, and financial penalties for non-compliance.

REFERENCES

Alloway, B.J. (Ed.). (2008). Micronutrient deficiencies in global crop production. *Springer*, Dordrecht. https://doi.org/10.1007/978-1-4020-6860-7

Amgain, S., Poudel, S.R., Bista, D.R., & Poudel, S.R. (2017). Government intervention on organic fertilizer promotion: A key to enhancing soil health and environment. *Journal of Agriculture and Environment*, 18, 131–139.

Andersen, P. (2007). A review of micronutrient problems in the cultivated soil of Nepal: An issue with implications for agriculture and human health. *Mountain Research and Development*, 27(4), 331–335. https://doi.org/10.1659/mrd.0915

Bevis, L., Kim, K., & Guerena, D. (2023). Soil zinc deficiency and child stunting: Evidence from Nepal. *Journal of Health Economics*, 87, 102691. https://doi.org/10.1016/j.jhealeco.2022.102691

Business Research Company. (2024). *Micronutrient Fertilizer Global Market Report 2024*. The Business Research Company, London.

CFIA. (2020). Trade Memorandum T-4-129: Requirements for Micronutrient Fertilizers. Canadian Food Inspection Agency, Government of Canada, Ottawa. https://inspection.canada.ca/plant-health/fertilizers/trade-memoranda/t-4-129/

Coherent MI. (2023). Micronutrient fertilizers market – global industry analysis, size, share, growth, trends and forecast, 2023–2030. Coherent Market Insights, Burlingame, CA.

Corpseed. (2025). Government updates Fertiliser Control Order under 2025 amendment. Corpseed Law Update. https://www.corpseed.com/law-update/fertiliser-control-order-under-2025-amendment

European Union. (2019). Regulation (EU) 2019/1009 of the European parliament and of the council laying down rules on the making available on the market of EU fertilising products. *Official Journal of the European Union*, L170, 1–114.

Fortune Business Insights. (2023). Specialty fertilizers market size, share & COVID-19 impact analysis, 2023–2030. Fortune Business Insights, Pune, India.

Government of India. (1985, as amended 2024*). Fertilizer (Control) Order 1985*. Ministry of Agriculture and Farmers Welfare, New Delhi, India.

GoN. (1999). *Fertilizer Control Order 2055 (1999).* Government of Nepal, Ministry of Agriculture and Livestock Development, Kathmandu, Nepal.

GoN. (2021). *Organic and Bio-fertilizer Directive 2078 B*S. Government of Nepal, Ministry of Agriculture and Livestock Development, Kathmandu, Nepal.

Legality Simplified. (2024, April 27). Government updates Fertilizer Control Order to add new categories and nano fertilizers. Legality Simplified. https://www.legalitysimplified.com/government-updates-fertilizer-control-order-to-add-new-categories-and-nano-fertilizers/

MoALD. (2022). *Statistical Information on Nepalese Agriculture 2020/21*. Ministry of Agriculture and Livestock Development, Singhadurbar, Kathmandu.

Mordor Intelligence. (2025). Micronutrient fertilizer market – growth, trends, COVID-19 impact, and forecasts (2025–2030). *Mordor Intelligence*, Hyderabad.

Paudel, J., & Crago, C.L. (2018). Fertilizer subsidy and agricultural productivity in Nepal. *American Journal of Agricultural Economics,* 100(5), 1457–1475. https://doi.org/10.1093/ajae/aay030

Shrestha, R., Broeders, B., Wittig, A., Becker, M., & Asch, F. (2020a). Boron and zinc fertilizer applications are essential in emerging vegetable-based crop rotations in Nepal. *Journal of Plant Nutrition and Soil Science*, 183(3), 370–382. https://doi.org/10.1002/jpln.202000151

Shrestha, R., Wittig, A., Becker, M., & Asch, F. (2020b). Diagnosis of zinc and boron availability in emerging vegetable-based crop rotations in Nepal. *Journal of Plant Nutrition and Soil Science*, 183(3), 353–369. https://doi.org/10.1002/jpln.202000020

Vista, S.P., & Shrestha, A. (2019). *Status of micronutrients, plant growth regulators and soil conditioners in the Kathmandu Valley market.*

Vista, S. P., Devkota, S., Shrestha,S., Kandel, S., Rawal, N., Amgain, R., Joshi, S., Paneru, P., Rayamajhi, K. & Timilsina, S. (2022). *Fertilizers in Nepal*. Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, Nepal. https://doi.org/10.13140/RG.2.2.17645.89440

MORPHOLOGICAL AND BIOCHEMICAL CHARACTERIZATION OF *AZOTOBACTER* ISOLATED FROM DIFFERENT RHIZOSPHERIC SOILS OF KATHMANDU VALLEY

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ABSTRACT

Biological nitrogen fixation by free-living diazotrophic bacteria, particularly Azotobacter spp., offers a sustainable way to replenish soil nitrogen. This study aimed to isolate and characterize Azotobacter from rhizospheric soils of ten crop species collected across Kathmandu Valley, and examine the influence of soil pH on bacterial colony count and Azotobacter prevalence. The study was conducted at the Microbiology Laboratory of NSSRC, NARC, Khumaltar, Lalitpur over four months using a Completely Randomized Design (CRD) with 20 treatments established by subjecting two dilutions (10^{-3} and 10^{-5}) to ten soil samples, each replicated three times. A pure Azotobacter strain served as a reference. Bacteria were isolated on Jensen's nitrogen-free agar and identified through colony morphology, Gram staining, and biochemical tests. Out of 33 isolates obtained from 60 experimental units, Azotobacter was confirmed in 7 treatments (35%). Other N_2-fixing bacteria identified included Azospirillum (25%) and Clostridium (20%), while 20% of isolates remained unidentified. Soil pH showed a strong positive correlation with bacterial colony count (r = 0.887, $p \leq 0.001$), while Azotobacter occurrence showed a positive but non-significant relationship with pH (coefficient = 0.801, p = 0.114). Morphological and biochemical characterization confirmed the presence of Azotobacter in rhizospheric soils of five crop species, providing baseline information on native Azotobacter isolates in Kathmandu valley.

1. INTRODUCTION

N is one of the most important nutrients limiting crop production, and its supply in agroecosystems is commonly maintained through the application of chemical fertilizers. However, excessive use of nitrogen fertilizers contributes to greenhouse gas emissions, soil acidification, and water pollution (Kumar, 2019; Tripathi et al., 2020). Biological nitrogen fixation by diazotrophic bacteria provides a sustainable alternative by converting atmospheric nitrogen into plant-available forms (Basalingappa, 2018; Jaweria & Qayum, 2020). Among these bacteria, Azotobacter spp. are free-living nitrogen-fixing microorganisms that contribute to soil fertility and plant growth.

Azotobacter spp. are free-living, aerobic, Gram-negative diazotrophic bacteria commonly found in neutral to alkaline soils (Aquilanti et al., 2004; Nongthombam et al., 2021; Shankar & Maitra, 2021). Besides fixing atmospheric nitrogen, they produce plant growth-promoting substances such as indole acetic acid, gibberellins, cytokinins, vitamins, and antifungal compounds, and also help in phosphate solubilization and soil aggregation (Elbaz et al., 2010). These attributes make *Azotobacter* a versatile common bioinoculant for many crops. Its application as a biofertilizer can enhance soil health, enhance plant growth, and increase crop yield while reducing the environmental impact of chemical fertilizers (Jnawali et al., 2015; Gurikar et al., 2016).

The rhizosphere is the soil zone around plant roots where microbial activity is high due to root exudates that support diverse microorganisms, including PGPR (Hinsinger & Marschner, 2006; Ling et al., 2022). Previous studies have reported that the occurrence and abundance of *Azotobacter* are influenced by several environmental factors, particularly soil pH, moisture, temperature, and nutrient availability (Barnes et al., 2007; Chen et al., 2018; Sumbul et al., 2020; Aasfar et al., 2021). Although the association between soil pH and *Azotobacter* occurrence has been reported in different regions, information on the distribution and characteristics of native *Azotobacter* populations in the rhizospheres of crops grown in Kathmandu valley remains limited. Furthermore, little information is available regarding how soil pH relates to bacterial colony abundance and *Azotobacter* prevalence in these agricultural soils.

Kathmandu valley is an important agricultural region with diverse cropping systems, making it a suitable area for exploring native nitrogen-fixing bacterial populations. Characterization of indigenous *Azotobacter* isolates is important for understanding their occurrence and potential utilization in sustainable agriculture. Therefore, this study was conducted to isolate and characterize bacterial strains from rhizospheric soils of different crops, identify *Azotobacter* using morphological and biochemical characteristics with a reference strain, and assess the relationship between soil pH, bacterial colony count, and *Azotobacter* prevalence.

2. MATERIALS AND METHODS

2.1 Experimental location

Rhizospheric soil samples were collected from districts of Kathmandu valley based on commonly cultivated crops. Only fields that had been continuously cultivated with the same crop for at least three years were included in the study to ensure a well-established crop rhizosphere. Laboratory isolation, culture, and characterization work was conducted at the Microbiology Laboratory of the National Soil Science Research Centre (NSSRC), National Agriculture Research Council (NARC), Khumaltar, Lalitpur.

2.2 Collection of soil samples

Composite rhizospheric soil samples were collected from the uppermost 15 cm of soil from ten different crop species grown at ten locations across the three districts of Kathmandu valley: Kathmandu, Bhaktapur, and Lalitpur following strict aseptic technique. Approximately 100 g of composite soil per sample was collected in sterilized plastic bags, stored in an ice box, and processed promptly.

2.3 Experimental design and treatments

The experiment was conducted using Completely Randomized Design subjecting soil samples to two serial dilutions (10^{-3} and 10^{-5}), yielding twenty experimental treatments, each replicated three times (Table 1). A known pure culture of *Azotobacter* obtained from the NSSRC microbiology laboratory was included as a reference check to confirm bacterial identification by comparison of morphological and biochemical characteristics.

Table 1. Experimental treatments used in the study.

Soil Sample Treatment	Code	Soil Sample Treatment	Code
Asparagus soil @10^{-3} dilution	T1	Brassica soil @10^{-3} dilution	T11
Asparagus soil @10^{-5} dilution	T2	Brassica soil @10^{-5} dilution	T12
Colocasia soil @10^{-3} dilution	T3	Avena soil @10^{-3} dilution	T13
Colocasia soil @10^{-5} dilution	T4	Avena soil @10^{-5} dilution	T14
Cucumis soil @10^{-3} dilution	T5	Solanum soil @10^{-3} dilution	T15
Cucumis soil @10^{-5} dilution	T6	Solanum soil @10^{-5} dilution	T16
Phaseolus soil @10^{-3} dilution	T7	Raphanus soil @10^{-3} dilution	T17
Phaseolus soil @10^{-5} dilution	T8	Raphanus soil @10^{-5} dilution	T18
Zea soil @10^{-3} dilution	T9	Triticum soil @10^{-3} dilution	T19
Zea soil @10^{-5} dilution	T10	Triticum soil @10^{-5} dilution	T20
Azotobacter pure culture (Check)	—		

2.4 pH measurement

The pH of each soil sample was measured using a glass electrode pH meter. The instrument was calibrated using buffer solutions of pH 4.0 and pH 7.0. A 1:2 soil-to-water suspension was prepared (20 g soil in 40 mL distilled water), stirred thoroughly, and allowed to settle for 30 minutes before measurement. The electrode was rinsed with distilled water between readings.

2.5 Preparation of Jensen's selective medium

Jensen's agar medium, a nitrogen-free selective medium was used for the isolation and culture of N_2-fixing bacteria. Jensen's agar powder (39.1 g) was dissolved in 1000 ml of distilled water in a conical flask, heated to near boiling with continuous stirring in a water bath, and sterilized by autoclaving at 121°C, 15 psi for 30 minutes. The sterilized medium was poured into sterile Petri plates (approximately 2/3 full) inside a laminar airflow cabinet to avoid contamination and allowed to solidify before use.

2.6 Serial dilution and isolation

One gram of each soil sample was transferred to a sterile test tube and serially diluted from 10^{-1} to 10^{-5} in sterile distilled water (1 mL into 9 mL blanks). Bacterial isolation was performed by the spread plate method. 0.1 mL aliquots of the 10^{-3} and 10^{-5} dilutions were inoculated onto Jensen's agar plates then well distributed using a sterilized bent glass rod. These dilutions were chosen to obtain countable, well-separated colonies for accurate enumeration and isolation of bacteria. Plates were incubated at 25–30°C for 48–72 hours.

After incubation, colony counting was performed on primary plates. Well-grown, water-droplet-like colonies (characteristic of *Azotobacter*) were selected for sub-culturing. Contaminated plates were discarded; uncontaminated replicates were processed further. Selected colonies were sub-cultured on fresh Jensen's medium using quadrant streak technique and incubated again at 25–30°C for 48–72 hours. The sub-culturing process was repeated two to three times to obtain pure cultures for downstream analyses (Hala & Ali, 2019).

2.7 Morphological characterization

2.7.1 Macroscopic examination. Pure cultures were examined visually for colony morphology, including colour, shape, texture, transparency, surface features, and margin characteristics.

2.7.2 Microscopic examination. Gram staining was performed on all pure isolates. A loopful of each culture was smeared on a glass slide, heat-fixed, and stained using the standard four-step Gram protocol. Slides were examined under a compound microscope at 4×, 10×, 40×, and 100× magnification (oil immersion) to determine cell shape and Gram reaction.

__2.8 Biochemical characterization__

All isolates were subjected to five biochemical tests. (i) **Nitrogen fixation:** growth on Jensen's nitrogen-free medium confirmed the ability to fix atmospheric N_2. (ii) **Catalase test:** 4–5 drops of hydrogen peroxide (H_2O_2) were placed in a test tube; positive results were indicated by bubble formation on addition of bacterial culture. (iii) **Oxidase test:** bacterial culture was rubbed onto an oxidase disk; appearance of deep purple or blue colour within 5–10 seconds indicated a positive result. (iv) **Simmons citrate utilisation test:** culture was inoculated onto Simmons citrate agar (SCA) slants, incubated at 37°C for 24–48 hours; a colour change from green to blue indicated citrate utilisation. (v) **Urease test:** culture was inoculated onto Christensen's urea agar slants, incubated at 37°C for 24–48 hours; colour change from yellow to pink indicated urease activity. (vi) **Indole production test:** culture was inoculated into SIM broth and incubated at 37°C for 24–48 hours; 1–2 drops of Kovac's reagent were added and a red/pink layer indicated positive indole production. Results were interpreted in comparison to the reference check, following Upadhyay et al. (2015) and Hala & Ali (2019).

__2.9 Data analysis__

All data were recorded in Microsoft Excel, cleaned, and analyzed using R-Studio software. One-way analysis of variance (ANOVA) was performed to assess differences in mean colony count across treatments, with the least significant difference (LSD) test at the 5% level of significance. Pearson's correlation coefficient was calculated to evaluate the relationship between soil pH and bacterial colony count.

3. RESULT AND DISCUSSION

A total of 33 bacterial isolates were obtained from 60 experimental units (20 treatments × 3 replicates). Isolation via serial dilution and culture on Jensen's selective nitrogen-free agar yielded well-grown colonies after 48–72 hours of incubation at 28°C. The mother culture of Azotobacter from NSSRC was also cultured concurrently for comparative reference.

Colony counts varied significantly across treatments (ANOVA: $p \leq 0.001$). Higher mean colony counts were recorded in T6 (Cucumis soil @ 10^{-5}; 34.67 CFU), followed by T17 (Raphanus soil @ 10^{-3}; 32.67 CFU) and T4 (Colocasia soil @ 10^{-5}; 31.00 CFU). The lowest colony counts were observed in T15 (Solanum soil @ 10^{-3}; 16.33 CFU), T11 (Brassica soil @ 10^{-3}; 18.00 CFU), and T19 (Triticum soil @ 10^{-3}; 18.33 CFU). The LSD value at the 5% significance level was 0.0456, indicating that treatment differences exceeding this threshold are statistically significant. Overall, the highest bacterial populations were recorded in the rhizosphere of Cucumber (Cucumis sativus), Taro (Colocasia esculenta), and Radish (Raphanus sativus), while significantly lower populations were associated with Mustard (Brassica juncea), Oats (Avena sativa), and Wheat (Triticum aestivum).

The significant variation in mean colony counts across treatments (ANOVA $p = 0.000763$) indicates that crop species, soil physiochemical properties, and level of dilution influence bacterial population density. Treatments T6 (Cucumis @ 10^{-5}) and T17 (Raphanus @ 10^{-3}) showed markedly higher colony counts compared to T15 (Solanum) and T11 (Brassica), indicating that root exudate composition and rhizosphere pH of different crop species differentially support bacterial growth. These findings align with reports that soil factors such as pH, Mn, Zn levels, temperature, moisture, carbon, and nitrogen sources significantly influence the growth and diversity of Azotobacter (Chen et al., 2018; Aasfar et al., 2021).

Macroscopic and microscopic examinations of all 33 isolates are presented in **Table 2**. Colony morphology across all treatments was consistent with Azotobacter-like characteristics, displaying round colonies with smooth surfaces and entire margins. Colony colour ranged from creamy to yellow, and cells were predominantly rod-shaped, with two treatments (T9 and T20) showing coccus cell shapes. All isolates were opaque except T10, which was translucent with a rough surface.

Table 2. Morphological characterization of bacterial isolates across all treatments

Treatment	Cell Shape	Colony Shape	Colony Colour	Transparency	Surface	Margin
Check*	Rod	Round	Yellow	Opaque	Smooth	Entire
T1	Rod	Round	Yellow	Opaque	Smooth	Entire
T2	Rod	Round	Yellow	Opaque	Smooth	Entire
T3	Rod	Round	Creamy	Opaque	Smooth	Entire
T4	Rod	Round	Creamy	Opaque	Smooth	Entire
T5	Rod	Round	Yellow	Opaque	Smooth	Entire
T6	Rod	Round	Yellow	Opaque	Smooth	Entire
T7	Rod	Round	Yellow	Opaque	Smooth	Entire
T8	Rod	Round	Yellow	Opaque	Smooth	Entire
T9	Coccus	Round	Yellow	Opaque	Smooth	Entire
T10	Rod	Round	Yellow	Translucent	Unsmooth	Entire
T11	Rod	Round	Creamy	Opaque	Smooth	Entire
T12	Rod	Round	Creamy	Opaque	Smooth	Entire
T13	Rod	Round	Creamy	Opaque	Smooth	Entire
T14	Rod	Round	Creamy	Opaque	Smooth	Entire
T15	Rod	Round	Yellow	Opaque	Smooth	Entire
T16	Rod	Round	Creamy	Opaque	Smooth	Entire
T17	Rod	Round	Creamy	Opaque	Smooth	Entire
T18	Rod	Round	Yellow	Opaque	Smooth	Entire
T19	Rod	Round	Creamy	Opaque	Smooth	Entire
T20	Coccus	Round	Yellow	Opaque	Smooth	Entire

*Check = Known Azotobacter strain from NSSRC.

Morphological characterization showed that the majority of isolates displayed Azotobacter-like colony characteristics: round colonies, smooth surfaces, entire margins, and creamy to yellow pigmentation, consistent with previously published descriptions (Gangavane & MJ, 2018; Upadhyay et al., 2015). However, morphological characteristics alone were insufficient to definitively identify Azotobacter, making biochemical characterization essential for confirmation.

Results of biochemical testing for all treatments are presented in **Table 3**. Comparing isolate profiles against the reference check (Gram-negative, oxidase-positive, catalase-positive, citrate-positive, urease-positive, indole-negative), Azotobacter was confirmed in seven treatments: T1, T2, T5, T6, T11, T18, and T19. This represents 35% of the total treatments. *Azospirillum* (oxidase-negative, catalase-positive, Gram-negative) was identified in T7, T8, T10, T12, and T17 (25%). Clostridium (oxidase-negative, catalase-positive, Gram-positive) was identified in T9, T13, T14, and T15 (20%). The remaining four treatments — T3, T4, T16, and T20 — showed variable results inconsistent with any single genus and remained unidentified (20%), indicating a heterogeneous microbial community requiring further molecular analysis.

Table 3. Biochemical characterization of bacterial isolates across all treatments

Treatment	Gram Stain	Oxidase	Catalase	Simmons Citrate	Urease	Indole	Identification
Check*	−	+	+	+	+	−	***Azotobacter***
T1	−	+	+	+	+	−	***Azotobacter***
T2	−	+	+	+	+	−	***Azotobacter***
T3	−	−	−	+	+	−	Unidentified
T4	−	−	−	+	+	−	Unidentified
T5	−	+	+	+	+	−	***Azotobacter***
T6	−	+	+	+	+	−	***Azotobacter***
T7	−	−	+	+	+	−	*Azospirillum*
T8	−	−	+	+	+	−	*Azospirillum*
T9	+	−	+	+	+	−	*Clostridium*
T10	−	−	+	+	−	−	*Azospirillum*
T11	−	+	+	+	+	−	***Azotobacter***
T12	−	−	+	+	+	−	*Azospirillum*
T13	+	−	+	+	+	−	*Clostridium*

T14	+	−	+	+	+	−	*Clostridium*
T15	+	−	+	+	−	−	*Clostridium*
T16	+	+	+	+	+	−	Unidentified
T17	−	−	+	+	+	−	*Azospirillum*
T18	−	+	+	+	+	−	***Azotobacter***
T19	−	+	+	+	+	−	***Azotobacter***
T20	−	+	+	+	+	+	Unidentified

**Check = Known Azotobacter strain from NSSRC. +, positive; −, negative.*

The biochemical characterization of isolates against the reference check confirmed Azotobacter in 35% of treatments. According to Bergey's Manual of Systematic Bacteriology, Azotobacter is typically oxidase-positive, catalase-positive, citrate-positive, urease-positive, Gram-negative, and indole-negative (Upadhyay et al., 2015; Gangavane & MJ, 2018), a profile matched precisely by T1, T2, T5, T6, T11, T18, and T19. Azotobacter was confirmed in the rhizospheres of five crops: Asparagus, Cucumber, Maize, Radish, and Wheat.

The identification of *Azospirillum* (25%) and Clostridium (20%) alongside Azotobacter indicates the presence of a broader N_2-fixing microbiome in Kathmandu valley soils. *Azospirillum* is a known diazotrophic PGPR associated with grasses and cereals, while Clostridium performs anaerobic nitrogen fixation (Timofeeva et al., 2023). The remaining 20% of isolates with variable biochemical profiles may represent mixed cultures or taxa requiring molecular characterization for confirmation.

The colony count did not show appreciable variability between the two dilution levels (10^{-3} and 10^{-5}), which is consistent with the literature: Azotobacter tends to form colonies at similar rates across a range of dilutions when selective nitrogen-free media are employed (Malek & Ishac, 1968). This finding lends confidence to the representativeness of results across dilutions.

Pearson correlation analysis revealed a strong positive relationship between soil pH and bacterial colony count ($r = 0.8874$, $p = 1.82 \times 10^{-7}$) (Figure 1). This highly significant result indicates that soil pH is an important determinant of bacterial population density in the rhizosphere under study: as soil pH increased, bacterial colony counts also increased.

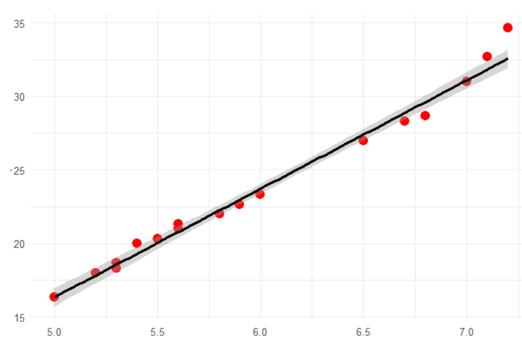

Figure 3. Scatter plot showing the correlation between colony count and pH

The strong positive Pearson correlation ($r = 0.887$) between soil pH and bacterial colony count is a notable finding and aligns with the well-documented preference of Azotobacter for neutral to slightly alkaline conditions (pH > 6.5) (Barnes et al., 2007; Kumar et al., 2025). Soil pH influences microbial growth by affecting nutrient availability, enzyme activity, and cellular functions. Neutral to slightly alkaline conditions generally favour bacterial growth, whereas acidic conditions can reduce microbial activity and limit the survival of aerobic N_2-fixing bacteria such as Azotobacter. A highly significant p-value (1.82×10^{-7}) confirms this relationship is not due to chance. Similar positive associations between soil pH and Azotobacter abundance have been reported in rice and other crop rhizospheres by Chen et al. (2018) and Aasfar et al. (2021).

The present study successfully isolated and characterized N_2-fixing bacteria, including Azotobacter, from the rhizospheric soils of diverse crop species cultivated across the Kathmandu Valley. A total of 33 isolates were obtained, representing a diversity of N_2-fixing taxa. The significant variation in mean colony counts across treatments indicates that crop species, soil physicochemical properties, and rhizosphere conditions may influence bacterial population density.

The results highlight the abundant presence of N_2-fixing bacteria, particularly Azotobacter, in the diverse rhizospheric soils of the Kathmandu Valley. These indigenous strains represent a valuable resource for developing locally adapted biofertilizer formulations. The use of Azotobacter-based biofertilizers provides a cost-effective and environmentally safe alternative to chemical nitrogen fertilizers, contributing to improved soil health and sustainable farming systems in Nepal (Jnawali et al., 2015; Sumbul et al., 2020).

4. CONCLUSION

This study demonstrated that N_2-fixing bacteria including *Azotobacter*, *Azospirillum*, and *Clostridium* are widely distributed in the rhizospheric soils of diverse crop species in the Kathmandu valley. *Azotobacter* was confirmed in 35% of isolates, representing five crop rhizospheres, using a combination of morphological and biochemical characterization. A robust positive correlation between soil pH and bacterial population density was established. These findings highlight the viability of *Azotobacter* strains as biofertilizers and underline the importance of soil pH management for effective nitrogen fixation in agricultural systems. Naturally occurring Azotobacter offers a cost effective, and eco-friendly pathway to improving soil fertility, reducing chemical fertilizer dependency, and supporting long-term agricultural productivity in Nepal.

REFERENCES

Aasfar, A., Bargaz, A., Yaakoubi, K., Hilali, A., Bennis, I., Zeroual, Y., & Meftah Kadmiri, I. (2021). Nitrogen fixing *Azotobacter* species as potential soil biological enhancers for crop nutrition and yield stability. *Frontiers in Microbiology*, 12, 628379. https://doi.org/10.3389/fmicb.2021.628379

Abd-el-malek, Y., & Ishac, Y. Z. (1968). Evaluation of methods used in counting *Azotobacter*s. *Journal of Applied Bacteriology*, 31(2), 267–275.

Aquilanti, L., Favilli, F., & Clementi, F. (2004). Comparison of different strategies for isolation and preliminary identification of *Azotobacter* from soil samples. *Soil Biology and Biochemistry*, 36(9), 1475–1483. https://doi.org/10.1016/j.soilbio.2004.04.024

Barnes, R. J., Baxter, S. J., & Lark, R. M. (2007). Spatial covariation of *Azotobacter* abundance and soil properties: A case study using the wavelet transform. *Soil Biology and Biochemistry*, 39(1), 295–310. https://doi.org/10.1016/j.soilbio.2006.08.001

Basalingappa, K. M. (2018). Biofertilizer for crop production and soil fertility. *Academia Journal of Agricultural Research*, 6(8), 299–306. https://doi.org/10.15413/ajar.2018.0130

Chen, S. L., Tsai, M. K., Huang, Y. M., & Huang, C. H. (2018). Diversity and characterization of *Azotobacter* isolates obtained from rice rhizosphere soils in Taiwan. *Annals of Microbiology*, 68(1), 17–26. https://doi.org/10.1007/s13213-017-1312-0

Elbaz, A. F., Ragab, A. A., Hamza, H. A., & El Halafawy, K. A. (2010). Identification and characterization of *Azotobacter chroococcum* isolated from some Egyptian soils. *Journal of Agricultural Chemistry and Biotechnology*, 1(2), 55–64.

Gangavane, L. V., & PN, M. J. (2018). Cultural, morphological and biochemical characteristics of *Azotobacter* isolates from the rhizosphere soils of crop plants irrigated with sewage. *International Journal of Current Microbiology and Applied Sciences*, 7(12), 1–10.

Gurikar, C., Naik, M. K., & Sreenivasa, M. Y. (2016). *Azotobacter*: PGPR activities with special reference to effect of pesticides and biodegradation. In *Microbial Inoculants in Sustainable Agricultural Productivity* (pp. 229–244). Springer India. https://doi.org/10.1007/978-81-322-2647-5_13

Hala, Y., & Ali, A. (2019). Isolation and characterization of *Azotobacter* from neem's rhizosphere. *Journal of Physics: Conference Series*, 1244(1), 012019. https://doi.org/10.1088/1742-6596/1244/1/012019

Hinsinger, P., & Marschner, P. (2006). Rhizosphere — perspectives and challenges. *Plant and Soil*, 283(1–2). https://doi.org/10.1007/s11104-006-0057-5

Jaweria, R., & Qayum, P. (2020). Evaluation and assessment of *Azotobacter*, *Rhizobium* and phosphate solubilizing bacteria with potential biofertilizer production. *International Research Journal of Engineering and Technology*, 4(6), 1–8.

Jnawali, A. D., Ojha, R. B., & Marahatta, S. (2015). Role of *Azotobacter* in soil fertility and sustainability — a review. *Advances in Plants & Agriculture Research*, 2(6), 250–253.

Kumar, C., Shrivastava, A., Dash, D., & Porte, S. (2025). Effect of bio-inoculants (Azotobacter and PSB) on growth and yield of Chili (Capsicum annum L.). *Journal of Scientific Research and Reports*, *31*(9), 643–651. https://doi.org/10.9734/jsrr/2025/v31i93529

Kumar, R. (2019). The impact of chemical fertilizers on our environment and ecosystem. ResearchGate. https://www.researchgate.net/publication/331132826

Ling, N., Wang, T., & Kuzyakov, Y. (2022). Rhizosphere bacteriome structure and functions. *Nature Communications*, 13(1), 836. https://doi.org/10.1038/s41467-022-28448-9

Nongthombam, J., Kumar, A., Sharma, Y. S. P., & Ahmed, M. (2021). *Azotobacter: A Complete Review*. ResearchGate. https://www.researchgate.net/publication/352312058

Shankar, T., & Maitra, S. (2021). Biofertilizers: Role in crop production and soil fertility improvement. ResearchGate. https://www.researchgate.net/publication/357378245

Sumbul, A., Ansari, R. A., Rizvi, R., & Mahmood, I. (2020). *Azotobacter*: A potential bio-fertilizer for soil and plant health management. *Saudi Journal of Biological Sciences*, 27(12), 3634–3640. https://doi.org/10.1016/j.sjbs.2020.08.004

Timofeeva, A. M., Galyamova, M. R., & Sedykh, S. E. (2023). Plant growth-promoting soil bacteria: nitrogen fixation, phosphate solubilization, siderophore production, and other biological activities. *Plants*, *12*(24), 4074. https://doi.org/10.3390/plants12244074

Tripathi, S., Srivastava, P., Devi, R. S., & Bhadouria, R. (2020). Influence of synthetic fertilizers and pesticides on soil health and soil microbiology. Agrochemicals Detection, Treatment and Remediation (pp. 25–54). https://doi.org/10.1016/B978-0-08-103017-2.00002-7

Upadhyay, S., Kumar, N., Singh, V. K., Singh, A., & Vigyan Kendra, K. (2015). Isolation, characterization and morphological study of *Azotobacter* isolates. *Journal of Applied and Natural Science*, 7(2), 892–897.

PERCEIVED INNOVATION ATTRIBUTES AND ADOPTION OF ICT TOOLS AMONG SMALLHOLDER PADDY FARMERS IN NEPAL

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ABSTRACT

Agricultural innovation and digital adoption are key drivers for transforming smallholder farming. In developing economies like Nepal, Information and Communication Technology (ICT) tools offer unprecedented opportunities to bridge information gaps in cereal crop production. This study analyzes the perceptions of paddy farmers from Jhapa, Kapilbastu, and Bardiya districts regarding the attributes of ICT tools used in paddy farming. A total of 390 paddy farmers, selecting 130 randomly from each district by using a multistage random sampling technique, were interviewed about their perception of relative advantage, complexity, compatibility, observability, and predictability of ICT. The collected data were analyzed using descriptive statistics, scaling techniques, chi-square, and F-test. The majority of respondents believed that ICT tools are more complex, require more skills, and face maintenance issues, which were viewed as barriers to adoption. Among the core innovation attributes, trialability and observability features emerged as the primary facilitators, while complexity functioned as the dominant perceived innovation barrier. Significant variations across the study districts in results indicated differences in socio-demographic, organizational, and institutional contexts. Additionally, this study clarifies the importance of co-operatives and local-level organizations to enhance adoption through access to credit and need-specific extension and implementation strategies to promote better adoption of ICT tools among paddy farmers.

1. INTRODUCTION

Information and Communication Technologies (ICTs), which are advancing rapidly, have transformed many sectors, including agriculture. ICTs are a broad category of technical tools that enable communication and information exchange between individuals across various media, including computers and mobile devices (Nkambule & Agholor, 2021). In modern agricultural extension systems, digital dissemination serves as a conduit for maximizing productivity, where the perceived attributes of these digital tools determine their ultimate field-level integration (Regmi & Schulz, 2023).

Many countries already use ICT tools for various purposes to enhance productivity and competitiveness (Salampasis & Theodoridis, 2013). Better communication among stakeholders is crucial for better results in the agricultural value chain, improving farmers' decision-making (Ghimire et al., 2022). Within the scope of digital extension, ICT tools do not operate in isolation; rather, they serve as the operational interface for managing, tracking, and scheduling information, weather alerts, plant protection, and market data (Shrestha & Bhattarai, 2022).

The Agriculture Information and Communication Center (AICC) is a separate division under the Department of Agriculture (DoA) to promote digital extension services from the government side. Existing knowledge and information systems in the agricultural extension system are not enough to promote research and learning, hindering proper adoption of improved technologies (FAO, 2018). The major challenge is the poor linkage between education, research, and extension. Apart from this, the unavailability and poor access of the farmers to the findings and information on time negatively affect the overall adoption of innovation. Increasing use of mobile phones and the internet has significantly improved the ICT sector in agriculture (Sharma & Rijal, 2018).

Mobile phones and the internet are used to provide essential agricultural information to low-income farmers in an affordable way, promoting agricultural production and productivity through the adoption of improved technologies (Tiwari & Gartaula, 2021).

The traditional extension system cannot meet the increasing demand for information. Modern institutional frameworks emphasize that integrating digital advisory platforms across agricultural steps-from pre-production planning to post-production logistics-preserves the original structural purpose of public extension systems (Poudel et al., 2024).

The timely availability of information in paddy farming with the use of ICT tools enhances the production and productivity of paddy, whereas various apps like Smart Krishi Project provide information on weather conditions, production-related information, and market linkages on time lead to better returns to farmers (Bhandari et al., 2021). Despite these advancements, a prominent research gap persists in South Asian literature: there is a lack of empirical clarity on how localized geographic and district-level disparities affect a farmer's psychological scaling of innovation attributes. This research directly addresses this gap by mapping how smallholders evaluate specific technological traits within the unique institutional landscapes of Nepal's lowland Terai region.

Even having the potential to transform the agricultural extension system of the nation, the government is still not active in promoting ICT tools for widespread use across the nation, as it is seen that there is a disparity of awareness, infrastructure, and use of ICT tools across the urban and rural areas of the nation (Tiwari & Gartaula, 2021). Farmers' knowledge, perceptions, and attitudes regarding ICT tools are the key factors that influence the uptake and use of ICT tools. Additionally, farmers' perceptions of these technologies, such as utility, complexity, compatibility, and observability of the results, may affect their decisions to adopt them (Debele et al., 2020).

However, the emphasis on digital agriculture and ICT-enabled extension is growing, but there is still limited evidence regarding the innovation attributes of the ICT tools. Previous studies were primarily focused on awareness, access, and utilization of ICT tools as compared to understanding the farmers' perception on their characteristics that may influence their adoption behavior.

To understand the farmer's perception of ICT tools' features, Rogers' diffusion of innovation framework was considered.

2. METHODOLOGY

Jhapa, Kapilbastu, and Bardiya were selected for the study because these districts represent the lowland Terai region, which serves as the primary rice bowl of the nation from east to west, and are recognized as prominent paddy producers by the government. Paddy was purposively chosen as the focal crop for this study because it represents Nepal's primary agricultural staple, handles the highest volume of input mobilization, and stands as the priority crop for national digital extension applications. A total of 390 respondents, with 130 from each district, were selected using multistage sampling techniques from the list provided by the respective NAMP offices. Primary data were collected in 2020 using a structured interview schedule and verified through Focused Group Discussion (FGD), Key Informant Interview (KII), and observation. Socio-demographic characteristics, organizational involvement, access to credit, ownership of ICT tools, and farmers' perceptions of various attributes of ICT tools were collected. Perceived attributes of ICT tools were measured using scaling techniques based on multiple statements under six attributes of ICT technologies.

The collected data was analyzed using descriptive statistics such as frequency, percentage, mean and standard deviation. Chi-square tests were conducted to observe variations in categorical variables—specifically gender distribution, family structures, institutional affiliation, and credit source channels—across the three districts. - F-test (One-Way ANOVA) was deployed to analyze the differences in continuous mean index values for perceptions across the study locations. This test is highly appropriate because the perception indices span continuous scale intervals, and the three distinct districts serve as independent categorical groups, enabling a robust assessment of spatial variation in innovation evaluation.

3. RESULTS AND DISCUSSION

3.1 Socio-demographic characteristics of respondents

The socio-economic characteristics of the respondents were collected, analyzed, and presented in Table 1 in Annex 1 with chi-square values after comparing frequencies across the study districts. These individual attributes of the surveyed household heads provide the basic analytical foundation, as household heads act as the primary decision-makers regarding technology adoption and capital deployment. The table revealed a predominance of male respondents in all districts, and the chi-square test shows a statistically significant association between gender and district.

The table shows that the age of the respondents ranges from 20 to 82 years, with a mean age of 47.62 years and a standard deviation of 11.73 years, indicating a predominance of middle-aged respondents and significant age differences among districts.

Most of the respondents were Hindu, with only 3 being Buddhist, and 5 being Muslim from Jhapa. The majority of the respondents were Brahmins and Chhetri, who were involved in agriculture and lived in nuclear families, although joint and extended families were common in Kapilbastu and Bardiya.

Jhapa had more respondents with education beyond the secondary level, whereas Bardiya had more illiterate respondents. The average land area of the respondents was 0.35 hectares, showing a predominance of medium landholders. All baseline socio-demographic parameters collected were utilized as independent control variables to evaluate variations in the primary ICT perception indices.

The majority of the respondents in the study area show that the demographic insights of Nepal reflect poor involvement of the youth in agriculture. The average age of the respondents from the study area is 47.62 years, which aligns with the national data, which is 48 years (CBS, 2022; ICIMOD, 2020). The data reflects that there would be long-term impacts on labor availability, innovation adoption and sustainability of digital agriculture and ICT adoption. The majority of the male respondents relate that the patriarchal society of Nepal reflects that decision-making roles are assigned to males, and the data aligns with the national data, which shows 60 % of the household heads are male in Nepal (CBS, 2022). This further shows the disparities based on gender in resource access and decision-making. The findings of ethnic distribution in study areas also align with the national data as Brahmin and Chhetri are the dominating castes of Nepal, and Agriculture as the primary occupation for the majority of the households (Adhikari, 2016). Land area is a very important variable regarding the adoption of ICT tools by the paddy farmers as the average size of the land parcel of the study area is 0.35 hectares as they need more agricultural information (Koirala, Thapa, & KC, 2020). These baseline demographic attributes are deeply intertwined with digital extension outcomes; older, illiterate household heads with fragmented lands face steeper learning curves, lowering their scalability marks on relative advantage and inflating their perceived complexity indices (Maharjan & Devkota, 2023).

Differences in the findings across the study districts show the heterogeneity, as the majority of respondents with nuclear families and literacy in Jhapa, as compared to other study areas, reflect variation in social structure and development throughout the nation, which is important for extension approaches and technology dissemination.

3.2 Organizational characteristics and access to credit

Data related to organizational characteristics and access to credit were collected, analyzed, and presented in Table 2 in Annex 2. The large majority of the respondents were found to be associated with at least one organization. Further chi-square analysis was performed to determine a significant association between organizational involvement and study districts.

Co-operatives were the dominant type of organization in Kapilbastu, while group-based organizations were more prevalent in other districts. Most of the respondents were ordinary members in the organization, with only 13% holding leadership roles. On average, respondents were affiliated with organizations for 6.6 years, ranging from 1 to 32 years.

In addition, access to credit also showed significant variation across the study districts. Respondents from Jhapa and Kapilbastu had better access compared to those in Bardiya. In these areas, co-operatives were the primary sources of credit for the farmers.

Farmers' affiliation to organization is very important to have access to resources and information for them. In Nepal, high levels of participation in farmers' groups and co-operatives are prevalent. Poor incidence of multiple organizations suggests limited institutional networking among farmers, restricting services and opportunities.

The role of co-operatives as the primary source of credit aligns with previous studies showing similar results as co-operatives are the most trusted and accessible for credit access. This also aligns with national data showing poor access to formal bank financing for agricultural households (CBS, 2022). Farmers without credit access contradict the argument that credit is widespread showing financial exclusion.

3.3 Perceived attributes of ICT tools

Table 3 in Annex 3 displays the index values calculated for the perceptions of respondents on various attributes of ICT tools based on statements asked. Six perceived attributes were ranked according to the index values calculated. In terms of relative advantage, respondents considered ICT tools as time saving and informative but disagreed on easy to use and cheaper technologies. The analysis did not show any differences across the study districts. Respondents perceived ICT tools as more complex requiring skills and expertise among other aspects so difficult to learn and understand. Respondents from Bardiya considered the ICT tools more complex significantly. This district-level cross-comparison provides vital spatial insights, revealing that rural infrastructure gaps directly shape local smallholder psychology.

Respondents viewed compatibility positively believing that ICT tools was culturally and socially compatible. However, trialability received mixed responses as some disagreed with trying out ICT tools before adoption due to limited opportunities for experimentation.

Additionally, observability and predictability were perceived positively by respondents indicating that it is better to see visible results and performance of ICT tools.

The overall index value (0.35) indicates a moderate level of agreement on the perceived attributes of ICT tools. This analysis shows variation across districts in three features except for relative advantage, compatibility, and observability.

Perception on various attributes of ICT tools is important for understanding adoption behavior. Findings under relative advantage align with previous studies indicating that it is important for ICT adoption (Uddin et al., 2019). Ghimire et al. (2022) focused those advantageous technologies improves ICT tools' adoption.

Complexity was perceived as a constraint, as ICT tools require more skills and operations and maintenance. These findings align with previous studies showing that farmers need technical capacity and post-adoption support (Uddin et al., 2019). Higher and positive perceptions of compatibility reflect that economic factors are more influential than cultural norms in technology adoption, aligning with the previous studies (Uddin et al., 2019). Similar results on trialability show the importance of demonstrations and opportunities to test ICT tools before adoption, as in previous studies.

Observability was also valued by respondents as visible results and timely feedback were positively perceived for better decision-making aligning with previous research (Davis, Bagozzi, & Warshaw, 1989). Predictability received mixed responses indicating, that ICT advancements could improve forecasting and planning, showing growing awareness of digital tools.

Overall, the discussion highlights the importance of socio-demographic features, organizational involvement and district level variation in developing context specific strategies and policies for better results (CBS, 2022; ICIMOD, 2020; Rogers, 2003).

4. CONCLUSION

The study finds that the adoption of ICT tools among paddy farmers is a complex interaction of socio-demographic characteristics, organizational features, and perceived attributes of ICT tools. Local co-operatives serve as trusted nodes that channel credit and technical info to smallholders, satisfying the core institutional objective of providing localized agricultural safety nets. ICT tools' attributes are major contributing factors to adoption, with relative advantage strongly perceived as saving time and labor, while complexity adversely affects adoption. Compatibility, trialability, observability, and predictability were positively perceived and positively affect adoption. Therefore, less complex and better compatible ICT tools with relatively advantageous features, along with quality trialability and observability, would have better adoption among paddy farmers. To foster scalable adoption, it is recommended that longitudinal studies to examine the structural sustainability of ICT adoption; (b) conduct impact evaluation of ICT use on productivity, costs, and income; (c) analyze gender and socio-demographic disparities in digital tools utilization; and (d) compare the operational effectiveness of different digital delivery models across varying agronomic zones.

REFERENCES

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural Economics*, *9*(4), 297–311.

Adhikari, J. (2016). *Agricultural transformation in Nepal: Trends, prospects, and policy options*. Nepal Institute of Development Studies.

Bhandari, S., Shrestha, A., & Pokhrel, D. (2021). Digital tools in Nepalese agriculture: Assessing mobile apps for real-time market linkages. *Nepalese Journal of Agricultural Sciences*, *19*, 114–125.

CBS. (2022). *Statistical year book of Nepal 2022*. Central Bureau of Statistics, Government of Nepal.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982–1003.

Debele, B., Negash, R., & Wondimu, H. (2020). Farmers' perception and use of information and communication technologies in agriculture. *Information Development*, *36*(3), 412–425.

FAO. (2018). *Strengthening agricultural innovation systems for improved service delivery*. Food and Agriculture Organization of the United Nations.

Ghimire, R., Suvedi, M., & Kaplowitz, M. (2022). Factors influencing discontinuance of agricultural technology adoption in Nepal. *Sustainability*, *14*(6), 3374. doi.org

ICIMOD. (2020). *Agriculture and rural transformation in Nepal*. International Centre for Integrated Mountain Development.

Koirala, K. H., Thapa, S., & KC, S. (2020). Landholding size and food security in Nepal. *Land Use Policy*, *97*, 104737.

Maharjan, S., & Devkota, M. (2023). Overcoming the digital divide: Infrastructure disparities and ICT adoption patterns among agrarian households in lowland Terai, Nepal. *Journal of Agricultural Extension and Rural Development*, *15*(2), 89–102.

Nkambule, T., & Agholor, A. I. (2021). Information and communication technologies as enablers of agricultural development. *Journal of Agricultural Informatics*, *12*(1), 45–56.

Poudel, R., Shrestha, S., & Khanal, S. (2024). Scaling digital agriculture in South Asia: A review of institutional frameworks, agricultural machinery extension, and mobile-enabled advisory services. *South Asian Agricultural Review*, *8*(1), 45–61.

Regmi, P. P., & Schulz, S. (2023). Determinants of digital agricultural extension services adoption among smallholders in Central Terai of Nepal. *Technology in Society*, *72*, 102–115.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Salampasis, M., & Theodoridis, A. (2013). Information and communication technology in agricultural development preface. Procedia Technology. 8, 1–3, 6th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2013). https://doi.org/10.1016/j.protcy.2013.11.001

Sharma, P., & Rijal, S. (2018). ICT infrastructure and agricultural development in Nepal. *Journal of Agriculture and Environment*, *19*, 1–12.

Shrestha, K., & Bhattarai, R. (2022). Assessing the alignment of digital agriculture tools with physical farm machinery operations in rice-based systems of Nepal. *Journal of Agriculture and Forestry University*, *5*, 141–153.

Tiwari, K. R., & Gartaula, H. (2021). ICTs and farmers' livelihoods in Nepal. *Sustainability*, *13*(9), 5023. doi.org

Uddin, M. N., Sultana, M., & Islam, M. A. (2019). Farmers' perception and adoption of ICT tools in agriculture. *Information Development*, *35*(2), 268–280

Annexures

Annex 1

Table 1. Distribution of respondents by various social characteristics (n=390)

Characteristics		Districts				Chi-square value
		Jhapa	Kapilbastu	Bardiya	Total	
		Frequency	Frequency	Frequency	Frequency	
Gender	Male	105 (80.8)	69(53.1)	86(66.2)	260(66.7)	22.45***
	Female	25(19.2)	61(46.9)	44(33.8)	130(33.3)	
Age (yrs)		Mean: 47.27 ±10.95 Min:21yrs, Max:74yrs	Mean: 47.48±11.33 Min:21yrs, Max:74yrs	Mean: 45.44±12.04 Min:23yrs, Max: 77yrs	Avg: 47.62±11.79 Min:20yrs, Max: 82yrs	
	Young	10(7.7)	19(14.6)	27(20.76)	56(14.35)	9.58**
	Adult	102(78.5)	96(73.84)	91(70)	289(74.1)	
	Old	18(13.8)	15(11.56)	12(9.24)	45(11.55)	
Religion	Hinduism	122(93.8)	130(100)	130(100)	382(97.9)	
	Buddhism	3(2.3)	0(0)	0(0)	3(0.8)	
	Muslim	5(3.8)	0(0)	0(0)	5(1.3)	
Ethnicity	Bhramin	49(37.7)	77(59.2)	52(40)	178(45.6)	123.98***
	Janajati	10(7.7)	37(28.5)	42(32.3)	89(22.8)	
	Madheshi	36(27.7)	0(0)	0(0)	36(9.2)	
	Chhetri	34(26.2)	13(10)	23(17.7)	70(17.9)	
	Dalit	1(0.8)	3(2.3)	13(10)	17(4.4)	
Family type	Nuclear	118(90.8)	66(50.8)	6(48.5)	247(63.3)	101.53***
	Joint	12(9.2)	53(40.8)	27(20.8)	92(23.6)	
	Extended	0(0)	11(8.5)	40(30.8)	51(13.1)	
Educational level	Illiterate	7(5.4)	13(10)	37(28.5)	57(14.6)	31.43***
	Only read and write	40(30.8)	41(31.5)	29(22.3)	110(28.2)	
	Up o SLC	58(44.6)	53(40.8)	45(34.6)	156(40)	
	More than SLC	25(19.2)	23(17.7)	19(14.6)	67(17.2)	

Characteristics		Districts				Chi-square value
		Jhapa	Kapilbastu	Bardiya	Total	
		Frequency	Frequency	Frequency	Frequency	
Occupation	Agriculture	119(91.6)	118(90.8)	98(75.4)	335(85.9)	17.82***
	Non-agriculture	11(8.4)	12(9.2)	32(24.6)	55(14.1)	
Land Area	Small	3(2.3)	8(6.1)	16(12.2)	27(6.9)	33.73***
	Medium	98(75.4)	116(89.2)	106(81.5)	320(82.1)	
	Large	29(22.3)	6(4.6)	8(6.3)	43(11)	

Source: Field Survey, 2020 Note: Figures in parentheses indicate percentage
*, **, *** indicates 10, 5 and 1 percent level of significance

Annex 2

Table 2. Distribution of respondents by organization characteristics (n=390)

Organizational characteristics		Districts				Chi-square value
		Jhapa	Kapilbastu	Bardiya	Total	
		Frequency	Frequency	Frequency	Frequency	
Involved in the first organization	Yes	123(94.6)	130(100)	82(63.1)	335(85.9)	85.38***
	No	7(5.4)	0(0)	48(36.9)	55(14.1)	
Type of the organization involved	Group	88(71.54)	51(39.2)	51(62.20)	190(56.72)	117.10***
	Co-operative	35(28.46)	79(60.8)	31(37.80)	145(43.28)	
Position in organization	Ordinary member	81(65.85)	105(80.8)	56(68.30)	242(72.24)	95.60***
	Executive member	15(12.20)	8(6.2)	7(8.53)	30(8.95)	
	Secretary	10(8.13)	4(3.1)	7(8.53)	21(6.27)	
	President	17(13.82)	13(10)	12(14.64)	42(12.54)	
Duration of the involvement (yrs)		Mean:6.74±3.55	Mean:6.35±4.75	Mean:6.8±5.87	Mean:6.60±4.66	
	Yes	45(36.59)	64(49.2)	21(25.60)	96(28.65)	

Organizational characteristics		Districts				Chi-square value
		Jhapa	Kapilbastu	Bardiya	Total	
		Frequency	Frequency	Frequency	Frequency	
Involved in second organization	No	78(63.41)	66(50.8)	61(74.40)	239(71.35)	
Position in organization	Ordinary member	42(93.33)	57(43.8)	16(76.20)	78(81.25)	
	Executive member	3(6.67)	4(3.1)	3(14.28)	9(9.38)	
	Secretary	0(0)	1(0.8)	2(9.52)	5(5.20)	
	President	0(0)	2(1.5)	0(0)	4(4.17)	
Duration of the involvement (yrs)		Avg: 1.6±1.05	Mean:7.78±5.85	Mean:5.52± 2.36	Mean:6.78±5.14	
Access to credit	Yes	104(80)	125(96.2)	55(42.30)	284(72.8)	100.29***
	No	26(20)	5(3.8)	75(57.70)	106(27.2)	
Type of credit source	Group	18(17.3)	57(43.8)	14(25.45)	89(31.34)	
	Co-operative	73(70.2)	68(52.3)	27(49.10)	168(59.16)	
	Bank	13(12.5)	0(0)	14(25.45)	27(9.50)	
Credit taken from organization	Yes	25(24.04)	85(65.4)	38(69.10)	148(52.11)	65.09***
	No	79(75.96)	40(30.8)	17(30.90)	136(47.89)	

Source: Field Survey, 2020 Note: Figures in parentheses indicate percentage

*, **, *** indicates 10, 5 and 1 percent level of significance

Annex 3

Table 3. Perceived attributes of ICT tools (n=390)

S.N.		Perceived attributes		Index value			Average	F-value
				Jhapa	Kapilbastu	Bardiya		
1	i	Relative advantage	Time saving	0.71	0.95	0.76	0.81	1.50
	ii		Economical as to reach many	0.85	0.18	0.48	0.50	(P-value; 0.24)
	iii		Informative	0.52	0.83	0.68	0.68	
	iv		No time limitation to use	0.09	0.53	-0.12	0.17	
	v		Low investment	0.09	-0.12	-0.51	-0.18	
	vi		Up to date	0.10	0.81	-0.03	0.29	
	vii		Easy to use	0.22	-0.10	-0.55	-0.14	
	viii		Social recognition	0.55	0.35	0.07	0.33	
			Average	0.39	0.43	0.10	0.31	
2	i	Complexity	Need skills and expertise	0.78	0.77	0.95	0.83	4.33**
	ii		Difficult to learn	0.68	0.33	0.88	0.63	(P-value; 0.04)
	iii		Difficult to maintain	0.66	0.12	0.88	0.55	
	iv		Difficult to understand	0.08	0.35	0.84	0.42	
			Average	0.55[b]@10%	0.39[b]	0.89[a]	0.61	
3	i	Compatibility	Applicable to all without social discrimination	-0.12	0.85	0.51	0.41	
	ii		No language barriers	-0.15	-0.67	-0.42	-0.42	0.74
	iii		No cultural barriers	0.21	0.82	-0.03	0.33	(P-value; 0.49)
	iv		No social barriers	0.23	0.83	0.22	0.43	
	v		Felt need of farmers	0.41	0.35	0.44	0.40	
			Average	0.12	0.44	0.14	0.23	
4	i	Trialability	Try even without purchasing	0.37	-0.72	-0.18	-0.17	35.09***
	ii		Ease in trying majority of features	0.19	-0.58	-0.33	-0.24	(P-value; 0.008)
			Average	0.28[a]	-0.65[c]@10%	-0.26[b]	-0.21	
5	i	Observability	Immediate feedback	0.45	0.19	0.37	0.33	0.02

S.N.		Perceived attributes		Index value			Average	F-value
				Jhapa	Kapilbastu	Bardiya		
	ii		Gives accurate information	0.24	0.57	0.34	0.38	(P-value; 0.97)
			Average	0.35	0.38	0.36	0.36	
6	i	Predictability	Impacts may predict easily	-0.06	0.04	0.36	0.11	3.6*
	ii		Results may predict easily	0.08	0.04	0.39	0.17	(P-value; 0.091)
	iii		Future needs due to ICT can be identified	0.33	0.14	0.25	0.24	
			Average	0.12[b]	0.07[b]	0.33[a]	0.17	
			Overall average of the attributes	0.31	0.29	0.26	0.29	0.09 (P-value; 0.91)

Source: Field Survey, 2020

Note: Index value ranges from -1 to +1

*, **, *** indicates 10, 5 and 1 percent level of significance

PESTICIDE RESIDUE IN VEGETABLES FROM COLLECTION CENTERS OF DIFFERENT DISTRICTS IN NEPAL

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ABSTRACT

Pesticide residues in vegetables pose a significant public health concern in Nepal, where systematic residue monitoring remains limited. This study assessed the occurrence of pesticide residues in commonly consumable vegetables collected from major collection centres across Nepal and examined their statistical association with selected post-harvest quality parameters. Vegetable samples collected from different collection centers around Nepal were subjected to Rapid Bioassay of Pesticide Residue (RBPR) test kit to examine residue of Carbamate, Organophosphate, Synthetic-Pyrethroid and Dithiocarbamate. 71% of samples were detected with synthetic pyrethroid followed by dithiocarbamate (25%), organophosphate (3%) and none with carbamate. 2% of sample were found at hazardous level of organophosphate, 50% of synthetic-pyrethroid and 2% for dithiocarbamate at unsafe level. The research findings indicate the presence of pesticide residues in common vegetables and recommend validation, comparison and assessment with acknowledging the limitation of preliminary screening RBPR and following other advance test with larger sample sizes.

1. INTRODUCTION

Agriculture continues to be the mainstay of Nepal's national economy, accounting for over 23.95% of the country's Gross Domestic Product (GDP) (NRB, 2021/22) and engagement of around 60.4% of population (AITC, 2022). Together with the production and self-sufficiency of food being a serious issue, protection of agricultural commodities on and off field has also become a problem to be addressed. As Nepal together with several countries in the world has focused more towards conventional agriculture and pesticide as an easy means to kill these pests, Nepal introduced pesticide in 1952 (Aryal et al., 2016). The rural dwelling are the primer drivers if Nepalese agriculture but always placed to the bottom in the need of commercialized agriculture which needs higher use of improved and hybrid cultivars, machinery, fertilizers and pesticides the fear of under recognitions and dream to sustain themselves to commercialization leads to unmanaged utilization of these resources such as pesticides (Nyaupane, 2021).

The wider and incorrect perspective of farmers as their only chemical measures available for quick and easy cure of pests in the field has been accelerating the consumption of these poisons together with improper handling and not applying improper waiting period continuously exposing the farmers and consumers to their health hazards. In the field of agriculture, the utilization of pesticide has become indispensable in the least development countries like Nepal where farmers to compete with the international market need a quick, efficient and cheap method to get rid of the pest (Atreya et al., 2011). According to the Rapid Bioassay Pesticide Residue (RBPR) analytical facility at Kalimati, out of the total 1903 analyzed samples, 5 require quarantine and 22 require disposal in 2016/17 (PPD, 2017). The Central

Development Region has the greatest pesticide usage of all the development regions, with 1.015 a.i. Kg/ha. The use is more prevalent in agricultural commodities such as brinjal, tomatoes, root vegetables, green vegetables, and so on whose residue is becoming a growing problem due to a lack of effective testing and monitoring. (Kalauni & Joshi, 2019). Though on an average basis the consumption of pesticide inactive ingredient of Nepal is very low compared to other countries such as India (0.481 Kg/ha), China (2.0-2.5 Kg/ha), Japan (10.8 Kg/ha), Europe (1.9 Kg/ha) and USA (1.5 Kg/ha) (Sharma, 2019), Nepal's annual import of pesticides in FY 2021/22 i.e., 1135504.35 Kg a.i. is 44.9 % higher as compared to FY 2020/21 and 20 folds increase in the last two decades (PQPMC, 2022). Contrary to the idea of learning from other nations Nepal has been acting in opposition to what other nations have been doing to lower their annual pesticide usage, such as Sweden, which has decreased by 68%, Indonesia by 65%, and India, which has decreased during the past year (Atreya et al., 2012).

Poisoning by pesticides is a major concern around the world, but estimates vary. According to Rajendran (2003), chemical pesticides cause over 500,000 diseases and 20,000 deaths worldwide each year. According to WHO data, 3,000,000 cases of pesticide poisoning are reported each year around the world, with 220,000 deaths (Down to Earth, 2001). Human exposure to the Pesticides even at modest concentrations causes chronic health impacts such as immune suppression, hormone disruption, reproductive abnormalities, and damage of kidney, liver, neural region, cancer and malignancies (Mnif et al., 2011). Several cancer cases have been documented in India as a result of pesticide residue in food (Mittal & Vishwakarma, 2014; Rao, 2016). Poor farming practices have been recognized as a major cause of pesticide residue in food and poisoning by cutaneous and oral consumption in impoverished countries.

Different research by Rijal et al. (2018), Sapkota et al. (2020) at different part of Nepal reported that the majority of farmers don't use protective measures in the field and as well do not follow the waiting periods after pesticide application which is the foremost reason for the producer and consumer contamination. The analysis of 50 human blood samples from Ludhiana and Nepal shows that pesticide residues occurred with a frequency of 96 and 94 %, respectively, in which the levels were higher in the Nepalese population (Shrestha et al., 2011). Despite having a low national average in comparison to other nations in the globe, pesticide use for agricultural purposes is rising in Nepal. However, compared to other nations, the danger and hazards to farmers are greater (Ghimire and G.C., 2018).

One of the most pressing needs of the Nepalese economy is and will continue to be sufficient food production and independency of supply. Pest control is heavily reliant on chemicals and pesticides for the majority of commercialized farmers. Despite the fact that many of them are aware that pesticides are harmful to their health, they appear to overlook this knowledge and treat the chemicals as if they are innocuous. As a result of their exposure to harmful pesticides on a regular basis, farmers as well consumers experience both acute and chronic health impacts.

So, in order to decrease the negative effects of chemicals on human health, a thorough study of every meal we consume is critical. However, the program RBPR by Nepal government is still in infancy and is primarily focused on data collected in and around Kathmandu, Nepal's capital and unknown to the scientific communities (Giri et al., 2012). Following the existing literatures in Nepal which has mapped out the baseline pesticide use accompanying with acute and chronic health hazards (Atreya et al., 2012; Bhandari et al., 2019), a critical gap remained on how the field level contamination compromises the food quality and producer to consumers health. So, research was conducted in the year 2022 to assess the pesticide residue level within vegetables produced from different part of Nepal.

2. MATERIALS AND METHODS

The research is completely based on primary data obtained by pesticide residue assessment of vegetable samples collected from different part of Nepal.

Site selection and sample preparation: All together 126 vegetable samples were collected (3 replication of each) and each replication from different stalls representing different farmers from different collection centres across Nepal which gave a variance residue result within the replication as well. (Figure 1, Table 1) within the month of April to June, 2022.

Table 4. Different locations and different vegetables under research

SN	Locations	Vegetables
1	Jhapa	Bitter gourd, Cowpea, Green Chilli, Okra and Tomato
2	Sarlahi	Bitter Gourd, Brinjal, Cowpea, Cucumber, Green Chilli, Okra, Tomato
3	Kavre	Beans, Bitter Gourd, Cowpea, Cucumber, Green Chilli, Summer squash, Tomato and Sponge Gourd
4	Nuwakot	Beans, Bitter Gourd, Cucumber and Summer squash
5	Bhaktapur	Beans, Brinjal and Summer squash
6	Dhading	Beans, Bitter Gourd, Brinjal, Okra, Cucumber and Sponge Gourd
7	Kailali	Beans, Bitter Gourd, Brinjal, Cucumber, Green Chilli, Okra, Summer squash and Tomato

A rigorous and systematic approach applied for vegetable samples (Bitter gourd, Beans, Brinjal, Cowpea, Cucumber, Green chilly, Okra, Summer squash, Sponge gourd and Tomato) each replicated three times from different stalls in compliance with the FAO rules (1999) allowed a diverse range of examination, contributing to a comprehensive and diversed understanding of pesticide residues and nutrient parameters. After collection, the samples were placed into zip lock plastic bags to maintain their integrity and prevent contamination during transportation. Vegetable samples using a knife excluding the tops such as the sepal and peduncle, was prepared according to annex I of European Commission regulation (EC) No. 333/2007 EU (2010) and well mixed. Each sample's leftovers were stored in a separate plastic bag at -10 ^{0}C until pesticide residue analysis was completed.

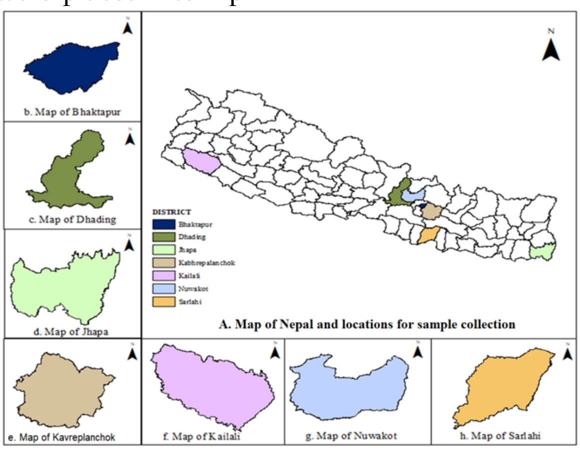

Figure 4. Map of Nepal and sample collection sites

Assessment of pesticide residue: Rapid Bioassay of Pesticide Residue (RBPR) lab, Kalimati Kathmandu Nepal with RBPR test kit method and PY/DTC kits under Standard Operating Procedure (SOP number: RBPR/01/2017) developed by Plant Protection Directorate were applied to analyze Carbamate, Organophosphate (OP) pesticidal residue. During analysis of Carbamate and Organophosphate, the reduction of absorbance for the sample to control (Blank) test was compared and the inhibition percentage of the enzyme was calculated and grouped as follows.

$$Enzyme\ inhibition(\%) = \frac{\{Absorbance\ change\ (Control) - Absorbance\ change\ (Sample)\}}{Absorbance\ change\ (Control)} \times 100$$

The inhibition % than were categorized as per the following rule;

Table 2. Indicator for carbamate and organophosphate residue

Inhibition	Indicator	Description
Below 35%	1	Not harmful consumption as pesticide residue was found low
35%-45%	2	Need to keep in quarantine for minimum 2 days as the presence of pesticide residue was found in considerable amounts that may be degraded withholding for a certain period.
Above 45%	3	Not suggested for sale and consumption purposes since a significantly high amount of pesticide residue was found in the sample.

(Source: Ghimire, 2020)

For synthetic pyrethroid (PY) and Dithiocarbamate (DTC) kits developed by Taiwan Agriculture Research Institute (TARI) have been used to assess the insecticide and fungicide residue in each vegetable sample. These kits include a series of chemicals which is used in different concentrations to result in the final color in the mixture and is analyzed on the basis of a color chart.

Statistical analysis

The data obtained after lab analysis of collected samples were first gathered and managed using MS Excel: Descriptive analysis. Data analysis was performed using R-studio 4.3.1: Kruskal-Wallis test and SPSS base 23.0

Limitations of the study

The study has the limitation as RBPR only operates as primary screening mechanism limiting the delivery the direct quantitative parts-per-million(ppm), nor isolating the individual chemical isomer. However these basic indices are valuable to have a regional survelliance to pesticide residue further requiring sophisticated assessment [Gas Chromatography-Tandem Mass Spectrometry (GC-MS/MS) and Liquid Chromatography-Mass Spectrometry (LC-MS/MS)] and evaluation.

3. RESULTS AND DISCUSSION

Pesticide residue in vegetables

The research synthetic pyrethroid were the group of pesticide detected in highest portion of vegetable samples i.e. 71 % followed by dithiocarbamate 25 %, organophosphate 3% and none of the samples were detected with the carbamate pesticide residue during research period (Figure 2). Survey Report on National Pesticide Consumption Statistics in Nepal (2014) and PPD (2015) identified that the highest portion of pesticides in Nepal had been consumed by vegetable commodities followed by cash crops and Cereals. Additionally, according to CBS (2006), the proportion of vegetable growers using pesticides increased from 7.1% in 1991/92 to 16.1% in 2001/2002. The reason for Synthetic Pyrethroid pesticide showing residue in highest number of samples was because of its chemical nature considered to be amongst the safest insecticides (Yadav & Devi, 2017). Bhandari et al. (2019) found 97% of vegetables were detected with at least one pesticide residue (organophosphates, organochlorines, acaricides, fungicides, and insecticides of biological origin) among crops from Southern Nepal i.e. Eggplant, Chilli and Tomato.

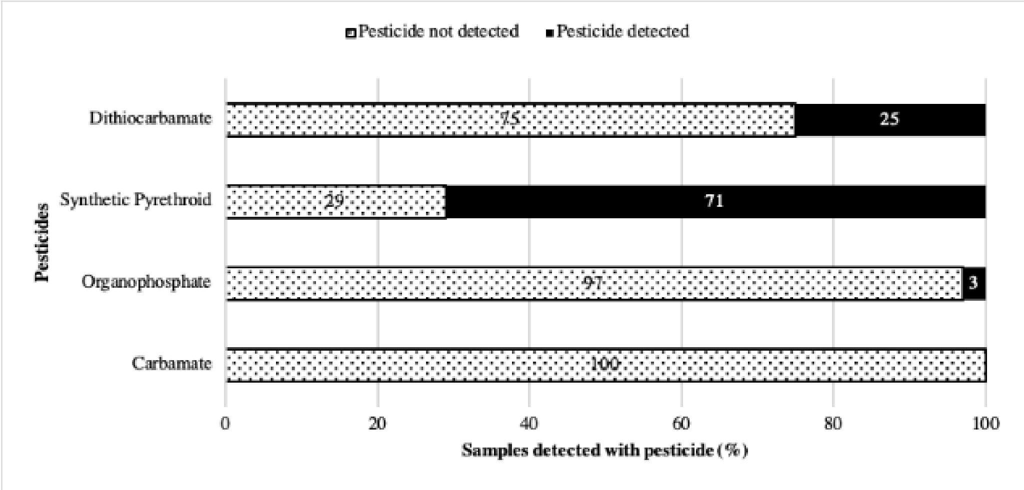

Figure 2. Pesticide residue with in vegetable samples under analysis

Organophosphate pesticide residue in vegetables

The research results that among the samples analyzed all together 2 % of samples were at hazard level of organophosphate pesticide where sponge gourd and tomato were only two vegetables detected with residue. 11% of sponge gourd vegetable were detected with quarantine level of organophosphate pesticide residue and 25 % of tomato vegetable were detected with hazard level of organophosphate pesticide (Figure 3). The result was also supported by Ghimire (2020) where tomato and cowpea were the major vegetable with high residue of organophosphate pesticide collected from commercial pocket of Nepal i.e. Sarlahi and Kavre district. Koirala et al. (2009) also found that the organophosphate pesticide residue under their research was at highest level on root vegetables followed by leaf vegetables. Koirala et al. (2010) in their research to identify pesticide residue in vegetable samples from five different districts of Nepal observed organophosphate to be one of the major identified pesticides to be applied in the field by farmers. Koirala et al. (2010) in their research to identify pesticide residue in vegetables from different districts of Nepal found majority of residue belongs to the moderately hazardous group of pesticides as per WHO classification and the organophosphate group of pesticides belongs to this group. The absence of residues aligns with the susceptibility to rapid environmental hydrolysis and higher water solubility (Yadav & Devi, 2017)

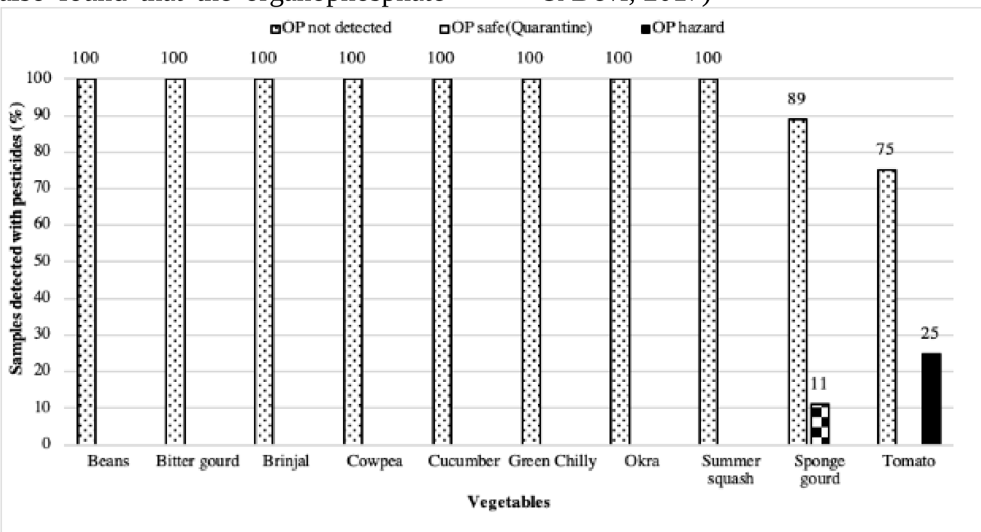

Figure 3. Vegetable-wise organophosphate residue

Synthetic pyrethroid pesticide residue in vegetables

The result shows that among different vegetable samples analyzed for synthetic pyrethroid pesticide residue 50% of vegetables were detected with hazard level where sponge gourd samples was the vegetable with highest portion residue followed by cowpea (89%), beans (86%), summer squash (84%), tomato (75%), brinjal (67%), green chilli (66%), okra (67%), cucumber (60%) and bitter gourd (45%) was the vegetable with lowest portion of samples detected (Figure 4). Research by Koirala et.al. (2010) in five different districts of Nepal identified that cypermethrin was a common pesticide applied by farmers in the field which belong to the synthetic pyrethroid group. Another research by Sharma (2015) also found the highest residue of cypermethrin and Deltamethrin from the synthetic pyrethroid group of pesticides in tomato and brinjal from the central region of Nepal. As per GC and Palikhe (2021-22) a wider perception to farmers that only chemical applications are available to control pest effect in their crop and lack of awareness, management of chemical and governmental regulation leads to over utilization and residue of pesticides in our vegetables reaching to consumers with a sever health impact on the applicator as well. The result was also supported by research done by Bhandari et.al. (2019) with vegetable farmers of Dhading which reported that farmers use maximum pesticides, mostly in tomato and only 56% follow the waiting period. High frequency of synthetic pyrethroid aligns with regional pesticide use trend (Bhandari et al., 2019) and lipophilic nature favoring long-term binding with cuticular waxy layers (Yadav & Devi, 2017).

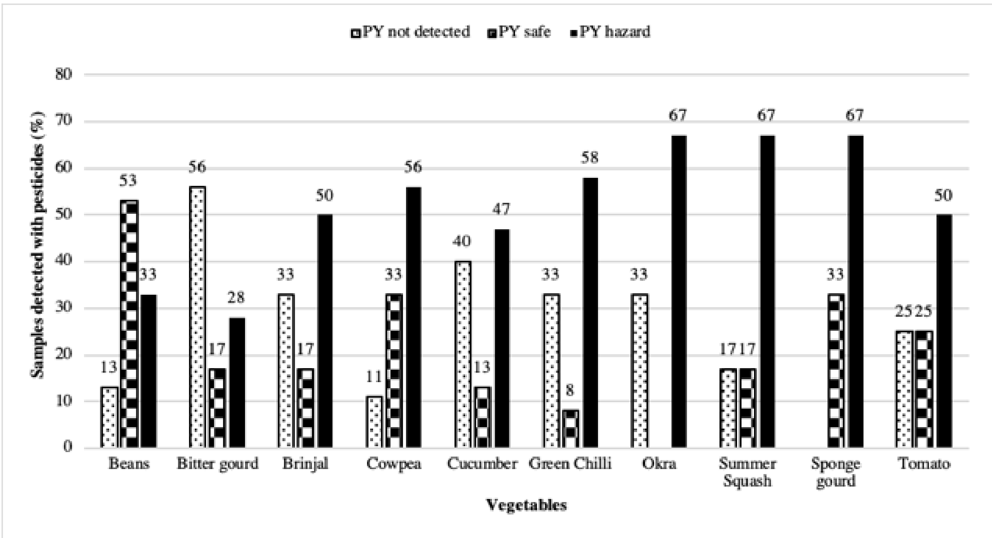

Figure 4. Vegetable-wise synthetic pyrethroid pesticide residue

Dithiocarbamate pesticide residue in vegetables

The result shows that among different vegetable samples analyzed for dithiocarbamate pesticide only 2%(3 Samples) of samples showed the unsafe level of pesticide residue where brinjal(50%) was the vegetable with highest portion of samples detected with pesticide followed by green chilli (33 %), summer squash (33 %), sponge gourd (33 %), tomato (33 %), bitter gourd (28 %), cucumber (20 %), cowpea (11 %), okra (8 %) and beans (7 %) was the vegetable with lowest portion of samples detected (Figure 5). Research by Sharma (2015) in the central region of Nepal under pesticide residue analysis of vegetables identified the residue of carbendazim and mancozeb to be highest in tomatoes followed by bottle gourd and chilli. The mancozeb belongs to the dithiocarbamate group of pesticides.

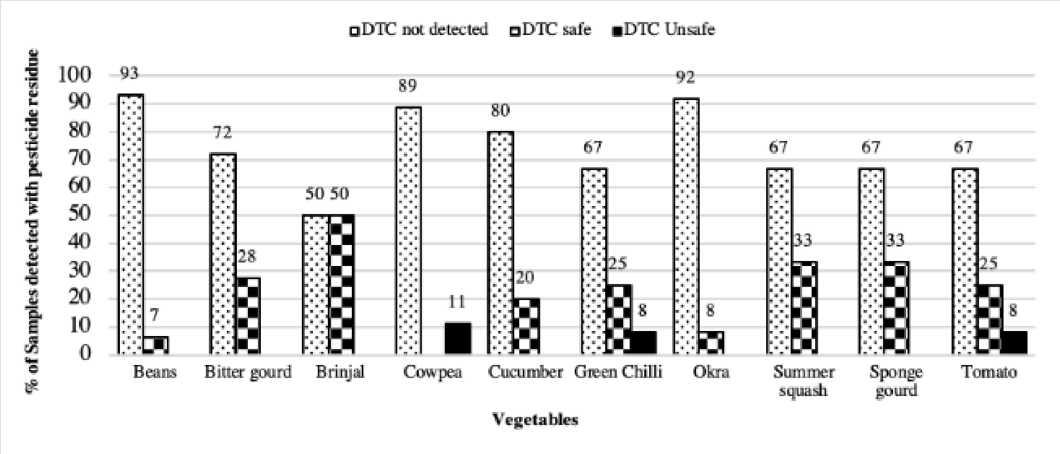

Figure 5. Vegetable-wise dithiocarbamate pesticide residue

4. CONCLUSION

In conclusion, this investigation highlights significant presence of pesticides in majority of the vegetables within distribution channel. Most of the samples exhibiting the presence of pesticide underscores a need of immediate systematic and continuous residue assessment facilities across regional collection centers safeguarding public health and ensuring food safety. Furthermore, the research suggests requiring comprehensive and sophisticated test procedure advanced than RBPR to result evidences. The investigations emphasize that implementing local RBPR points will provide practical on farm data’s and help to screen national food system supporting agriculture supply chain.

The research findings should be further validated and experimented within upcoming days with more samples from different parts of Nepal as well agriculture imports specifying pesticide. A comparative analysis with the application of different pest management practices in the farmer's field in comparison to biological solutions together with washing methodology before the consumption of vegetable is needed after this research as most of the samples were identified with contact pesticide.

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REFERENCES

AITC. (2022). *Agriculture diary.* Agriculture Information and Training Center, Hariharbhaban, Lalitpur.

Aryal, K., Neupane, S., Lohani, G. R., Jors, E., Neupane, D., Khanal, P., Jha, B., Dhimal, M., Shrestha, B., Bista, B., Poudyal, A., & Karki, K. (2016). *Health effects of pesticide among vegetable farmers and the adaptation level of integrated pest management program in Nepal, 2014.* Nepal Health Research Council. https://doi.org/10.13140/RG.2.2.23328.79363

Atreya, K., Sitaula, B. K., Johnsen, F. H., & Bajracharya, R. M. (2011). Continuing issues in the limitations of pesticide use in developing countries. *Journal of Agricultural and Environmental Ethics, 24(1), 49–62. https://doi.org/10.1007/s10806-010-9245-2*

Atreya, K., Sitaula, B. K., Overgaard, H., Bajracharya, R. M., & Sharma, S. (2012). Knowledge, attitude and practices of pesticide use and acetylcholinesterase depression among farm workers in Nepal. *International Journal of Environmental Health Research, 22(5), 401–415.* https://doi.org/10.1080/09603123.2011.650154

Bhandari, G., Zomer, P., Atreya, K., Mol, H., Yang, X., & Geissen, V. (2019). Pesticide residues in Nepalese vegetables and potential health risks. *Environmental Research, 174, 72–81.* https://doi.org/10.1016/j.envres.2019.04.008

CBS. (2006). *National Sample Census of Agriculture N, 2001/2002 highlights:* Central Bureau of Statistics, Kathmandu, Nepal.

Down to Earth. (2001). *Editorial. Down to Earth, 9(19), 28–35. European Union. (2010). Commission Regulation (EU) No 270/2010 amending Annexes II, III and IV to Regulation (EC) No 396/2005 of the European Parliament and of the Council as regards maximum residue levels for pesticides in or on certain products. Official Journal of the European Union, L84, 1–45.*

FAO. (1999). *Recommended methods of sampling for the determination of pesticide residues for compliance with MRLs (Codex Alimentarius Vol. 2A).* Food and Agriculture Organization.

GC, Y., & Palikhe, B. R. (2021). From the field to dining table: Pesticide residues. *Journal of Agriculture and Environment,* 22, 1–16. https://doi.org/10.3126/aej.v22i1.43321

Ghimire, K., & Arun, G. C. (2018). Trend of pesticide use in Nepal. *Journal of the Plant Protection Society,* 5, 32–42. https://doi.org/10.3126/jpps.v5i0.47352

Ghimire, P. (2020). Status of pesticide residue in vegetable and fruit samples collected from Kalimati wholesale market of Kathmandu, *Nepal. The Journal of Agriculture and Environment,* 21, 163–172. https://doi.org/10.3126/aej.v21i0.36442

Giri, Y. P., Aryal, S., & Paneru, R. B. (2012). *Review and future strategies on the pesticide residue works of agricultural commodities in Nepal. In Proceedings of the Workshop on Review and Strategy Development of Entomological Research Works in Nepal (pp. 64–73).* Nepal Agricultural Research Council, Entomology Division.

Kalauni, D., & Joshi, A. (2019). *Pesticides import, use, consumption and residue status among food crops in Nepal: A review. Big Data in Agriculture,* 1(1), 21–25. https://doi.org/10.26480/bda.01.2019.21.25

Koirala, P., Dhakal, S., & Tamrakar, A. S. (2009). Pesticide application and food safety issue in Nepal. *Journal of Agriculture and Environment*, 10, 128–132. https://doi.org/10.3126/aej.v10i0.2137

Koirala, P., Dahal, N. R., Bhandari, M. R., Shrestha, K. B., Dawadi, G., & Lama, J. P. (2010). *Food Research Bulletin. Department of Food Technology and Quality Control (DFTQC), 3, 5–15.*

Mittal, S., Kaur, G., & Viswakarma, G. S. (2014). Effects of environmental pesticides on the health of rural communities in the Malwa Region of Punjab, India: A review. *Human and Ecological Risk Assessment: An International Journal*, 20(2), 366–387. https://doi.org/10.1080/10807039.2013.788972

Mnif, W., Hassine, A., Bouaziz, A., Bartegi, A., Thomas, O., & Roig, B. (2011). Effect of endocrine disruptor pesticides: A review. *International Journal of Environmental Research and Public Health*, 8(6), 2265–2303. https://doi.org/10.3390/ijerph8062265

NRB. (2022). *Current macroeconomic and financial situation of Nepal (Annual Data 2021/22).* Nepal Rastra Bank, Economic Research Department., Kathmandu, Nepal.

Nyaupane, S. (2021). *Use of insecticides in Nepal, its impact and alternatives of insecticides for Nepalese farmers.* IntechOpen. https://doi.org/10.5772/intechopen.101091

PPD. (2015). *Annual progress report.* Plant Protection Directorate, Ministry of Agricultural Development, Government of Nepal.

PPD. (2017). *Year wise compilation of rapid bioassay of pesticide residue analysis results of RBPR analysis unit at Kalimati.* Plant Protection Directorate, Hariharbhawan, Lalitpur..

PQPMC. (2022). *List of registered pesticides and consumption data.* Plant Quarantine and Pesticide Management Centre, Hariharbhawan, Lalitpur.

Rajendran, S. (2003). *Environment and health aspects of pesticides use in Indian agriculture. In Development Policy Review (Vol. 21, pp. 112–125).* Allied Publishers.

Rao, J. U. (2016, October 18). *Andhra Pradesh and Telangana suffer from high pesticide residues. Deccan Chronicle. https://www.deccanchronicle.com/nation/current-affairs/181016/andhra-pradesh-andtelangana-suffer-from-high-pesticide-residues.html*

Rijal, J., Regmi, R., Ghimire, R., Puri, K., Gyawaly, S., & Poudel, S. (2018). Farmers’ knowledge on pesticide safety and pest management practices: A case study of vegetable growers in Chitwan, Nepal. *Agriculture,* 8(1), 16. https://doi.org/10.3390/agriculture8010016

Sapkota, K. R., Sapkota, S., Sapkota, S., & Katuwal, K. (2020). Pesticides handling practices among potato growers in Kavrepalanchok, Nepal. *Journal of Agriculture and Natural Resources,* 3(1), 77–87. https://doi.org/10.3126/janr.v3i1.27093

Sharma, D. R. (2015). Use of pesticides and its residue on vegetable crops in Nepal. *Journal of Agriculture and Environment, 16, 33–42.* https://doi.org/10.3126/aej.v16i0.19838

Sharma, P. (2019). Pesticides use practices in the vegetables growing areas at Dhading and Lalitpur districts. *The Journal of Agriculture and Environment,* 20, 89–98.

Shrestha, S. K., Aulakh, R., Bedi, J. S., & Gill, J. P. (2011). *Monitoring of pesticide residues in the human population of Nepal. In Proceedings of the 2011 5th International Conference on Bioinformatics and Biomedical Engineering (pp. 1–3). IEEE*. https://doi.org/10.1109/icbbe.2011.5780112

WHO. (2009). *Health implications from monocrotophos use: A review of the evidence in India.* World Health Organization Regional Office for South-East Asia.

WHO. (2020). *The WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition.* World Health Organization. https://www.who.int/publications/i/item/9789240005662

Yadav, I. C., & Devi, N. L. (2017). Pesticides classification and its impact on human and environment. *Environmental Science and Engineering*, 6, 140–158

PROFITABILITY AND RESOURCE USE EFFICIENCY OF TOMATO PRODUCTION UNDER PLASTIC TUNNEL IN KATHMANDU, NEPAL

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ABSTRACT

Tomato is one of the most important vegetable crops in Nepal, but its productivity and profitability are constrained by inefficient resource use and production-related challenges. A study was conducted in the Kathmandu district in 2024 to analyze the profitability and resource use efficiency of tomato production under plastic tunnels. Data from 150 farmers, selected by using simple random sampling technique, from Chandragiri, Tarakeshwar, and Kirtipur municipalities were collected through interviews using a semi-structured questionnaire. Analysis was performed using descriptive statistics, benefit-cost ratio, Cobb-Douglas production function, and multiple linear regression with SPSS and STATA software. The average production cost was NRs. 31.74 per kg of tomato, with a total production cost NRs. 1,979,921 per hectare, an average yield of 65,917 kg per hectare, a gross revenue of NRs. 3,534,467 per hectare, and a benefit-cost ratio of 1.77. Land rent, labor, seed, pest management were positively associated with gross revenue. The return to scale was nearly constant at 0.998. Resource use efficiency analysis indicated that land rent, labor, seeds, farm yard manure, pest management, and tillage costs were under-utilized, while chemical fertilizer and other associated costs were over-utilized. Key factors positively influencing revenue included education, group membership, extension advisory services, training, credit access, recommended variety use, and drip irrigation. Enhancing efficiency and profitability of tomato farming under plastic tunnel system in Nepal requires addressing inefficiencies, resource pooling, stakeholder collaboration, strong policies, and technology adoption

1. INTRODUCTION

Agriculture contributes 24.12% to Nepal's Gross Domestic Product (GDP) (MOALD, 2025). According to the National Population and Housing Census (2021), 57.3% of the economically active population were engaged in agriculture (MOALD, 2025). Vegetables, considered high-value crops, have garnered significant attention in Nepal's development initiatives (PACT, 2014), with the potential to alleviate poverty and reduce reliance on imports (NMDP, 2015). Tomatoes, globally the second most important crop after potatoes, are worth around USD 96 billion annually (FAOSTAT, 2024), with production rising 300% over the past four decades (Costa & Heuvelink, 2007).

The growing demand for fresh tomatoes year-round, coupled with higher off-season prices, makes tomato farming a profitable option for improving farmers' livelihoods (Pokharel, 2021). In Nepal, tomato ranks third among vegetable crops, covering 26,291 ha with an annual production of 552,607 metric tons and a productivity of 20.63 mt/ha (MOALD, 2025), thereby meeting the national target of the 15th Five-Year Plan to increase vegetable yields to 20 mt/ha. However, challenges related to production efficiency and profitability still exist, particularly in terms of input use and production systems. Plastic tunnel technology is becoming a popular method for year-round tomato production especially among peri-urban farmers in Kathmandu Valley (Gautam, 2019). Tomato farmers, using plastic tunnels, can earn about NRs. 85,400 per ropani, and 2–3 times more than traditional open-field farming (Budhathoki, 2006). Tunnel farming offers a low-cost solution to stabilize temperatures and produce quality off-season yields (Pal, 2022), yet Nepal still imports large volumes of vegetables, revealing gaps in domestic production.

Despite these advances, inefficiencies in resource use, such as overuse or underuse of land, labor, seeds, and pesticides, limit profitability and productivity (Bhatta & Rijal, 2022; Tambo & Gbemu, 2010). Many studies lack comprehensive economic analyses and overlook socio-economic impacts, institutional support, and factors influencing resource allocation in tunnel farming (Pokharel, 2021; Pal, 2022). Efficiency is the measure of how effectively inputs are transformed into outputs (Otieno et al., 2012). Improving smallholder efficiency through better understanding of economics, resource use and its predisposing factors is crucial for maximizing profits and sustainability (Okello et al., 2019). This study aims to fill gaps by providing a holistic economic assessment of plastic tunnel tomato production in Kathmandu, offering insights applicable to broader regions in Nepal.

2. METHODOLOGY

2.1 Study area

The study was conducted in Kathmandu district of Bagmati Province, Nepal, covering 413.69 sq. km with a population of 2,041,587 (NSO, 2024), the highest density in the country. It lies between 27°27′–27°49′N latitude and 85°10′–85°32′E longitude and is well known for plastic tunnel tomato farming as one of the agricultural production enterprises.

2.2 Sampling procedure and data collection

Purposive sampling method was used to select tomato growing areas under plastic tunnels in Chandragiri, Tarakeshwar, and Kirtipur Municipalities. From 255 growers registered in the Agriculture Knowledge Center (AKC), Lalitpur, and the Project Implementation Unit (PIU), Kathmandu, 150 households, 50 from each municipality, were chosen using simple random sampling. The sample size was determined using Yamane's (1967) formula

$$n = \frac{N}{1 + N * e2}$$

Where, N is the population size, n is the sample size and e is the margin of error (maintained at 5% in this study).

Both primary and secondary data were used while following standard research ethical procedures. Primary data were collected through face-to-face interviews with a questionnaire, supplemented by key informant interviews and focus group discussions with farmers and agricultural staff. The study was based on cross-sectional data collected from farmers during 2024 tomato production season. However, information on all major inputs, costs, and outputs incurred throughout the complete production cycle, from planting to final harvest, was collected and used for the analysis. Secondary data were obtained from government and non-government reports, annual agricultural statistical books, relevant journal articles, and official websites.

2.3 Data analysis

The collected data were coded and managed in Microsoft Excel and analyzed using SPSS and STATA. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to summarize the respondents' socio-demographic and farm characteristics. Profitability was assessed through benefit-cost ratio (BCR). The Cobb-Douglas production function was used to estimate resource-use efficiency and return to scale, while multiple linear regression was employed to identify factors affecting gross revenue from tomato production under plastic tunnel. Multicollinearity was assessed using the Variance Inflation Factor (VIF).

2.3.1 Descriptive analysis

The socio-demographic and farm characteristics of the respondents were summarized using descriptive statistics, including frequency, percentage, mean, and standard deviation.

2.3.2 Analysis of cost of production

Tomato production costs under plastic tunnel were estimated using the standard cost approach;

$$Total\ cost = Fixed\ cost\ (FC) + Variable\ cost\ (VC)$$

Here, fixed costs included land rent, depreciation of tunnel construction and drip installation, and annual loan interest. Tunnel construction and drip pipe installation costs were depreciated over the expected lifespan of tomato cultivation. Similar approaches were used by Mwangi (2012); Ali et al. (2017); Paudel and Adhikari (2018); and Paudel (2022).

Similarly, total variable costs encompass all ongoing expenses associated with production as calculated by Paudel and Adhikari (2018); Pokharel (2021) and can be expressed as;

$TVC = C_{seed} + C_{media} + C_{tillage} + C_{FYM} + C_{fertilizer} + C_{pest\ management} + C_{intercultural\ operations} + C_{labor} + C_{other}$

Where,

TVC = Total variable cost of tomato production under plastic tunnel (NRs./ha)

C_{seed} = Cost of seed/seedlings (NRs./ha)

C_{media} = Cost of media used for seed sowing (NRs./ha)

$C_{tillage}$ = Cost on tillage by mini-tiller (NRs./ha)

C_{FYM} = Cost of farm yard manure (NRs./ha)

$C_{Fertilizer}$ = Cost of chemical fertilizers (NRs./ha)

$C_{pest\ management}$ = Cost of pesticides, micronutrients, and lure and trap installed (NRs./ha)

$C_{intercultural\ operations}$ = Cost of irrigation, and mulching (NRs./ha)

C_{labor} = Cost of human labor used (NRs./ha)

C_{other} = Other cost of cultivation (repair and maintenance, transportation, etc.) (NRs./ha)

2.4.3 Return and margin analysis

Gross and net margin were calculated following Ali et al. (2017) and Usman (2013).

Gross Margin (NRs.) = Gross return (NRs.) – Total variable cost (NRs.)

Where, Gross return (NRs.) = Total quantity marketed (kg) × Price (NRs./kg)

And, Net margin (NRs.) = Gross return (NRs.) – Total cost (NRs.)

2.4.4 Benefit-cost analysis

The BCR is a quick measure of business profitability, comparing benefits gained per unit of cost. Following Ali et al. (2017); Usman (2013), BCR was calculated as;

$$BCR = \frac{Gross\ return}{Total\ cost}$$

2.4.5 Production function analysis and estimation of efficiency ratios

The Cobb-Douglas production function was used to assess resource use efficiency in tomato production under plastic tunnels. Efficiency was measured as the ratio of Marginal Value Product (MVP) to Marginal Factor Cost (MFC). The state of resource use (i.e., underutilization, optimum utilization, and overutilization) was estimated by following Ali et al. (2017); Dhakal et al. (2015);

The Cobb-Douglas production function is;

$Y = aX_1^{b1}X_2^{b2}X_3^{b3}\ X_4^{b4}\ X_5^{b5}\ X_6^{b6}X_7^{b7}\ X_8^{b8}e^u$

By taking natural logarithm on both side,

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + u$

Where,

Y = Gross revenue from tomato production under plastic tunnel (NRs./ha)

X_1 = Land rent for tomato production under plastic tunnel (NRs./ha)

X_2 = Human labor cost (NRs./ha)

X_3 = Seed cost (NRs./ha)

X_4 = FYM cost (NRs./ha)

X_5 = Chemical fertilizer cost (NRs./ha)

X_6 = Pest management cost (pesticides, micronutrients, and lure/trap) (NRs./ha)

X_7 = Tillage cost by mini-tiller (NRs./ha)

X_8 = Other associated cost (media, irrigation, mulching, transportation, repair and maintenance, etc.) (NRs./ha)

a = intercept

ln = Natural logarithm

e = Base of natural logarithm

u = Error term

Following Goni et al. (2013) as cited in Dhakal et al. (2015), efficiency can be expressed as;

$$r = \frac{MVP}{MFC}$$

Where,
r = efficiency ratio
MVP = Marginal Value Product
MFC = Marginal Factor Cost
The MVP was estimated by using the formula:

$$MVP_i = b_i * \frac{Y}{X_i}$$

Where,
b_i = Estimated regression coefficients
Y = Geometric mean of total income from tomato production under plastic tunnel
X_i = Geometric mean of i^{th} inputs
<u>Decision rule:</u>
r = 1 or MVP = MFC indicates the efficient utilization of the resources
r > 1 or MVP > MFC indicates the under-utilization of the resources
r < 1 or MVP < MFC indicates the over utilization of the resources
The relative percentage change in MVP of each resource was estimated as follows:

$$D = \left(1 - \frac{MFC}{MVP}\right) * 100 = \left(1 - \frac{1}{r}\right) * 100$$

Where, D = Absolute value of percentage change in MVP of each resource

2.4.6 Return to scale (RTS) analysis

Return to scale (RTS) was calculated using the Cobb-Douglas production function:

$$\text{RTS} = \sum bi$$

Where,
b_i = coefficient of i^{th} explanatory variables obtained from OLS regression of Cobb-Douglas production function.
<u>Decision rule:</u>
RTS = 1 indicates the constant return to scale
RTS > 1 indicates the increasing return to scale
RTS < 1 indicates the decreasing return to scale

2.4.7 Factors affecting the revenue from tomato production under plastic tunnel

Gross revenue per hectare from tomato production under plastic tunnels was regressed with socioeconomic, demographic, and social capital factors using multiple linear regression. The effects of independent variables were estimated via the Ordinary Least Squares (OLS) method. Following the Paudel (2022), the regression function used in the model was;

$$\ln(Y) = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + e$$

Where,
Y = Gross revenue from tomato production under plastic tunnel (NRs./ha)
X_1 = Schooling of the household head (years)
X_2 = Economically active members (No.)
X_3 = Membership in farmers group (Yes = 1)
X_4 = Extension advisory service from government (Yes = 1)
X_5 = Training received about plastic tunnel tomato farming (Yes = 1)
X_6 = Access to agricultural credit (Yes = 1)
X_7 = Variety used (Srijana = 1)
X_8 = Irrigation type (Drip = 1)
ln = Natural logarithm
b_0 = constant
e = error term
Variance Inflation Factor (VIF) was used to assess multicollinearity among predictors within the regression model, check homoscedasticity, and validate regression assumptions (Gujarati & Porter, 2009).

3. RESULTS AND DISCUSSION

3.1 Socio-economic and demographic information

Table 1 presents the socio-economic profile of 150 randomly selected tomato farmers cultivating under plastic tunnels. The findings indicate that household heads had an average of 7.7 years of schooling, reflecting a moderately educated farming population. On average, households had 3.25 economically active members (aged 15–59 years), accounting for 68.3% of the total household population. Regarding institutional participation, 56.7% of farmers were members of groups such as farmer organizations, women's groups, or cooperatives, with 42% specifically engaged in farmer groups. Access to agricultural credit was reported by 42.7% of farmers, while only 36% had participated in agricultural training programs. In terms of varietal adoption, four tomato varieties were cultivated, with 'Srijana' being the dominant choice, adopted exclusively by 72.7% of farmers. This highlights its strong adaptability and preference among growers. With respect to irrigation practices, 45.4% of farmers employed drip irrigation, while others relied on sprinkler systems and wells.

The results suggest high adoption of improved tomato varieties under tunnel farming. However, the relatively low participation in agricultural training, limited access to credit, and partial adoption of modern irrigation systems point to gaps in the uptake of complementary practices that could further enhance productivity.

Table 1. Socio-economic and demographic characteristics of the respondents in the study area

Continuous Variables	Unit	Mean	SD
Schooling of the HHH	Year	7.70	5.62
Economically active members	Number	3.25	1.30
Categorical Variables	Unit	Frequency	%
Membership	Involved in farmers group, Yes=1	63	42
Training received	Yes=1	54	36
Access to agri. credit	Yes=1	64	42.7
Variety used	Srijana=1	109	72.7
Irrigation type	Drip irrigation, Yes=1	68	45.4

Source: Field Survey, 2024

3.2 Production economics

3.2.1 Cost of production of tomato using plastic tunnel

The average cost of constructing a 28×5 m² bamboo-based plastic tunnel was NRs. 23,647.64, with three tunnels typically accommodated per ropani of land. This finding is consistent with previous studies (Kafle & Shrestha, 2017; Ghimire et al., 2023).

Table 2 summarizes the production costs of tomatoes under plastic tunnels. The mean production cost per hectare was NRs. 1,979,921.33, comprising fixed costs of NRs. 766,466.45 and variable costs of NRs. 1,213,454.88. The total cost was lower than Pokharel (2021); Ghimire et al. (2023), but higher than Kafle and Shrestha (2017); Gautam (2019). Production costs varied significantly across the three municipalities. The total cost was significantly higher in Tarakeshwar and Chandragiri than in Kirtipur.

Table 2. Cost per hectare of tomato production under plastic tunnel

Cost items	Cost (NRs./ha)			Overall	F-value	p-value
	Chandragiri	Tarakeshwar	Kirtipur			
Land rent	367356.74	395565.44	254197.15	339039.78	64.763***	0.000
Depreciated tunnel construction cost	354797.39	354321.99	283615.43	330911.60	3.905**	0.022
Depreciated drip pipe installment cost	76135.60	78040.55	78834.63	77146.52	0.303	0.739
Annual interest on loan	82732.35	180822.46	157715.97	148891.90	9.614***	0.000
Total fixed cost	806359.60	859028.39	634011.38	766466.45	18.420***	0.000
Seed	39472.14	41943.25	27145.04	36186.81	4.404**	0.014
Media	10737.94	12647.11	9121.31	10659.62	1.987	0.142
Tillage	29214.20	26663.44	26596.37	27503.43	2.355*	0.099
FYM	121115.72	125865.01	104884.49	117288.41	5.463***	0.005
Chemical Fertilizer	42903.91	30845.26	32755.81	35871.69	5.897***	0.004
Pest management	320782.62	325215.61	289741.75	311913.33	0.298	0.743
Labor	290316.44	301416.34	252112.39	281281.72	1.910	0.152

Intercultural operation	81981.80	126245.94	107326.02	104910.74	2.297	0.104
Other cost (Repair, management and transportation)	370547.33	309152.79	246521.66	308311.50	3.638**	0.029
Total variable cost	1286747.78	1266358.37	1087258.48	1213454.88	2.857*	0.061
Total cost	2093107.38	2125386.76	1721269.85	1979921.33		

Note: *, **, and *** indicate level of significance at 10%, 5%, and 1%, respectively.
Source: Field survey, 2024

3.2.2 Benefit-cost ratio

The average cost of production was NRs. 31.74 per kg of tomato produced. The average production of tomato under plastic tunnel was 16895.23 kg with an average yield of 65916.94 kg per hectare. This was higher than Gautam (2019); but lower than Khan and Khan (2020). The average revenue from tomato production under plastic tunnel in the study area was NRs. 3534466.52 per hectare. This is higher than the findings of Kafle and Shrestha (2017); Khadka and Adhikari (2021), but lower than Pokharel (2021).

The BCR was 1.77, indicating good profitability. This ratio was higher than BCR of 1.5, reported by NARC (2016) for poly-house farming in mid hills, and BCR of 1.34 found by Subedi et al. (2020) for tomato production under open field conditions. Though this was comparable with findings from Kafle and Shrestha (2017); Paudel and Adhikari (2018). Among the municipalities, Tarakeshwar had the highest BCR, followed by Chandragiri and Kirtipur, with no significant differences observed (Table 3)
.

Table 3. Benefit cost analysis of tomato under plastic tunnel

Variable	Chandragiri	Tarakeshwar	Kirtipur	Overall	F-value	p-value
Production in household (kg)	24938.11	13085.31	12662.28	16895.23	5.265***	0.006
Yield (kg/ha)	69982.85	72623.25	55144.73	65916.94	8.044***	0.000
Gross revenue (NRs./ha)	3752480.42	3894058.86	2956860.27	3534466.52	8.044***	0.000
Gross margin (NRs./ha)	2465732.64	2627700.48	1869601.80	2321011.64	7.988***	0.001
Net margin (NRs./ha)	1659373.04	1768672.09	1235590.42	1554545.18	5.135***	0.007
Cost of production (NRs./kg)	31.36	30.68	33.19	31.74	2.286	0.105
BCR	1.79	1.82	1.70	1.77	0.989	0.374

Note: *, and *** indicate level of significance at 10%, and 1% respectively.
Source: Field survey, 2024

3.3 Production function analysis

Table 4 shows the Cobb–Douglas production function for tomato farming under plastic tunnels. The model was highly significant (p=0.000) and explained 42.18% of variation in gross revenue (R^2 = 0.4218; adj. R^2 = 0.3890). Land rent, labor, seed, pest management, and other costs had a positive and significant effect, indicating that a 1% increase in these inputs raises returns by 0.487%, 0.176%, 0.096%, 0.140%, and 0.033%, respectively. Similar results were reported by Subedi et al. (2020); Khadka and Adhikari (2021); Pal (2022), highlighting the importance of efficient input use.

The sum of the estimated coefficients (0.998) indicates near-constant returns to scale in tomato production, suggesting that a proportional increase in all inputs leads to a nearly proportional increase in output. This finding shows slight variation compared to Kunwar and Maharjan (2019), who reported decreasing returns to scale, and Subedi et al. (2020), who found increasing returns to scale.

Table 4 . Production function analysis of tomato production under plastic tunnel

Variables	Coef.	SE	t	P>t
Land rent	0.487***	0.092	5.32	0.000
Labor cost	0.176**	0.068	2.58	0.011
Seed cost	0.096*	0.057	1.69	0.093
FYM cost	0.059	0.093	0.64	0.526
Chemical fertilizer	-0.002	0.003	-0.50	0.620
Pest management cost	0.140***	0.035	4.07	0.000
Tillage cost	0.008	0.022	0.37	0.710
Other associated cost	0.033**	0.014	2.39	0.018
Constant	2.723	1.512	1.80	0.074
Number of observations	150			
F (8,141)	12.86			
Prob>F	0.000			
R-squared	0.422			
Adjusted R-squared	0.389			
Root MSE	0.307			
Return to scale	0.998			
Mean VIF	1.13			

Note: *, **, and *** indicate level of significance at 10%, 5%, and 1%, respectively.
Source: Field survey, 2024

3.4 Resource use efficiency

Table 5 showed that several inputs are underutilized, indicating scope for improving input use efficiency under the current production system. The resource use efficiency ratio was highest for seed cost (10.07), followed by land rent (4.91) and labor (2.25). However, land rent in this context represents the cost of land use rather than a policy variable, and its higher value may also reflect farm size differences rather than a direct recommendation for increased land use. Overall, the results suggest that efficiency gains are possible through better allocation and optimization of existing resources rather than simply increasing input use. The results were consistent with findings by Tambo and Gbemu (2010); Subedi et al. (2020); Anthony et al. (2022).

Conversely, chemical fertilizer (-4.18), and other associated costs (0.39), such as irrigation, mulching, media, transportation, repair and maintenance, and miscellaneous were over utilized. The negative marginal value product of chemical fertilizer indicates that its application has exceeded the economically optimal level, implying that additional fertilizer use reduces gross revenue. This aligns with Ibitoye et al. (2015), but in contrast with Tambo and Gbemu (2010); Subedi et al. (2020); Anthony et al. (2022). These results suggest that, under the current input use pattern, efficiency could potentially be improved through better allocation of resources, particularly by addressing over-utilized inputs such as fertilizer and other associated expenditures, while increasing the use of underutilized inputs that show higher marginal returns.

Table 5. Resource use efficiency of tomato production under plastic tunnel

Cost (NRs. ha^{-1})	GM	Coefficient	MVP	MFC	r	Efficiency
Land rent	325947.45	0.487	4.91	1	4.91	Underutilized
Labor	257945.40	0.176	2.25	1	2.25	Underutilized
Seed	31206.00	0.096	10.07	1	10.07	Underutilized

FYM	112698.85	0.059	1.72	1	1.72	Underutilized
Chemical fertilizer	1181.90	-0.002	-4.18	1	-4.18	Over-utilized
Pest management	234215.70	0.140	1.97	1	1.97	Underutilized
Tillage	23235.22	0.008	1.13	1	1.13	Underutilized
Other associated	283174.02	0.033	0.39	1	0.39	Over-utilized

Source: Field survey, 2024

3.5 Factors affecting revenue

Multiple linear regression identified factors affecting revenue from tomato farming under plastic tunnel (Table 6). The model explained 54% of revenue variation, and the F-test was significant at 1%, confirming predictor relevance. Multicollinearity was not an issue, with a mean VIF of 1.99.

a. *Education*

The schooling years of the household head are positively associated with tomato farm revenue at the 10% significance level, indicating that better-educated farmers tend to achieve higher revenue, likely due to improved decision-making and adoption of better practices. This aligns with Adejoh et al (2010), and Ibitoye et al. (2015).

b. Membership

Membership in farmers' groups positively associated with revenue at the 10% level, suggesting that members tend to achieve higher revenue, possibly due to better access to information and collective benefits. This is consistent with the findings of Mwaura (2014).

c. Extension advisory service

Extension services from the government positively influence revenue, indicating that farmers receiving extension support tend to perform better in terms of revenue. This was in accordance with Ibitoye et al. (2015); Shrestha et al. (2016).

d. Training

Training on plastic tunnel tomato farming is positively and significantly associated with revenue at the 1% level, reflecting better practices and technology adoption among trained farmers. The findings supported the conclusions of Shrestha et al. (2016).

e. Access to agricultural credit

Access to agricultural credit positively and significantly affects revenue at a 5% level. This implies that credit users tend to have higher investment capacity and better farm performance. Shrestha et al. (2016) also reported that easy access to agricultural credit in the eastern high hills of Nepal significantly increase revenue from vegetable farming.

f. Variety

Use of the Srijana variety is positively associated with higher revenue at the 5% level. The higher adoption rate of this variety may be due to its higher yield potential (NARC, 2016), market preference, and suitability for local production conditions, while other varieties are adopted based on seasonal needs and farmer preferences.

g. Irrigation type

Drip irrigation is positively associated with revenue at the 10% significance level, indicating relatively better performance among users. This may be attributed to its efficiency in water use and improved nutrient management through fertigation, as reported by Zhai et al. (2010), and Holmer and Schnitzler (1997).

Table 6. Factors affecting revenue from tomato production under plastic tunnel

Variables	Coefficient	S.E.	t	p-value
Schooling of HHH (Year)	0.008*	0.004	1.83	0.070
Economically active members (No.)	0.026	0.018	1.47	0.144
Membership in farmers group (1=Yes)	0.155*	0.093	1.67	0.096
Extension service from government (1=Yes)	0.142*	0.083	1.72	0.087
Training received (1=Yes)	0.202***	0.076	2.66	0.009
Access to agri. credit (1=Yes)	0.130**	0.052	2.52	0.013

Variety used (1=Srijana)	0.129**	0.051	2.50	0.013
Irrigation type (1=Drip)	0.091*	0.047	1.93	0.056
Constant	14.481***	0.089	163.62	0.000
Number of observation	150			
F(8,141)	21.32			
Prob>F	0.000			
R-squared	0.5474			
Adjusted R-squared	0.5217			
Root MSE	0.2711			
Mean VIF	1.99			

Note: *, **, and *** indicate level of significance at 10%, 5%, and 1% respectively.
Source: Field survey, 2024

4. CONCLUSION

The study concludes that tomato production under plastic tunnel in Kathmandu district is profitable. Results show scope for improving efficiency through better allocation of inputs, with evidence of both underutilization and overutilization of resources. Inputs such as land rent, labor, seed, pest management, and other costs significantly influenced revenue, highlighting the importance of efficient input management. The production system exhibits nearly constant returns to scale. Socioeconomic factors such as education, group membership, extension advisory services, training, access to agricultural credit, improved varieties, and drip irrigation are also positively associated with higher revenue. Overall, the findings suggest that enhancing input use efficiency along with strengthening institutional support and technology adoption can improve profitability of tomato production under plastic tunnel systems in Nepal.

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REFERENCES

Adejoh, S. O., Onuche, U., & Edoka, M. H. (2010). Evaluating the factors influencing the adoption of selected soil management technology by yam farmers Olamaboro LGA of Kogi State, North Central Nigeria. International Journal of Agricultural Economics Management & Development, 1(1), 1-5. Retrieved from www.daeeksu/journal.com

Ali, Q., Ashfaq, M., & Khan, M. T. (2017). An economic analysis of off-season tomato production in Punjab. The Journal of Animal & Plant Sciences, 27(1), 294-301.

Anthony, L., Ajibare, D. B., Alabi, O. O., Njoku, V. O., Ukaoha, C. A., & Oluleye, O. D. (2022, October). Resource use efficiency and profitability analysis of tomato production (Lycopersicum Esculetum Species) in federal capital territory, Nigeria. European Journal of Agriculture and Food Sciences, 4(5). https://doi.org/10.24018/ejfood.2022.4.5.539

Bhatta, S., & Rijal, U. K. (2022, July). An analysis of resource use efficiency of vegetable growers in Chitwan district of Nepal. Nepalese Journal of Agricultural Sciences, 23. Retrieved from https://www.cabidigitallibrary.org/doi/pdf/10.5555/20230329825

Budhathoki, K. (2006). Bajarmukhi, organic ra bemausami tarkari kheti prabidhi [Market oriented organic and off-season vegetable production technology]. Lalitpur, Nepal: Shrimati Basanti Budhathoki.

Costa, M., & Heuvelink, E. (2007). Today's worldwide tomato production. Fruit &veg tech, 14-16. Retrieved from http://refhub.elsevier.com/S2667-0100(21)00108-6/sbref0016

Dhakal, S. C., Regmi, P. P., Thapa, R. B., Sah, S. K., & Khatri-Chhetri, D. B. (2015, December). Resource use efficiency of mustard production in Chitwan District of Nepal. International Journal of Applied Sciences and Biotechnology, 3(4), 604-608. https://doi.org/10.3126/ijasbt.v3i4.13525

FAOSTAT. (2024). Statistical Database. Food and agriculture organization of the United Nations. Retrieved from www.fao.org

Gautam, P. (2019). Economics of tomato production under plastic tunnel technology in peri-urban areas of Kathmandu valley. Nepalese Journal of Agricultural Sciences, 18, 149-156.

Ghimire, A., Aryal, D., Karki, R., Dhital, D., Dahal, M., & Poudel, A. (2023, September). Navigating the economics of production and marketing of tomatoes in Lalitpur, Nepal. Global Scientific Journals, 11(9), 160-168. Retrieved from http://www.globalscientificjournal.com/

Goni, M., Umar, M., & Sman, M. (2013). Analysis of resource-use efficiency in dry season vegetable production in Jere Borno State, Nigeria. J. Bio. and Agri. Health, 3(19), 18-23.

Gujarati, D. N., & Porter, D. C. (2009). Basic Econometrics (5th ed.). McGraw-Hill. Retrieved from https://www.cbpbu.ac.in/userfiles/file/2020/STUDY_MAT/ECO/1.pdf

Holmer, R., & Schnitzler, W. H. (1997). Drip irrigation for small scale tomato production in the tropics. Kasetsart Journal - Natural Science, 32(5), 54-55.

Ibitoye, S. J., Shaibu, U. M., & Omole, B. (2015, January). Analysis of resource use efficiency in tomato (Solanum lycopersicum) production in Kogi State, Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology, 6(4), 220-229. https://doi.org/10.9734/AJAEES/2015/18112

Kafle, A., & Shrestha, L. K. (2017). Economics of tomato cultivation using plastic house: A case of Hemja VDC, Kaski, Nepal. International Journal of Agriculture, Environment and Biotechnology, 2(01). Retrieved from www.ijaeb.org

Khadka, S., & Adhikari, R. K. (2021, January). Comparative economics of tomato production under polyhouse and open field condition in Dhading district of Nepal. Nepalese Journal of Agricultural Sciences, 20, 100-107.

Khan, M. B., & Khan, J. (2020, February). An economic analysis of tunnel farming in enhancing productivity of off-Season vegetables in district Peshawar. Sarhad Journal of Agriculture, 35(1), 153-160. https://doi.org/10.17582/journal.sja/2020/36.1.153.160

Kunwar, B., & Maharjan, B. (2019). Economic analysis of off-season tomato production under poly-house in Okhaldhunga, Nepal. The Journal of Agriculture and Environment, 20, 67-77. https://doi.org/10.3126/aej.v20i0.25012

MOALD. (2025). Statistical information on Nepalese agriculture 2080/81 (2023/24). Singhdurbar, Kathmandu: Government of Nepal. Retrieved from https://moald.gov.np/content/307/statistics-information-on-nepalese-agriculture-2080-81/

Mwangi, W. J. (2012). Comparative analysis of greenhouse versus open-field small scale tomatoproduction in Nakuru-North District, Kenya. Egerton University, Deptt.of Agri. Econ. and Agribusiness Management, Kenya.

Mwaura, F. (2014). Effect of farmer group membership on agricultural technology adoption and crop productivity in Uganda. African Crop Science Journal, 22(s4), 917-927.

NARC. (2016). Srijana hybrid tomato: A potential technology for enterprise development in Nepal. Socioeconomics & agricultural research policy division. Khumaltar, Lalitpur, Nepal: Nepal Agricultural Research Council (NARC). Retrieved from http:// www.narc.gov.np

NMDP. (2015). Vegetable sector in Nepal: Rapid post earthquake market analysis. Kathmandu, Nepal: SAMARTH-NMDP.

NSO. (2024). National population and housing Census 2021, Population composition of Nepal. Thapathali, Kathmandu: Government of Nepal, National Statistics Office. Retrieved from https://censusresults.nsonepal.gov.np

Okello, D. M., Wabbi, J. B., & Mugonola, B. (2019). Farm level allocative efficiency of rice production in Gulu and Amuru districts, Northern Uganda. Agricultural and Food Economics, 19. https://doi.org/10.1186/s40100-019-0140-x

Otieno, D. J., Hubbard, L., & Ruto, E. (2012). Determinants of technical efficiency in beef cattle production in Kenya. Paper presented at the International Association of Agricultural Economist (IAAE) Triennial Conference. Foz do Iguacu, Brazil.

PACT. (2014). Value chain development plan for tomato. Kathmandu, Nepal: Government of Nepal, Ministry of Agricultural Development, Project for Agriculture Commercialization and Trade (PACT).

Pal, S. K. (2022, June). An economic analysis of tunnel tomato farming in Chandragiri Municipality, Kathmandu. Master's thesis, Tribhuvan University. Retrieved from https://elibrary.tucl.edu.np

Paudel, A. (2022). Economic analysis of honeybee production and marketing in Myagdi District, Nepal. Unpublished Master's Thesis, Agriculture and Forestry University, Department of Agricultural Economics and Agribusiness Management, Rampur, Chitwan, Nepal.

Paudel, P., & Adhikari, R. K. (2018). Economic analysis of tomato farming under different production system in Dhading district of Nepal. Nepalese Journal of Agricultural Sciences, 16.

Pokharel, A. (2021). Economic analysis of offseason tomato production in Kathmandu, Nepal: A study of Nepalese tomato growers. [Bachelor degree thesis]. Centria University of Applied Sciences.

Shrestha, R. B., Huang, W. C., Gautam, S., & Johnson, T. G. (2016, April). Efficiency of small scale vegetable farms: Policy implications for the rural poverty reduction in Nepal. Agricultural Economics (AGRICECON), 62(4), 181-195. https://doi.org/10.17221/81/2015-AGRICECON

Subedi, M., Pandey, M., Ojha, R. K., & Acharya, B. (2020). Production economics and resource use efficiency of tomato under open field condition in Kapilvastu, Nepal. Journal of Agriculture and Natural Resources, 3(1), 282-289. https://doi.org/10.3126/janr.v3i1.27181

Tambo, J. A., & Gbemu, T. (2010). Resource-use efficiency in tomato production in the Dangme West District, Ghana. Paper presented at the Conference on International Research on Food Security, Natural Resource Management and Rural Development. ETH Zurich: Tropentag.

Usman, M., Ashfaq, M., & Ali, I. (2013). An economic analysis of staticecut-flower production in Punjab, Pakistan. J. Agri. Sci., 50(2), 311-315.

Yamane, T. (1967). Statistics, An introductory analysis (2nd ed.). New York: Harper and Row.

Zhai, Y. M., Shao, X. H., Xing, W. G., Wang, Y., Hung, T. T., & Xu, H. L. (2010). Effects of drip irrigation regimes on tomato fruit yield and water use efficiency. Journal of Food, Agriculture & Environment, 8(3), 709-713. Retrieved from www.world-food.ne

POLITICAL ECONOMIC ANALYSIS OF DAIRY SECTOR IN NEPAL: POWER AND STRUCTURAL DIAGNOSIS.

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ABSTRACT

Nepal's annual milk production is growing by 4–5%, but domestic market demand is increasing by 9–10% over the last decade, creating a potential demand–supply gap in the dairy sector. This study adopts a qualitative Political Economy Analysis framework to examine the structural and political economy factors that determine how power relations, institutional arrangements, and stakeholder interests interact to shape policy outcomes and sectoral governance. The Constitution of Nepal 2015 along with relevant policy documents, legislative instruments, and regulatory frameworks governing the dairy sector were analysed. The study reveals that constitutional authority over food safety, technology, and nutrition has been distributed among federal, provincial, and local governments, leading to complex governance challenges. The dairy sector is struggling with institutional ambiguities, overlapping mandates, coordination gaps, and weak implementation. Federalization has diluted accountability, with local and provincial governments lacking adequate technical manpower to fulfil their mandated roles. The study recommends redefining the roles and responsibilities of government agencies at all levels, enacting a unified dairy governance framework, and fostering policy dialogue to create a business-friendly environment that ensures every citizen benefits from the dairy sector's potential and contributes to national prosperity.

1. INTRODUCTION

Agriculture is a crucial livelihood option in a developing country and the country's developing economy. In developing countries, contribution of agriculture to GDP varies from 15-35% (World Bank, 2023), while in developed nations, it ranges from 1-3% (USDA, 2023; EUROSTAT, 2023). The contribution of dairy sector to a country's GDP in developing countries is between 0.5-4% (Kenya Dairy Board, 2023; NDDB, 2023), compared to 0.2-1.5% in developed economies (European Dairy Association, 2023). Nepal, despite being an agrarian country, has experienced a significant decline in agriculture's share of Gross Domestic Product (GDP) over the past decade, indicating structural economic change. The contribution of agriculture to GDP was 35.8% in 2010/11, decreasing to 21.1% in 2023/24 (MoF, 2024). In addition to that, the percentage of the population involved in agriculture decreased from 71% in 2008 to 60.4% in 2018 (NLFS III, 2018) and further to 51.3% in 2022 (CBS, 2018; MoALD, 2023). Dairy sector is Nepal's second-largest agricultural sector, constituting 63% of livestock GDP (Heifer International Nepal, 2023).

Although the formal dairy industry has a nearly 70-year history in Nepal, the formal milk industry was started with the establishment of Dairy Development Corporation (DDC) in 1969, which assures a market and fair price for milk-producing farmers and quality products to consumers (FAO, 2010). Over time, different government institutions like the National Dairy Development Board (NDDB) (Government of Nepal, 1992), along with milk cooperatives and their associations, private dairy associations, etc., have been established.

From the beginning to the early 2000s, DDC's market share was very high, accounting for nearly 45% of milk collection and over 60% of the formal market (Acharya & Basnet, 2009; Sharma, 2017). Since the 1990s, the private sector has entered the dairy industry, and over the last decade, they have dominated the dairy industry (Singh *et al.*,2020).

Currently, annual milk production is experiencing a 4-5% of annual growth, and domestic market demand has been increasing by 9-10% in last decade, which creates a potential gap for investment in this sector. For a few years, the export potential of dairy products, especially dog cheese (Chhurpi), has been increasing enormously, supporting in trade balance of the country (Pant et al., 2023). Despite its potential for growth, dairy sector in Nepal is still facing numerous challenges. The dairy sector in Nepal is characterized by low productivity and seasonal production. Nepal experiences two distinct dairy production periods—the flush and lean seasons. The flush season, which lasts from August to February, results in an oversupply of milk, whereas the lean season is characterised by reduced production. The production ratio between the two is roughly 1:3.

Although The Constitution of Nepal, 2015, has clearly distributed the power of Federal, Provincial, and Local Government regarding Food Safety, Technology, and Nutrition (FSTN), the institutional development, predominantly provincial and local level is primitive. Schedule 10.1.5 of the Constitution of Nepal 2015 mentions that the local level has the power of "Inspection and regulation of price and quality of locally produced goods and services," but there is a lack of technical manpower for quality assurance at the local level. Furthermore, many locally produced foods are not listed by DFTQC, and many of these products lack quality standards. Local producers and processors are unaware of legal standards and other regulatory frameworks (MoALD, 2019; DFTQC, 2020; FAO, 2017). Most of the local governments are unaware of their power and responsibilities on FSTN and in the meantime provincial institutions are new and majority of province FSTN policy haven't been tabulated till date (MoALD, 2023).

In the trajectory of political transformation of Nepal in the last decade, constitutional authority of food safety, technology, and nutrition has been distributed between federal, provincial, and local government (Constitution of Nepal,2015), giving rise to complex governance challenges. The political economies of the dairy sector are struggling with institutional ambiguities, coordination gaps, and implementation challenges. The study examines the structural and political economy factors that determines how power relations, institutional arrangements, and stakeholder interests interact to shape policy outcomes and sectoral governance (Harris, 2013).

2. METHODOLOGY

2.1 ***Analytical framework***: For this research, a qualitative framework for Political Economy Analysis (PEA), according to Harris (2013), is used. The framework of Political Economy Analysis consists of four related analysis stages: (i) structural analysis, where the historical, economic, and social structure of the context influencing sectoral outcomes are analysed; (ii) institutional analysis, where the legal and informal rules, values, norms, and organizations guiding the behaviour of the actors are examined; (iii) actor analysis, which entails identifying actors in the sector and analysing their interests, incentives, and power relative to each other; and (iv) process analysis, where the way these three components interact in bringing about certain policy outcomes is traced. PEA investigates relationships of accountability between the government and its citizenry, uncovers governance-related structural issues, and power relations between actors

2.2 Data sources:

This study relies exclusively on secondary data sources. The primary legal and policy documents analysed include: the Constitution of Nepal (2015); the Food Act (1967) and Food Rules (1970); the Food Hygiene and Quality Act (2024); the Dairy Development Policy (2021); and the Agriculture Development Strategy 2015–2035. Institutional reports consulted include the Statistical Information on Nepalese Agriculture (MoALD, 2023), the Dairy Diary 2024 (NDDB, 2024), and the DDC Annual Report 2023/24. International frameworks referenced include the Codex Alimentarius standards, FAO Nepal Country Reports, and OECD/IDF dairy sector analyses. Regulatory instruments such as the Directives on Safety and Quality of Milk and Milk Products (2018), the Code of Practice for Dairy Industry (NDDB, 2004), and the Stakeholder Engagement Plan of the REED Project (MoALD, 2022) were also reviewed.

1. RESULTS AND DISCUSSION:

3.1 Overview of Nepal's dairy sector:

Over the last ten years, the dairy sector has experienced significant growth, with a 70% increase in production from 1,700 million tons of milk in 2014/15 to an estimated 2900 million tons in 2023/24 (MoALD, 2023/24). More than 1,700 primary milk producers and cooperatives play a vital role in channelling milk produced by smallholder farmers into the formal milk market. Nepal's dairy sector is highly localized. The dairy sector of Nepal is emerging, but its share of global milk production is minimal at 0.247 percent (CASA, 2020). Out of 3.8 million farming households in the country, 95% have dairy animals, but only about 14% of milk-producing households (around 500,000) are both producers and sellers (UK Aid, April 2020). Out of the total milk produced, only 17% enters the formal sector, nearly 35% goes to the informal market, and the remaining is used within households (MoALD, 2023).

3.1.1 Dairy cooperatives of Nepal:

Cooperatives "an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise" (ILO, 2002). Milk Cooperatives are dedicated cooperatives which primarily functions in dairy value chain. In Nepal are total 781 Milk Cooperatives or milk collection centres that are actively collecting milk, with an average daily collection of 6.26 lakhs litres (NDDB, 2024). Them seems contradictory in the number of milk cooperatives as always.

3.1.2 *Dairy industries of Nepal:*

At the same time, there are 316 milk processing plants or industries with the total installed daily processing capacity of 15.05 lakh litres per day, but these processing plants are operating at 57% of the installed capacity, i.e., 8.67 lakh litres. In addition, there were 34 cheese plants, 25 chhurpi plants, and 33 cooperatives or unions running their own milk processing plants (NDDB, 2024). Among these dairy industries and plants, most of them are operating without a license from DFTQC. Government-owned Dairy Development Corporation (DDC) operates 8 processing plants, 65 chilling centres, 10 yak cheese centres, 7 Kanchan cheese centres, and 6 paneer/mozzarella production centres across 47 districts in Nepal (NDDB, 2024).

3.1.3 Demand-supply scenario of finished products

According to the National Dairy Development Board (NDDB), the estimated annual growth in demand for milk and dairy products is 11% (NDDB, 2020). The total requirement of milk in Nepal per person per year is 91 liters, but the production of milk is only 88 liters per person on a yearly basis (Chapagaee et al., 2024). Although the Ministry of Agriculture and Livestock has declared self-sufficiency in milk along with milk powder, the shortfall is reflected in the trade balance too, with Nepal importing an estimated 20000 metric tonnes of dairy products annually, while in the meantime exporting only 5000 metric tonnes (IndexBox, 2026).

3.2 Political economic analysis:

3.2.1 Constitutional framework:

The Federal Constitution of Nepal (2015) has mentioned the clear provision on Food, Right to Food (Clause 36A), Right to Food Security

(Clause 36B), Right to Food Sovereignty (Clause 36C), and also the right to consume quality Food to every citizen (Clause 44A and 44B).

The constitution of Nepal, 2015, has distributed the subject of Power of food safety and quality governance across three government tiers;

3.2.1.1 Subject of the power as per constitutions of Nepal:

Local Government:

- Local Market management
- Local Trade/commerce, demand/supply, market management and inspection; implementation and regulation of policy
- Legislation and standards related to consumer rights and protection
- Inspection and regulation of price and quality of locally produced goods and services
- Local Market management
- Local Trade/commerce, demand/supply, market management and inspection; implementation and regulation of policy
- Legislation and standards related to consumer rights and protection
- Inspection and regulation of price and quality of locally produced goods and services
- Registration, permits, renewal, revocation, and regulation of commercial firms at the local level
- Promotion, facilitation, and regulation of local business
- Consumer awareness, data management of targeted consumers, and quality testing of locally produced goods and services

Provincial Government:

- Implementation and regulation of provincial agriculture, livestock, and food nutrition-related policy, legislation, and standards
- Implementation and regulation of provincial agriculture, livestock, and food nutrition-related policy, legislation, and standards
- Agricultural industrialization, development, and promotion of livestock-based industries and trade
- Provincial food security, food rights, and food sovereignty
- Agriculture, livestock, and food technology-related study, research, development, and promotion
- Development and management of Provincial Labs for the agriculture, livestock, and food sector

Federal Government:

Policy, legislation, and standards implementation and regulation of quality and safety related to food quarantine

An analysis of these constitutional clauses shows that there is indeed a careful yet sophisticated hierarchical structure of governance that has been developed within the Constitution. While it is true that the federal government has general control over the food quarantine regulations and other national issues, the Constitution does give substantial powers to the local governments to regulate and oversee all issues related to food safety and management of the markets as well as protecting consumers. In between these two extremes, the provincial governments act as an intermediary that is supposed to implement, conduct research, and ensure the food security at the provincial level. This hierarchy of powers is important for analysing the dairy governance, since this hierarchical structure makes sure that there is no single tier in the governance hierarchy that will have full authority over the dairy business.

3.2.2 Policy/Legislative framework and regulatory instruments:

The dairy sector of Nepal is guided by a comprehensive policy framework mainly aimed at increasing production and productivity, along with market competitiveness. Dairy Development Policy 2021 serves as the primary guiding document for the dairy sector, which has a long-term vision of contributing to national economic development through employment generation and poverty reduction by producing quality milk and dairy products (MoALD, 2021). Building upon the National Agriculture Policy

2004, which aims to transform subsistence agriculture to commercial one Agriculture Development Strategy (ADS) 2015-2035 serves as master plan for Nepal's agricultural development, aiming to transform Nepal from a net food importer to a net food exporter by achieving 6% annual agricultural growth and generating a 0.5% trade surplus by 2035 (MoALD, 2015). Major Policies, their governing institutions, provisons and gaps are listed in the table.

Table 1: Policy Mapping and Gap Analysis of Nepal's Dairy Sector Governance Framework

Policy/Legislation	Governing Institution(s)	Key Provisions	Identified Gaps
Constitution of Nepal	Federal, Provincial & Local Governments	FSTN powers distributed among three levels; ensures food rights (Arts. 36A-C, 44A-B).	Overlapping jurisdictions; lack of intertier coordination mechanism; local governments unaware of FSTN's jurisdiction; no dairy governance provision in constitution.
Food Act (1967) / Food Hygiene & Quality Act (2024)	DFTQC / MoALD	Legislation for food safety; licenses; more stringent penalties (Act of 2024); labelling provisions in Nepali/English languages.	Many locally produced dairy products are not registered with DFTQC; poor enforcement at provincial/ local level; delay in replacing 1967 Act took 57 years.
Dairy Development Policy (2021)	MoALD / NDDB	Provides guidelines for national dairy development; promotes job creation, poverty alleviation, and production of good quality milk.	No implementation mechanism; provincial level dairy policy virtually non-existent; NDDB does not have enforcement powers.
Agriculture Development Strategy (ADS) 2015–2035	MoALD (master plan)	Make Nepal an exporter rather than an importer of foods; 6% yearly growth in agriculture; 0.5% trade balance surplus till 2035.	Aspirational in terms of specific dairy targets; lacking sector specific dairy sub strategy; slow progress on commercialisation.
Directives on Safety & Quality of Milk and Milk Products (2018)	DFTQC / DLS	Functions of milk handlers/operators; manpower needs for quality assurance in the dairy industry.	Low compliance rate; majority plants do not possess license from DFTQC; lack of qualified manpower; overlap between DFTQC and DLS creates ambiguity.
Animal Health & Livestock Services Act (1998) & Regulations (1999)	DLS / Animal Quarantine Offices	Controls import/export of livestock; quarantining of animals; health and safety of animal products.	Overlap with DFTQC in case of food safety; limited coordination with NDDB; not reflective of federal structure of governance.
NDDB Act (1992) / Code of Practice for Dairy Industry (2004)	NDDB (coordination between public and private sector)	Standardisation of milk/milk products (organoleptic, COB, alcohol, FAT/SNF, adulteration, phosphate, microbial testing).	NDDB functions only in advisory capacity; no powers of enforcement; parallel standards with DFTQC creates confusion for cooperatives.

Note: FSTN = Food Safety, Technology, and Nutrition; MoALD = Ministry of Agriculture and Livestock Development; DFTQC = Department of Food Technology and Quality Control; NDDB = National Dairy Development Board; DLS = Department of Livestock Services; ADS = Agriculture Development Strategy.

Source:Review of the Constitution of Nepal (2015), Dairy Development Policy (2021), Agriculture Development Strategy 2015–2035, Directives on Safety and Quality of Milk and Milk Products (2018), Animal Health and Livestock Services Act (1998) and Regulations (1999), and NDDB Act (1992) / Code of Practice for Dairy Industry (2004)

Besides the above-mentioned domestic policy, rules, and regulations, Nepal is also bound by international rules and regulations too. Nepal is a member of the following international organizations that affect the food safety-related policy, rules, and regulations.

- Codex Alimentarius Commission
- World Trade Organization (WTO)
- Food and Agriculture Organization (FAO) of the United Nations (UN)
- South Asian Association for Regional Cooperation (SAARC)
- World Organization for Animal Health (OIE)
- Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC).

3.2.3 Power dynamics and stakeholder mapping/analysis:

The Ministry of Agriculture and Livestock Development (MoALD) is the apex government body in Nepal which oversees various departments, boards, committee etc which are directly involved in technical backstopping; quality control along with standardization of agriculture and dairy products. MoALD mainly responsible for formulating national policies, rules, regulations and laws, directives etc. It provides technical backstopping as well as lead overall country’s agriculture (Dhungana *et al.*,2024).

At the provincial level, each Provincial Government have Provincial Ministry of Land Management, Agriculture and Cooperatives (PMoLMAC) which formulate provincial level laws, rules, regulations, policy, directives etc by taking National policies, rules, regulations, laws, directives as a guiding principle. Likewise, MoALD, these ministry works through Directorates related to agriculture and livestock; till date no any provincial government have created Directorate or any agency which directly look after food quality and standardization sector (Ministry of Land Management, Agriculture and Cooperative, 2026).

Major institutions involved in Quality Control and Standardization are :

Department of Food Technology and Quality Control (DFTQC):

The Department of Food Technology and Quality Control, established in 1961, is the authority responsible for enforcing regulations related to food safety and quality management to ensure the availability of safe, high-quality food. It has the power to conduct inspections, issue licenses, keep records, serve as the SPS inquiry point, standardize, certify for export and import, and implement awareness programs, along with technology development and training. DFTQC has developed 24 legal and quality standards for milk and milk products (DFTQC, 2020). It operates through eight regional or provincial offices, 12 Food Import-Export Quality Certification Offices, and 22 division offices.

National Dairy Development Board (NDDB)

National Dairy Development Board (NDDB) is established to make dairy production business much stronger by bringing about harmony between the private sector and the government sector, by formulating a policy on dairy business at the national level, and by formulating a development plan relating to it. It was established by the Government of Nepal in 1992 under a separate Act based on the recommendation of “Ten Year Dairy Development Plan (1991-2000)”. NDDB has established the Code of Practice for Dairy Industry 2061 (2004), which directs six criteria for the standardization of milk and milk products, such as the Organoleptic test, COB test, Alcohol Test, FAT and SNF test, Adulteration test, Phosphate test, and microbial and coliform test (NDDB, 2004).

Department of Livestock Services (DLS)

Department of Livestock Services (DLS) is mainly involved in the growth of livestock development in the country, thereby enhancing the economic and social lifestyle of rural people. DLS mostly engages in animal health management; quarantine and trade regulation; genetic resource conservation and promotion; policy &regulatory framework development; production and productivity enhancement; extension and services. Directives on Safety and Quality of Milk and Milk Products 2018 have clearly given regulatory roles to DLS on food safety, quality, and promotions. Besides these, DLS also implements dairy-related projects funded by different donor agencies.

Provincial Directorates of Livestock and Fisheries Development:

It is mainly involved in livestock extension; animal health along with breed improvement and production enhancement. Besides this it also provides technical assistance to dairy farmers within their jurisdiction.

In addition to the above-mentioned institutions, the Provincial-level dairy development board, Dairy Development Corporation (DDC), Private dairies, Private dairies association, Milk Cooperative, and their union are also working as per their rules and regulations in the dairy sector.

Nepal Rural Economic and Enterprise Development Project (REED) have suggested that stakeholder engagement/mapping can be distinguished into four parts into four parts (MoALD, 2022) in their Stakeholder Engagement Plan (SEP):

1. High Influence; high interest (Manage closely)
2. High Influence, low interest (Keep satisfied)
3. Low Influence, high interest (Keep informed)
4. Low Influence and Low Interest (Monitor)

Mainly there are three tiers of stakeholders' Primary stakeholders (directly engaged in input supply, production, collection, processing and packaging, and domestic trading (wholesaling/ retailing)); Secondary Stakeholders who are engaged in enabling the dairy business (MoALD, DFTQC, NDDB, DLS, Provincial Ministries, Local Government, Development Agencies) and its constitute; Tertiary Stakeholders who are not directly involved but work as a watchdog (Nepal Consumers Societies, Political Parties, Education Institutions, Media) (MoALD, 2022).

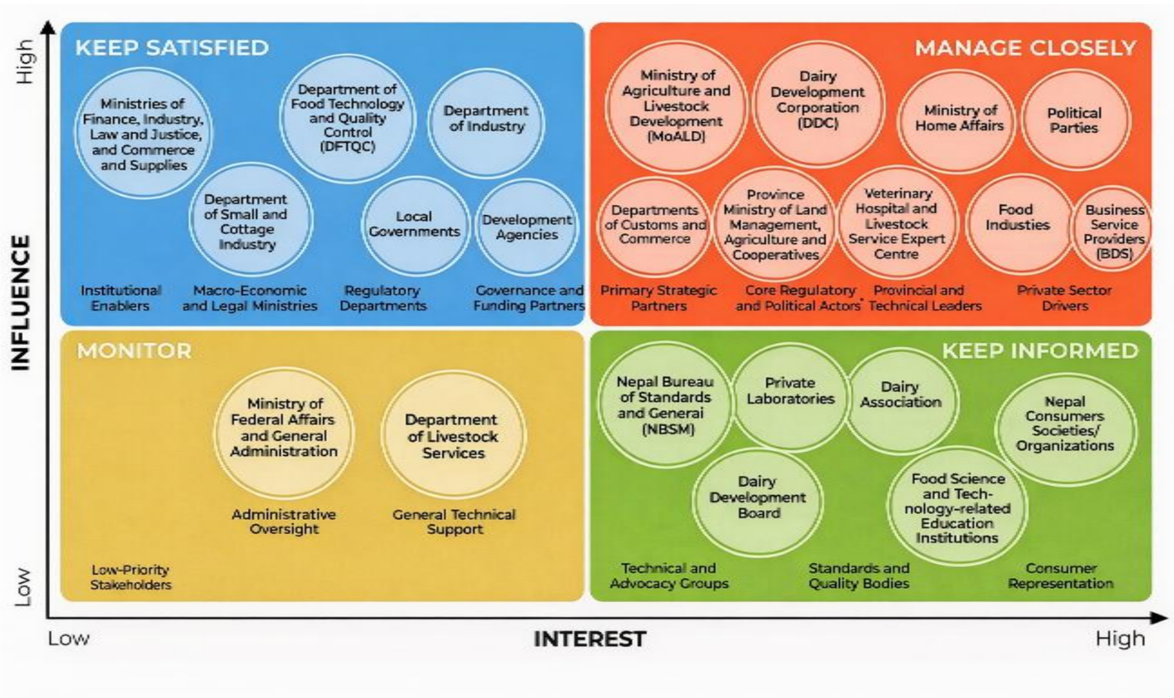

Figure 1: Stakeholders' Mapping (Source: MoALD, 2022)

Analysis of the distribution of powers among the various stakeholders of the dairy sector demonstrates considerable overlap in their mandates and coordination gaps. Each organization – including MoALD, DFTQC, NDDB, and DLS – has a specific mandate; however, the jurisdictions of these organizations converge around common roles such as quality control, licensing, and standard setting. For example, the role of DFTQC includes licensing and inspections at all milk processing plants; on the other hand, NDDB makes its own Code of Practice for cooperatives. DLS is responsible for livestock services and animal health, while simultaneously playing a role in formulating the dairy food safety directive. Such overlap leads to a situation in which a particular milk producer must approach several different agencies for the same approval process.

Another dimension that influences power dynamics in the dairy industry comes from varying ability and power to influence among actors' groups. The central government and ministries continue holding more legitimacy and expertise; however, their power remains weak at local levels. The provincial government, which has just been formed due to federalism, lacks the necessary bureaucratic machinery and skilled individuals capable of performing functions defined for them constitutionally and find themselves disadvantaged despite being on equal grounds formally. Privately owned dairy companies enjoy a lot of financial muscle and take part in policy making processes through their lobby organizations, having the power to influence pricing policies and rules for accessing markets. Dairy farmer cooperative societies, although many, find themselves with less bargaining power individually but somewhat strong collectively. The disparity in resources held by private actors and small-scale farmers remains one of the major factors perpetuating value chain inequities.

There are areas where there could be some potential for coordination and cooperation, but these areas have been under-utilized. For instance, the National Dairy Development Board had been established as a coordination agency between public and private stakeholders in the sector, but it is a body without enforcement power and functions largely in an advisory capacity. While there are inter-ministerial coordination arrangements within MoALD, the Ministry of Industries, and the Ministry of Health for such cross-sectoral challenges as food safety, labeling and inspection, and importation, the level of inter-agency coordination and cooperation still appears to be insufficient. The work of development partners and international organizations like the FAO, and donor-driven projects like the REED program, has certainly contributed to bridging some gaps in the area of coordination, but clearly the dependency on donors makes this approach unsustainable.

4. CONCLUSION:

The Constitution of Nepal (2015) and related food legislation clearly define stakeholder roles and rights, yet implementation remains critically poor. Post-federalization, agricultural responsibilities are fragmented across three government tiers, creating accountability gaps, while local and provincial governments lack the technical capacity to execute their mandates effectively. Decades of political transition have kept food safety and quality standards deprioritized, leaving Nepal governed by a new constitution but largely operating under outdated laws—only recently addressed through the Food Hygiene and Quality Act (2024)—compounded by institutional ambiguity that forces dairy enterprises to navigate multiple agencies for a single approval. To bridge these gaps, inter-agency coordination among DFTQC, DoA, DLS, NCS, and NBSM must be strengthened, local governments equipped with adequate technical resources, and production-site inspections rigorously enforced. Given consumers' willingness to pay premium prices for quality dairy products, parallel investment in hygiene standards, distribution infrastructure, and consumer awareness is essential, alongside further research into price sensitivity across specific quality attributes.

REFERENCES

Acharya, B. H., & Basnet, M. B. (2009). *Supply chain challenges in Dairy Development Corporation, Nepal*. Master's thesis, Molde University College.

CASA. (2020). *Nepal dairy sector analysis.* Centre for Agriculture and Sustainable Agriculture.

CBS. (2018). *National Population and Housing Census 2011* (Revised). Central Bureau of Statistics, Government of Nepal.

Chapagaee, P., Kunwar, A., Bist, D. R., & Khatri, L. (2024). *Socioeconomic impact of livestock farming: A case study of Baitadi and Darchula districts, Nepal.* International Journal of Applied Sciences and Biotechnology, 12(3), 166–179. https://doi.org/10.3126/ijasbt.v12i3.70155

Constitution of Nepal. (2015). *The Constitution of Nepal*. Government of Nepal.

DDC. (2024). *Annual report 2023/24.*Dairy Development Corporation, Nepal. Retrieved April 11, 2026, from www.ddc.gov.np

DFTQC. (2020). *Quality standards for milk and milk products*. Department of Food Technology and Quality Control, Government of Nepal.

Dhungana, J., Gauchan, D., Timsina, K. P., & Panta, H. K. (2024). *Insight into policy provisions and their gaps for dairy sector development in Nepal.* Journal of Agriculture and Food Research. https://doi.org/10.1016/j.jafr.2024.101134

European Dairy Association. (2023). *Annual report 2023*. European Dairy Association.

EUROSTAT. (2023). *Agricultural GDP Statistics 2023.* European Union.

FAO. (2010). *Dairy sector study of Nepal.* Food and Agriculture Organization of the United Nations. Retrieved February 15, 2026 from https://un.info.np/Net/NeoDocs/View/3388

FAO. (2017). *Nepal and FAO: Building food and nutrition security through sustainable agricultural development*. Food and Agriculture Organization of the United Nations. Retrieved February 15, 2026 from https://un.info.np/Net/NeoDocs/View/11171

GoN. (1992). *National Dairy Development Board Act, 1992 (No. 16 of 1992)*. Nepal Law Commission. Government of Nepal.

GoN. (2018). *Muluki Civil Code, 2074 (2018) and Muluki Criminal Code, 2074 (2018)*. Nepal Law Commission. Government of Nepal

GoN. (2024). *Food Hygiene and Quality Act, 2081 (2024).* Nepal Law Commission. Government of Nepal

Harris, D. (2013). *Applied political economy analysis: A framework.* Overseas Development Institute (ODI)

Heifer International Nepal. (2023). *Dairy sector report 2023.* Heifer International Nepal.

ILO. (2002). *Recommendation concerning promotion of cooperatives (R193)*. International Labour Organization. https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:R193

IndexBox. (2026). *Nepal - dried milk - market analysis, forecast, size, trends and insights*. Retrieved April 11, 2026, from https://www.indexbox.io/store/nepal-dried-milk-market-analysis-forecast-size-trends-and-insights/

Kenya Dairy Board. (2023). *Annual dairy industry report 2023.* Kenya Dairy Board.

Ministry of Land Management, Agriculture and Cooperative, Bagamati Province. (2024, March 15). *Functions of the ministry*. Government of Bagamati Province. Retrieved April 11, 2026 from http://molmac.bagamati.gov.np/en/about/functions/

MoALD. (2015). *Agriculture Development Strategy (ADS) 2015-2035.* Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. (2019). *Statistical information on Nepalese agriculture*. Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. (2021). *Dairy Development Policy 2021.* Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. (2022). *Stakeholders' engagement plan*. REED Project, Ministry of Agriculture and Livestock Development. https://reed.moald.gov.np/downloadfiles/Stakeholders-Engagement-Plan-1663480165.pdf

MoALD. (2023). *Statistical information on Nepalese agriculture 2022.* Ministry of Agriculture and Livestock Development, Government of Nepal.

MoF. (2024). *Economic Survey 2023/24.* Ministry of Finance, Government of Nepal

NDDB. (2004). *Code of practice for Dairy Industry 2061 (2004).* National Dairy Development Board, Nepal.

NDDB. (2020). *Demand growth estimates for milk and dairy products.* National Dairy Development Board, Nepal.

NDDB. (2023). *Annual report 2023.* National Dairy Development Board, Nepal.

NDDB. (2024). *Dairy Diary 2024.* National Dairy Development Board, Nepal.

NLFS III. (2018). *Nepal Labour Force Survey III (2017/18).* Central Bureau of Statistics, Government of Nepal.

Pant, R., Paswan, V. K., Kanetkar, P., Bunker, D. S., Rose, H., & Bakshi, S. (2023). *Exploring trade prospects of Chhurpi and the present status of Chhurpi producers and exporters of Nepal*. Journal of Ethnic Foods,10(1). https://doi.org/10.1186/s42779-022-00165-0

Sharma, B. (2017). *Milk Marketing and Dairy Value Chain Development in Nepal in Relation with Climate Resilience Effort in the Present Context.* Nepalese Veterinary Journal, *34*, 144-151.

Singh, S., Kalwar, C. S., Poudel, S., Tiwari, P., & Jha, S. (2020). A study on growth and performance of dairy sector in Nepal. *International Journal of Environment, Agriculture and Biotechnology*, *5*(4). https://doi.org/10.22161/IJEAB.54.36

UK Aid. (2020). *Nepal dairy value chain assessment.* United Kingdom Aid.

USDA. (2023). *Agricultural GDP statistics 2023.* United States Department of Agriculture.

World Bank. (2023). *World Development Indicators: Agriculture, forestry, and fishing, value added (%of GDP).* The World Bank

SURVEY OF GINGER RHIZOME FLY AND ASSOCIATED RHIZOME ROT IN MAJOR GINGER PRODUCING DISTRICTS OF NEPAL

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ABSTRACT

Ginger rhizome fly, Mimegralla coeruleifrons (Macquart,1884) is one of the major insect pest of ginger. This study was conducted to identify the major ginger pest problems across seven major ginger-growing districts of Nepal: Ilam, Dhankuta, Sindhuli, Syangja, Palpa, Gulmi, and Salyan. The study employed a dual-approach survey involving 70 randomly selected households in coordination with Agriculture Knowledge Centers and Agriculture Development Sections of the local government of Koshi, Bagmati, Gandaki, Lumbini and Karnali provinces. The survey focused on farmer-reported pest problems, including collection and analysis of five sample plants per farm to record M. coeruleifrons incidence, rhizome rot and their association. The average cultivated land of the study household was 1.03 hectare of which 0.16 hectare was allocated for ginger production. Descriptive statistical analysis revealed that insect pests and diseases were the major production barriers as reported by 68.57% of farmers. Rhizome fly, rhizome rot and their combined infestation recorded 15.17%, 30.68% and 54.13%, respectively. The findings indicate pest and disease pressure reducing the potential healthy yield from 28.62 t/ha to 14.59 t/ha and underscores a significant economic gap requiring integrated management strategy for both rhizome fly and rot complex to stabilize ginger production in the mid-hills of Nepal.

1. INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is a high value spice in the global market (FAO, 2023). It is a commercially valuable and exportable commodity and extensively grown in mid-hills of Nepal (GRP, 2023). In Nepal, ginger is grown in an area of 22,430 ha with an annual production of 2,89,330 metric tonnes (MoALD, 2025). Ilam is a leading district followed by Salyan , Palpa, Udayapur, Doti, Panchthar, Morang, Nawalparasi, Sindhuli and Rolpa, respectively, which cover about 50% of the total ginger cultivated area and production in the country (MoALD, 2025). Nepal (with 287.81 million metric tonnes of ginger shares 5.93% of global ginger production) and stands in the fourth position in global ginger production after India (45.73%), Nigeria (15.32%) and China (13.51%) (FAO, 2023). In Nepal, average productivity of ginger (12.83 t/ha) is very low. The ratio of rhizome seed to rhizome production is only 1: 3.21 but has potentiality to 1:7.5 (GRP, 2023). Ginger rhizome fly, white grub, red ant, ginger shoot borer, leaf roller and termites are the important insect pests responsible for reducing the quality and quantity of rhizome production (Sah et al., 2001; Sharma et al., 1998; Gautam & Acharya, 2014).

Among the insect pests, ginger rhizome fly, *Mimegralla coeruleifrons* (Macquart,1884) (Micropezidae: Diptera) is a dominant oligophagous pest of plant species under family Zingiberaceae (Ghorpade et al., 2008).) The fly is endemic, which resulted in 31.00% reduction in ginger yield in India (Ghorpade et al., 1983). Surveys conducted in Kerala revealed *M. coeruleifrons* as the most common pest occurring in ginger rhizomes and 26.4% of the diseased rhizome samples examined contained maggots (Koya, 1988). Sonatakke (2000) reported that 41.00% of the unprotected crop in Orissa, India was damaged *by M. coeruleifrons*. In Nepal, the fly is reported as a serious pest causing 25.00 to 31.12% infestation in the standing ginger crop and also causes rotting of the rhizome (Sharma et al., 1998; Gautam & Acharya, 2014). The occurrence and severity of the pest keeps changing across year and agroclimatic condition (Baral et al., 2021). The environmental conditions remain different across the districts and accordingly the pest occurrence and infestation. This survey was conducted across seven ginger growing districts to know the major pests and reducing ginger production in Nepal.

2. MATERIALS AND METHODS

The study was carried out following dual-appraoch household survey with ginger growers and ginger field sampling in seven major ginger growing districts (Ilam, Dhankuta, Sindhuli, Syangja, Palpa, Guilmi and Salyan) of Nepal during August-September in 2024. These seven districts cover about 33% of the area under ginger cultivation in Nepal (MoALD, 2025). A total of 70 ginger growers (10 from each district) were surveyed. Simple random sampling technique was employed for the household survey in which the list of farmers was obtained from the Agriculture Knowledge Center (AKC) in the district level and Agriculture Development Sections of the local government. For household survey, a set of semi-structured questions were asked to farmers regarding socio-economic variables and the problems of ginger rhizome fly and associated rot. The infested rhizome of the five plants from each farmer were collected randomly from the farmer' field and the ginger rhizome fly and their damage was identified in laboratory based on the symptoms, morphology, nature of damage and other distinguishing characters. Number of infected plant either by rhizome rot or by rhizome fly or by both were recorded. Field incidence was calculated from crop-cut data by using the formula number of clumps infected by total number of clumps per unit area expressed as percentage. Data on rhizome fly maggot and pupae number/plant were recorded. Descriptive statistics such as mean, range and inferential statistics; Pearson's chi-square test were calculated and the synthesis of results were presented in both graphs and tables. Finally, ginger farmers' problems, rhizome fly incidence and associated rhizome rot, and ginger rhizome loss in the field were discussed.

3. RESULTS AND DISCUSSION

3.1 Farm and household characteristics of the ginger producing farmers

The socio-economic characteristics of ginger farmers in study districts of Nepal during the year of 2024 showed diverse household, livelihood and farming characteristics (Table 1). On an average, a family had 5.61 members with 2.66 members as economically active for providing labor force in agriculture. The number can be seen as moderate level for supplying working manpower for farming. Education level averaged 7.14 years of schooling, while few farmers were also illiterate. Overall, the result of socio economic and farming characteristic suggests that moderately sized (approximately 6 family members per household) ginger farming households are involved in agriculture, and increasingly diversified their income sources. The moderate household size and heavy reliance on agriculture align with recent findings by Ghimire & Shah (2023), who noted agriculture as the economic pillar of farmers in the mid-hills and adopting "risk-spreading" strategies. Agriculture existed as the primary source of livelihood with 57.21% contribution to household income. Other sources were remittance and livestock rearing as the second and third most contributing to family income. The average landholding revealed that farmers used 1.03 hectare (range 0.10 to 0.40) of their land for cultivation, of which, ginger farming occupied almost 0.16 hectare on an average and some farmers allocating their land more than one hectare for ginger growing (Table 1). The remittance and livestock sector income are major contributors to household income after agriculture. Only small proportion of land allocated to ginger cultivation compared to total land area suggests that farmers are still limiting their crop land for ginger as a supplementary enterprise rather than the sole farming activity. Similar land-use patterns were observed in Sindhuli and Surkhet, where farmers limited their ginger acreage to mitigate the risks associated with high input costs particularly seed rhizomes and market volatility (Ghimire & Shah, 2023). The variation in term of education and income source highlights socio-economic heterogeneity among households, which may influence adoption of improved technologies and marketing of ginger. Households with higher education and diversified income are generally more likely to participate in market-oriented production and adopt Integrated Pest Management (IPM) practices. Mainly training and literacy were significantly associated with a farmer's ability to identify disease symptoms and implement mediation interventions (Adhikari et al., 2025; Shrestha & Joshi, 2024).

Table 1: Socio economic characteristics of ginger growing farmers (n=70)

SN	Variable	Mean±SD	Range
1	Family size (No.)	5.61±2.24	2.00-15.00
2	Active member in agriculture (No.)	2.66±1.13	1.00-7.00
3	Education level (Schooling year)	7.14±3.83	0.00-12.00
4	Income from agriculture (%)	57.21±27.12	15.00-100.00
5	Income from livestock (%)	14.50±16.18	0.00-65.00
6	Income from non-agriculture sector (%)	0.93±3.83	0.00-25.00
7	Income from Job (%)	6.00±13.90	0.00-50.00
8	Income from business (%)	2.00±9.26	0.00-70.00
9	Income from remittance (%)	19.36±24.97	0.00-80.00
10	Total landholding (Hectare)	1.03 ± 0.89	0.10-4.00
11	Ginger cultivation (Hectare)	0.16 ± 0.19	0.03-1.30

Source: Household survey and ginger field sampling (2024); SD=Standard deviation

3.2 Farmers' perceptions on ginger production and marketing problems

The statistical analysis using Pearson's Chi-square test ensured that the ginger problems across districts was highly significant ($p \leq 0.001$), indicating strong variation in problem occurrence among districts (Table 2). The findings revealed that the problem caused by insect pests and diseases were the top most challenges in all study districts (Figure 1). Rhizome rot (*Pythium*) was a widespread problem in all districts (11.60% in Syangja to 39.00% in Ilam), while rhizome fly was more severe in Palpa (34.70%). The findings revealed that both problems were severe as indicated by mean response of farmers for rhizome fly (20.67%) and for rhizome rot (25.34%), respectively. The result also depicted that Gulmi and Syangja districts appeared as less affected than other districts.

The problem linked to insect-pests and diseases across all districts underscores their critical role in limiting ginger productivity in Nepal. Similarly, the ginger farmers are compelled to have considerable yield losses primarily due to rhizome fly and associated rot, which together affect more than half of the total production (Table 2). Yield reduction from 28.62 t/ha in healthy plants to nearly half in infected plants indicates the economic significance of pest and disease control, which is consistent with the yield gap analysis reported by Gautam (2025). While the national average yield remains stagnant at approximately 12.83 t/ha, which demonstrates that the economic loss is not merely theoretical but a direct result of "rhizome rot-complex" where fly infestation often facilitates fungal entry (GRP, 2023). The widespread presence of this problem suggests critical economic loss and highlights the urgent need for integrated pest and disease management strategies. The findings highlighted that Ilam, Palpa and Sindhuli emerging as most affected districts, showing high levels of infestation under farmer's field. Palpa and Sindhuli recorded the highest rhizome fly infestation, indicating that pest management interventions should prioritize these areas. On the other hand, Ilam showed the highest incidence of rhizome rot, pointing to urgent needs for disease management practices such as improved soil health, crop rotation, and resistant varieties. Districts like Gulmi and Syangja reported relatively lower levels of both problems, which may reflect either better management practices or agro-ecological conditions less favorable to pest and disease development. Geographically, the high incidence of rhizome rot in Ilam and rhizome fly in Palpa and Sindhuli underscores the need for region/district-specific management practices. Ilam's vulnerability to rhizome rot may be attributed to its high rainfall and soil moisture levels, which favor *Pythium* species (Gautam & Acharya, 2014).

Table 2: Perceptions of farmers on production and marketing problems of ginger (n=70)

Problem	**District**								**χ^2**
	Dhankuta	**Gulmi**	**Ilam**	**Palpa**	**Salyan**	**Sindhuli**	**Syangja**	**Total**	
Insect-pests and diseases	7.00	3.00	10.00	10.00	4.00	10.00	4.00	48 (68.57)	Pearson $\chi^2(24)=76.611$ Prob = 0.000
Storage	1.00	0.00	0.00	0.00	4.00	0.00	0.00	5.0 (7.14)	
Markets	0.00	7.00	0.00	0.00	2.00	0.00	6.00	15 (21.43)	
Mulching	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2 (2.86)	

Source: Household survey and ginger field sampling (2024)

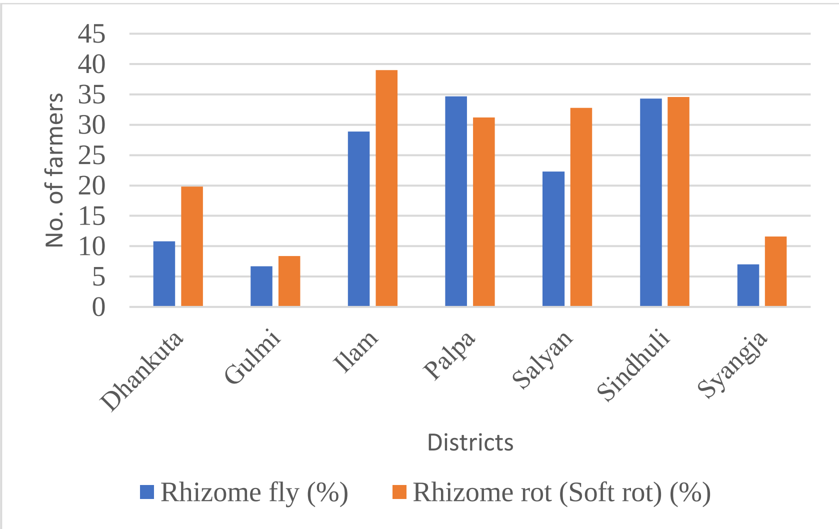

Figure1: Farmers facing pest problems (n=70) in major ginger growing districts

3.3 Incidence of ginger rhizome fly and associated rhizome rot

The ginger cultivation in different district varied considerably in term of area, disease pest infestation, crop damage and ultimately yield loss. Table 3 shows the plant density of ginger 130,000 plants per hectare, though it varied widely across farms. The infestation caused by rhizome fly alone was at 15.17%, while rhizome rot infestation alone was also more severe averaging 30.68%. The rhizome flies and rot combined affected over half (54.13%) of the plants, indicating a major ginger production challenge. The maximum field infestation of 25.00-31.12% caused by rhizome fly was reported in Nepal (Gautam & Acharya, 2014). Rhizome rot (*Pythium* spp.) was found wide spread and devastating disease of ginger with the average yield loss of 20% (Sharma et al., 1998). According to ANSAB (2011) rhizome production could be reduced up to 70% due to rhizome rot infestation in Nepal. On an average, 3.89 maggots and 1.81 pupae per rhizome were observed in ginger-cut in the laboratory, which shows significant pest pressure. Healthy plants yielded 28.62 t/ha of fresh rhizome, whereas fly-damaged edible yield was reduced to 14.03 t/ha, with an additional 4.94 t/ha classified of rhizome as non-edible. Overall, yield loss due to rhizome fly infestation averaged 14.59 t/ha, showing the substantial impact of pest and disease on productivity. Peak period of *M. coeruleifrons* incidence was in the first week of September and damaged was 20-25% and 40-42% in protected and unprotected ginger crops, respectively (Sonatakke, 2000). The occurrence of multiple maggots and pupae per rhizome reflects the key challenges hampering both quality and marketability of ginger. Baral et al. (2021) reported that variation on climate change in the mid-hills are responsible for shifting the epidemiology of soil-borne pathogens, striking a transition toward Climate Smart Agriculture (CSA). Unpredictable monsoon patterns and increasing average temperatures have shown to create "hotspots" for the development of *Pythium* responsible for rhizome fly infestation (Baral et al., 2021). These environmental shifts underscore the importance of recent findings which demonstrate that agronomic adjustments such as increasing seed rhizome size to 80g can significantly increase plant vigor and provide a physical barrier against both rhizome fly and rhizome rot infestation (Gautam, 2025). Integrating these resilient planting materials with better drainage and soil health management is no longer just a recommendation but a necessity for maintaining the stability of the mid-hill livelihood strategy in an increasingly unpredictable climate (NACCFL, 2025). These findings emphasize the urgent need for integrated disease and pest management strategies in ginger growing districts. Some strategies, like cultural practices, development of resistant varieties, and timely interventions could be improved over time. Also, strengthening farmer awareness and extension support could help mitigate yield losses and enhance ginger productivity.

Table 3: Field incidence of rhizome fly and rhizome rot (n=70)

Variable	Mean±SD	Range
Ginger plant (No/ha) (,000)	130.00±38.45	80.00-300.00
Rhizome fly infested (%)	15.17±16.57	0.00-60.00
Rhizome rot infested (%)	30.68±27.83	0.00-100.00
Rhizome fly + rot infected plant (%)	54.13±26.94	0.00-100.00
Rhizome fly maggot (No./rhizome)	3.89±8.03	0.00-48.00
Rhizome fly pupa (No./rhizome)	1.81±2.99	0.00-14.00
Fresh rhizome yield of healthy plant (t/ha)	28.62±6.14	17.20-40.40
Fly damaged edible yield (t/ha)	14.03±10.21	0.00-40.40
Fly damaged nonedible yield (t/ha)	4.94±4.35	0.00-16.00
Yield loss after rhizome fly infestation (t/ha)	14.59±9.10	0.00-36.60

Source: Household survey and ginger field sampling (2024); SD=Standard deviation

4. CONCLUSION

Ginger farming remains as a supplementary enterprise, largely due to high risks and small landholding, which suggests that this sector is functioning far below than its commercial potential. This study revealed that ginger production was vulnerable in the mid-hills of Nepal due to the infestation of insect pests and diseases. Among them, rhizome fly and rhizome rot are limiting factors in harnessing the benefits of ginger. The problems vary across geographical locations such as in Ilam rhizome rot is the main threat whereas rhizome fly is the major constraint in and Palpa/Sindhuli districts. Ginger rhizome fly, *Mimegralla coeruleifrons* (Macquart,1884) was found emerging and destructive insect pest of ginger in Nepal. The maggot of fly is a damaging stage, which is responsible for either initiating or hastening the *Pythium* rot diseases (rhizome rot). The damage of ginger rhizome by fly alone caused about 15.17%, rot alone 30.68% and their association 54.13%. This indicates that ginger production in Nepal is not a monolith. The current "one-size-fits-all" approach to agricultural extension is insufficient to address the nuanced needs of ginger producing districts. To overcome ginger rhizome fly problem, further researches are needed to identify resistant/tolerant genotypes, evaluation of different botanical and chemical pesticides and different management practices. Finally, ginger sector illustrates resilience through household diversification, its long-term sustainability depends on integrated insect pest and disease management in the context of climate change.

DECLARATION

The authors declare no conflict of interests.

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AUTHOR CONTRIBUTIONS

Author A: Investigation, conceptualization, software, data curation, formal analysis, investigating resource, writing original draft, writing review & editing.
Author B: Conceptualization, methodology design, supervision, writing review & editing, and validation.
Author C: Methodology design, supervision, validation, writing review & editing.
Author D: Investigation, supervision, visualization, writing review & editing, and validation.

REFERENCES

Adhikari, K. B., Tripathi, N., & Dhakal, A. P. (2025). Farmer's knowledge, perception, and management of major diseases of ginger in Palpa district, Nepal. *Nepalese Horticulture*, *18*(1), 43–51. https://doi.org/10.1079/pwkb.20157800154.

ANSAB. (2011). A report on "Value Chain/ Market Analysis of the Ginger Sub-Sector in Nepal". Asia Network for Sustainable Agriculture and Bioresources, New Baneshwor, Kathmandu Nepal.

FAO. (2023). Production trends overview of top 10 countries. Food and Agriculture Organization. code 0720. Production of whole ginger. HS code: 091011.

Gautam, J. & Acharya, B. (2014). Survey and monitoring of insect pest and disease of ginger in Nepal. *Nepalese Journal of Agriculture Science*, *12*, 118-123.

Gautam, J. (2025). Ginger rhizome fly, *Mimegralla coeruleifrons* (Macquart, 1844), management by planting appropriate seed rhizome size and suitable variety. *Journal of Agriculture and Forestry University*, *6*, 143–150. https://doi.org/10.3126/jafu.v6i2.88453.

Baral, R., Kafle, B. P., Panday, D., Shrestha, J., & Min, D. (2021). Adoption of good agricultural practice to increase yield and profit of ginger farming in Nepal. *Journal of Horticultural Research*, *29*(1). https://doi.org/10.2478/johr-2021-0009

Ghimire, A. & Shah M. (2023). Economics of production and marketing of ginger in Sindhuli district, Nepal. *Agriculture Extension in Developing Countries (AEDC)*, 1(2): 52-58.

Ghorpade, S. A., Jadhav, S. S., & Ajri, D. (1983). Survey of rhizome fly on turmeric and ginger in Maharashtra. *Journal of Maharashtra Agriculture University*, *8*, 292-293.

Ghorpade, S.A., Jadhav, S.S., & Ajri, D.S. (2008). Biology of rhizome fly *Mimegralla coeruleifrons* Macquart (Micropezidae: Diptera) in India, a pest of turmeric and ginger crop. *Tropical Pest Management*, 34(1), 40-51.

GRP. (2023). *Annual technical report 2022/2023*. Ginger Research Program (GRP), Kapurkot, Salyan, Nepal.

Koya, K.M.A., Premkumar, T., & Gautam, S.S.S. (1988). Chemical control of shoot borer *Dichocrocis punctiferalis* Guen. on ginger *Zingiber officinale* Rosc. *Journal of Plantation Crop, 16*, 58-59.

MoALD. (2025). *Statistical information on Nepalese agriculture* 2023/24. Ministry of Agriculture and Livestock Development, Planning and Development Cooperation Coordination Division, Statistics and Analysis Section, Singhadurbar, Kathmadu, Nepal.

NACCFL. (2025). *Top 7 climate-smart agriculture practices for small farmers in Nepal.* National Agricultural Central Co-operative Federation Limited, Dhobighat-3, Lalitpur, Nepal.

Sah, D.N., Malla, S. & Pokharel, D. (2001). Integrated management of rhizome rot disease of ginger in the hills of Nepal. *Journal of Lumle Technical Paper*. Agriculture Research Station Lumle, Pokhara, Nepal.

Sharma, B.P., Shrestha, S.K. & Giri, Y.P. (1998). Present status of diseases and insect pests of ginger in Nepal. In: *Proceedings of the Second National Horticulture Research Workshop* on 13-15 May 1998, Nepal Agriculture Research Council (NARC), Khumaltar, Lalitpur, Nepal. pp. 173-178.

Shrestha, A., & Joshi, S. (2024). Biotic stress and yield gap analysis in Nepalese ginger cultivation: Implications for food security. *Nepal Agricultural Research Journal*, *16*, 22–35.

Sonatakke, B. K. (2000). Occurrence, damage and biological observations on rhizome fly *Mimegralla coeruleifrons* infesting ginger. *Indian Journal of Entomology, 62*: 146-14

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