NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES
July, 2026, volume 31

\

Himalayan College of Agricultural Sciences and Technology (HICAST)
Purbanchal University affiliate
Kirtipur, Salyanthan, Kathmandu, Nepal

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES

July, 2026, volume 31



Himalayan College of Agricultural Sciences and Technology
(HICAST)
Purbanchal University affiliate
Kirtipur, Salyanthan, Kathmandu, Nepal

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

EDITORIAL BOARD

Founder & Chief Editor (Board Chair)
Binayak P. RAJBHANDARI, Ph.D. (Nepal)

Senior Editors (Board Members)
Upendra Man SINGH, Ph.D. (Nepal)
Bidur P. CHAULAGAIN, Ph.D. (Nepal)
Raj Kumar Adhikari, Ph.D. (Nepal)

Editors (Board Members)
Dharma Raj DANGOL, Ph. D. (Nepal)
Bishnu P. BHATTARAI, Ph. D. (Nepal)
Megh Raj Tiwari, Ph.D. (Nepal)
Sushil THAPA, Ph.D. (USA)
Olugbenga Omotayo, ALABI, Ph.D. (Nigeria)

Marketing Officer
Akabar Singh DHAMI

Computer Assistant
Asmita TAMANG

Published on: 10 July 2026
Access and download to online version is free of cost.

Price for hard copy	Nepal	NRs 500.00
(Including postage charge)	Other Countries	US $ 15.00

@ HICAST

PUBLISHER
Directorate of Research and Extension (DoRE)
Himalayan College of Agricultural Sciences & Technology (HICAST)
Purbanchal University affiliate
Post Box 25535, Kathmandu, Nepal
Email: info@hicast.edu.np; binayakprajbhandari@gmail.com
URL://www.nepjas.com/; URL://www.hicast.edu.np/; URL://www.nepjol.com/
Citation: Nepalese Journal of Agricultural Sciences, July, 2026, Volume 31
(e-ISSN: 2091-0428; p-ISSN: 2091-041X; esjindex ID = 6279)
Euro-Asian Scientific Journal Link: *http://esjindex.org/search.php?id=6279*

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

TABLE OF CONTENTS

RESEARCH ARTICLES

Evaluation of Growth Performance of African Rose Wood Seedlings on Different Soil in Kaduna Northern Guinea Savanna Eco-Zone Nigeria- Akintunde Isiaka, SODIMU; David, BAYO; & Muhammad Fatima, RASHEED…..5

Soil Nutrients Status and Cropping System in Plastic House Condition of Chandragiri Municipality, Kathmandu- Nisha PANTHA and Shova SHRESTHA…..14

Access to Formal Agricultural Credit and Barriers Among Farmers in Kathmandu Valley, Nepal- Brishti SUWAL and Rojan KARKI…27

Determinants of Farmers' Willingness to Grow Potato on a Commercial Scale in Rupandehi District, Nepal- Kriti BHANDARI, Sushmita BHATTA and Binayak Prakash MISHRA….41

Effect of Vermicompost–Soil–Cocopeat Casing Mixture on Growth, Morphology, and Biological Efficiency of Milky Mushroom (*Calocybe Indica)*- Zenita NEPAL, Sundar TIMALSINA, Alize Kumar SHAH, and Bidur P. CHAULAGAIN….52

Determinants of Farm Machinery Adoption among Maize Farmers in Khotang, Nepal- Bishal RAWAT, Anish Bilash PANTA, Sushmita BHATTA and Binayak Prakash MISHRA…65

Economic Analysis of Dragon Fruit Production in Dang Nepal - Rojan KARKI, Bharat Bikram RAWAT, Rajendra BHARI, & Koshila GIRI…75

Comparative Analysis of Technical Efficiency among Smallholder Rice Farmers Using Local and Improved Seeds in North Central Nigeria- Godfrey Ajayi, SUNDAY, Olugbenga Omotayo, ALABI, Josephine Bosede, AYOOLA…86

Effect of Cow Dung and NPK Fertilizer on the Early Growth Of Northern Black Wattle (*Acacia Auriculiformis* A. Cunn. Ex. Benth) in Kaduna Northern Guinea Savanna Eco - Zone of Nigeria- Akintunde Isiaka, SODIMU; Fatima Muhammad, RASHEED; and David, BAYO… 100

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Role of Beneficial Microbes in Enhancing Potato Vegetative Growth In Sindhupalchwok District- Koshila GIRI, Himal BHUSAL, Prashant SAPKOTA and Rojan KARKI…110

The Constraints Facing Contract and Non-Contract Rice Farmers: Evidence from Benue and Niger States, Nigeria- Christopher Adava, OHINOYI, Park Odojoma, IDISI., Muhydeen Mobolaji, GIWA, Joy Precious, ALABI, & Olugbenga Omotayo, ALABI… 122

Diagnosing Nepal's Fertilizer Crisis: Governance Failures and Systemic Bottlenecks in the Fertilizer Supply Chain- Kamana KAFLE, Bidur Prasad CHAULAGAIN, and Nanu JHA…134

Temporal Dynamics of Physical, Chemical and Biological Properties of a New *Panchagavya* Formulation- Sabita ARYAL KHANNA, and Janardan LAMICHHANE…150

Identification and Nutritional Evaluation of Native Forage Species for Establishing Field Gene Bank at Jiri, Dolakha, District- Sujaya UPRETI et al…167

The Effect of Non-Genetic Factors on The Success of Artificial Insemination of Goats 160in Nepal- Dipak ADHIKARI et al., ……173

Effect of Integrated Nutrient Management on LAI and Yield Formation of Cauliflower in Bhaktapur- Pushpa GOIT and Binayak P. RAJBHANDARI…184

Graduate Employability and Curriculum Gaps: A 20-Year Tracer Study from a Nepalese Agriculture College- Bidur Prasad CHAULAGAIN, and D. SHARMA….194

REVIEW ARTICLE

A Review on Vaginal Prolapse in Dog Breeds- Raju SHRESTHA…214

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

RESEARCH ARTICLES

Evaluation of Growth Performance of African Rose Wood Seedlings on Different Soil in Kaduna Northern Guinea Savanna Eco-Zone Nigeria

Akintunde Isiaka, SODIMU*[1], David, BAYO[2] & Muhammad Fatima, RASHEED[3]

[1]Savanna Forestry Research Station, Forestry Research Institute of Nigeria (FRIN), PMB 1039, Samaru – Zaria, Kaduna, NIGERIA;
[2]Northern Guinea Research Station, FRIN, Nasarawa, NIGERIA;
[3]Federal College of Forestry Mechanization, FRIN, PMB 2273, Afaka – Kaduna,
***Corresponding Author's Email**: sodimu.ai@frin.ng

ABSTRACT

Limited empirical studies have examined the nexus between soil properties survival and growth performance of *Pterocarpus erinaceous* under different soil and environmental conditions; this knowledge is however critical for the successful establishment of African rosewood plantations and general ecological balances in the forest ecosystem. Preliminary study was carried out on the growth performance of *Pterocarpus erinaceous* seedlings on different soil sources at the nursery of the Savanna Forestry Research Station situated in the Institute for Agricultural Research (I.A.R) farm Samaru, Kurumi Bomu village. Farm land soil were collected from Institute of Agricultural Research (I.A.R) farm Samaru at Kurumi Bomu village while forest soil and granulated iron stone soil were gotten within the Savanna Forest Research Station, plantations. The seedlings of four (4) weeks were gotten from Savanna Forest Research Station, and transplanted into these soil samples; replicated eight (8) times and readings were taken forth nightly for three (3) months. The experiment was laid using Complete Randomized Design method. Growth data were collected forth nightly and was subjected to Analysis of Variance (ANOVA) and Duncan Multiple Range Test. Result shows that there is significant ($P \leq 0.05$) difference in the height, stem diameter and number of leaf among the three (3) soil for the growth assessment. The growth rate recorded from the farm land soil is statistical higher ($P \leq 0.05$) in leaf width, plant height and stem diameter than the other two (2) soil while the growth parameters assessed are significantly lower ($P \leq 0.05$) in iron stone soil and Forest soil. It is recommended that soil from the farmland is the most suitable for raising and nurturing of *Pterocarpus erinaceous* in the nursery without additional of any plant nutrient media.

Key Words: Eco-zone, Guinea, nursery, plantation, Savanna, seedlings, soil

INTRODUCTION

African rosewood (*Pterocarpus erinaceous* Poir.) is a medium-size deciduous tree belonging to the Fabaceae family (Rabiou *et al.,* 2015; Obiri *et al.,* 2022). It is native to the semi-arid Guinneo-Sudano-Sahelian Forest zones of West Africa with presence in about 8 countries within the West African sub region due to its ability to thrive in a varied range of environmental conditions (Kossi *et al.,* 2019; Biaou *et al.,* 2023). Its superior wood qualities make it one of the most valuable and preferred timber species for the manufacture of valuable artifacts in Asia; China in particular stemming a rapidly increasing demand for its wood (Rabiou *et al.,* 2015;Anthionio & Antwi–Boasiako,2023). It has therefore emerged to become one of the most heavily traded tropical hardwood species on international markets and a major source of revenue and foreign exchange for many West African economies. The fruits, which take four months to mature, are disc-shaped, flat, and have winged margins. It is also central woody corky bulge containing several seeds. Unlike most legumes, *Pterocarpus erinaceous* fruit is indehiscent and is dispersed by wind. It also floats in water and can be water dispersed, Orwa *et al.,* (2009). Poor soil, multipurpose uses, exploitation without limit and lack of scientific knowledge on the suitable propagation methods and soil types is important regarding the increasing commercialization of their derivatives, added to an ineffective forest ecosystem management constitute one of the major cause of the decline of its population. The species population are mostly old and the transition from small size class to higher is low (Leakey, 1998). Apart from its contributions to national economies, *Pterocarpus erinaceous* provides many socioeconomic and cultural benefits to local communities who exploit it for timber and non - timber products (Rabiou *et al.,* 2015; Adjonou *et al.,* 2020; Obiri *et al.,* 2022;Biaou *et al.,*2023). However, despite its significant socioeconomic importance, recent rises in global demand and commercial value for its wood contributed to increased exploitation and consistent increase in its international trade (Dumenu & Bandoh, 2016; Johnson *et al.,* 2020). West Africa is currently the largest producer and supplier of African rosewood globally with large volumes of the exported timber sourced from illegal sources (Anthionio & Antwi – Boasiako, 2023). According to Dumenu & Bandoh (2016) African rosewood supply from Africa to China experienced a 700% increase since 2010. Kossi *et al.* (2019) also, reported that the West Africa region produced about 80% of the total volume of African rosewood exported to China in 2016. This high pressure exerted on the populations of *Pterocarpus erinaceous* makes it one of the most exploited, heavily traded, and threatened tropical hardwood species globally

(Rabiou *et al.,* 2015; Adjonou *et al.,* 2020) These anthropogenic pressures in addition to the eminent threat of climate change raise concerns on the sustainability of African rosewood in many African countries where climate impacts are very prominent (Biaou *et al.,* 2023; Adjonou *et al.,* 2020; Imarhiagbe *et al.,* 2022).The present trend of *Pterocarpus erinaceous* exploitation and global trade has raised serious concerns about its sustainability with many advocating the need to adopt appropriate measures to protect the species from the eminent threat of anthropogenic disturbance (Dumenu & Bandoh, 2016; Adji *et al.,* 2021). These advocacies have influenced major trading countries in West Africa to impose harvesting and export bans in recent years (Dumenu & Bandoh, 2016; Adjonou *et al.,* 2020; Adji *et al.,* 2021; Christine *et al.,* 2021). Conservation efforts for the species have ranged from the imposition of intermittent harvesting and export bans, restoration of natural stands, plantation establishment, and adsorption of export quotas, community sensitization, and imposition of minimum felling limits in many West African countries. (Kossi *et al.,* 2019; Dumenu & Bandoh, 2016). This was followed by the registration and enlistment of the species in Annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and change of conservation status to globally endangered on the red list of the International Union for Conservation of Nature (IUCN) (Dumenu & Bandoh, 2016). Anthionio & Antw –Boasiako (2023) however, argued that despite these challenges, the current commercial value of *Pterocarpus erinaceous* presents a huge prospect for economic transformation and livelihood improvement under appropriate conservation strategies in many African countries whose economies are largely natural resources dependent. It also has the potential for ecological balances in the fragile savanna ecosystems despite the imminent threats of climate change (Dumenu & Bandoh, 2016; Adji *et al.,* 2021; Obiri *et al.,* 2022;Biaou *et al.,*2023) There is therefore an urgent need to develop strategies for the sustainable management of this species. In response to these calls, many have recognized population restoration through the establishment of African rosewood plantations as a strategic measure to restore the rapidly declining population and ensure the sustainable management of the species (Adji *et al.,* 2021). However, many authors have argued that the success of these interventions requires an in-depth understanding of the species biology, ecology, survival, and growth performance (Biaou *et al.,*2023) Also, species-site matching has been widely recognized to be crucial for tree survival, growth, and general success of reforestation program (Adjonou *et al.,* 2020; Dimobe *et al.,* 2022). However, limited empirical studies have examined the nexus between soil properties and survival; and growth performance of *Pterocarpus erinaceous* under different environmental conditions (Ansah *et al.,* 2023) this knowledge is

however critical for the successful establishment of African rosewood plantations and general ecological balances in the forest ecosystem. Despite its importance, there is limited supply of *Pterocarpus erinaceous* to meet the demand of the people. Therefore, there is need for large scale production of *Pterocarpus erinaceous* on a most suitable soil source. The objective of the study is to evaluate the growth performance of *Pterocarpus erinaceous* on different soil sources.

MATERIALS AND METHODS

Study area

The study was conducted in Savanna Forestry Research Station nursery situated in the Institute for Agricultural Research (I.A.R) farm Samaru in Kurumi Bomu village. Located at Latitude 12°13'and 11°11'N / Longitude 8°39' and 7°38' E and 686m above sea level (Figure 1). It is located in Sabon – Gari Local Government Area of Kaduna State. The vegetation in the local Government Area is the Northern Guinea Savannah woodland type, characterized by short scattered drought resistant trees with undergrowth of grass that serves as fuel for bushfires in the long dry season with mean annual rainfall of 1000mm – 1500mm, temperature of 25.6°C (78.1°F), precipitation of 1,117.6mm and humidity of 69% respectively (Sodimu *et al.,* 2021)

Treatments and experimental design

The experiment consisted of three (3) soil types namely: Forest soil, Iron stone soil and farm land soil. That was laid in a Completely Randomized Design (CRD) method and each treatment was replicated eight (8) times. The forest soil were collected from Savanna Forest Research Station, plantation; Farmland soil were collected from Institute of Agricultural Research (I.A.R) farm Samaru at Kurumi Bomu village while the Granulated iron stone were collected from Savanna Forest Research Station, plantation.

Soil sample collection

The two (2) soil samples (farmland and forest soils) were collected using soil auger at 10cm depth while the iron stone soil was collected and grinded with a mortar to fine particles, then each soil samples were thoroughly mixed together to form a uniform sample10g of each soil were packed and labelled for laboratory analysis and the rest are then filled into polythene pots to commence the experiment. The seedlings of four (4) weeks were gotten from Savanna Forest

Research Station, and transplanted into these soil samples and readings were taken forth nightly for three (3) months.

Growth data parameters assessment

The growth data parameters were taken forth nightly for three (3) months. The height (cm) of the plant was assessed, measuring from the base of the plant to the apex. The average was computed and recorded; the number of leaves was counted, computed and recorded; the stem of the plant was assessed using a veneer caliper and was recorded. The number of the nodes were counted and then recorded. However, at the end of the terminal experiment, the plant was up rooted, the number of the longest root as well as the total number of root were counted and recorded.

Soil and statistical analysis

The three (3) soil types collected bulked, packed and labelled separately into white zip locked bag for analysis of its chemical properties at the soil science laboratory of Ahmadu Bello University Zaria, Nigeria. The data collected were analyzed using ANOVA at P≤0.05 probability level and the means with significant difference were separated using Duncan multiple range test (DMRT) at (P≤0.05).

RESULTS AND DISCUSSION

The data recorded for the evaluation of growth performance on *Pterocarpus erinaceous* seedlings for three (3) months on the three (3) different soil sources are presented in the following table below.

Table 1. Influence of soil type on number of leaves of *Pterocarpus erinaceous*

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP
Forest Soil	5.00^{ab}	4.38	4.25^{a}	4.25^{a}	4.2.5^{a}	4.25^{a}
Iron stone	4.38^{b}	3.38	3.00^{b}	3.00^{b}	3.00^{b}	3.00^{b}
Farmland soil	5.13^{a}	4.13	4.50^{a}	4.50^{a}	4.50^{a}	4.50^{a}
SE ±	0.23	0.59	0.23	0.23	0.23	0.23

i. *Means in the same column followed by unlike letters are significantly different at P≤0.05 Level of probability using Duncan's Multiple Range Test (DMRT).*

ii. *WAP = Weeks after planting.*

Number of Leaves of *Pterocarpus erinaceous* plant as influenced by different soil sources were significant (P≤0.05) at all the sampling intervals except at 4 weeks after planting. At 2 weeks after planting, farm land soil produced significantly higher number of leaves than all other soil types but statistically comparable to plants grown in forest soil. Least significant number of leaves resulted from plants grown in iron stone soil. At 6 to 12 weeks after planting, forest soil and farm land soil maintained consistent significantly (P≤0.05) higher number of leaves than iron stone soil. This observation is in consonance with the work of (Sodimu, 1998;Usharani *et al.,* 2019) that Farm land soil are good soil media source for nurturing *Pterocarpus erinaceous* seedlings.

Table 2. Influence of Soil type on Plant Height of *Pterocarpus erinaceous*

Treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP
Forest Soil	14.02^{a}	14.47^{a}	14.85^{a}	15.42^{a}	15.75^{a}	16.43^{c}
Iron stone	12.44^{b}	12.78^{b}	13.30^{c}	13.80^{c}	14.21^{b}	14.72^{b}
Farmland soil	14.28^{a}	14.64^{a}	15.00^{a}	15.76^{b}	16.24^{ab}	16.43^{a}
SE ±	0.70	0.67	0.65	0.66	0.66	0.67

i. *Means in the same column followed by unlike letters are significantly different at P≤0.05 level of probability using Duncan's Multiple Range Test (DMRT).*

ii. *WAP= Weeks after planting*.

Plant height of *Pterocarpus erinaceous* as influenced by different soil were significant (P≤0.05) higher in farmland soil than other two (2) Soil. The least significant (P≤0.05) growth of *Pterocarpus erinaceous* occur in the iron stone soil (Usharani *et al.,* 2019) reported that *Pterocarpus erinaceous* planted on farmland soil grew better than all other soil types and in contrary to the work of (Sodimu, 1998) that tree height of teak (*Tectona grandis*) planted on granulated iron stone soil does better in height than other soil.

Stem diameter of *Pterocarpus erinaceous* plant in table 3 above shows no significant (P ≥0.05) different at all the sampling interval for all the treatment. At 2 to 8 WAP forest soil and farm land soil maintained consistent significantly higher stem diameter than the iron stone soil. However, at 2 WAP, the iron stone soil was the highest followed by the forest soil while the farmland soil was the lowest. At 12 WAP, the forest soil was the highest at (4.95) followed by the farmland soil at (4.46) and the least was the iron stone soil at (4.41). The above result did not agree with the work of (Sodimu, 1998) that ironstone soil gives better growth of stem diameter of young seedlings.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Table 3. Influence of soil type on stem diameter of *Pterocarpus erinaceous*

TREATMENT	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP
Forest Soil	2.89[a]	3.30[b]	3.99[b]	4.42[a]	4.81[a]	4.95[a]
Iron stone	2.94[a]	3.09[b]	3.39[b]	3.88[b]	4.28[b]	4.41[b]
Farmland soil	2.70b	2.98[a]	3.43[b]	4.00[b]	4.31[b]	4.46[b]
SE ±	0.12	0.10	0.12	0.12	0.12	0.12

i. *Means in the same column followed by unlike letters are significantly different at P≤0.05 level of probability using Duncan's Multiple Range Test (DMRT).*
ii. WAP= Weeks after planting.

Table 4. Influence of soil type on leaf width of *Pterocarpus erinaceous*

TREATMENT	2WAP	4WAP	LEAVEWIDTH 6WAP	8WAP	10WAP	12WAP
Forest Soil	43.97[b]	62.8[b]	70.02[b]	71.48[b]	79.51[b]	0.00
Iron stone	49.82[a]	58.38[c]	61.44[c]	66.01[c]	69.02[c]	0.00
Farmland soil	45.84[ab]	26.53[a]	87.92[a]	91.90[a]	97.49[a]	0.00
SE ±	2.32	4.66	4.59	4.31	4.25	0.00

i. *Means in the same column followed by unlike letters are significantly different at P≤0.05 level of probability using Duncan's Multiple Range Test (DMRT)*
ii. *ii WAP= Weeks after planting.*

Leaf width of *Pterocarpus erinaceous* plant influenced by different soil were significant (P≤0.05) at all the sampling period from the 2 to the 12 WAP. *Pterocarpus erinaceous* plant on the farm land soil maintained the highest leaf width of the three (3) treatment, next was the plant in the forest soil while the least was the iron stone. These is in agreement with the work of (Usharani *et al.,* 2019) that nutrients composition of farmland soil gives good leave width when compared with other soil.

Table 5. Chemical properties of the soils use in the experiment

Soil	Soil pH	Ca	Mg	N	K	P
Iron stone	5.7	1.50	0.88	1.23	0.87	1.73
Farmland soil	6.0	2.40	1.41	1.05	0.43	8.28
Forest soil	6.35	4.80	2.82	1.58	0.70	2.12

Table 5 shows the chemical properties of the three (3) types of soil used in the experiment, two (2) of the three (3) soil (Farmland soil and Ironstone soil) were

slightly acidic while the forest soil closely neutral. The forest soil had the highest calcium (Ca) content followed by the farmland soil and the iron stone soil was the least, the forest soil had the highest magnesium(Mg) content next was the farmland soil and the least was the iron soil. The iron stone had the highest potassium (K) content followed by the forest soil and the farmland was the least. The farmland soil had the highest phosphorus (P) content followed by the forest soil while the iron stone was the least.

CONCLUSION

It is an evident from the result of this study that significant difference occurs among the three (3) soil in raising of *Pterocarpus erinaceous* in all the parameters assessed. The most suitable soil for the growth performance of *Pterocarpus erinaceous* is farmland soil while the least suitable soil is the granulated iron stone soil. This result implies that farmland soil has the highest nutrient capacity and soil pH for the growth and development of the seedlings. Based on the above results *Pterocarpus erinaceous* can be best raised using farmland soil without additional of any other potting media. Although, the other two (2) soil (granulated iron stone and forest soil) can be used in the absence of farm land soil but additional plant nutrient media like organic or inorganic fertilizers may be needed for optimum growth and development of the plant.

AUTHORS CONTRIBUTIONS

Akintunde Isiaka SODIMU: Investigation; data curation; writing-original draft; software / formal analysis; writing-review part, and editing.
Muhammed Fatima RASHEED: Conceptualization; validation,
David BAYO : Methodology, and editing

REFERENCES

Adji, B.I., Akafou, D.S., Kouassi, K.H., Houphouet, Y.P., Duminil, J. & Sabatier, S.A. (2021). "Bioclimate infuence on seed germination and seedling morphology parameters in Pterocarpus *erinaceous* Poir. 1804 (Fabaceae)," *International Journal of Environment, Agriculture and Biotechnology,* 6 (3), 001–015.

Adjonou, K., Abotsi, K.E., Segla, K.N. *et al.,* (2020). "Vulnerability of African rosewood (*Pterocarpus erinaceous*, Fabaceae) natural stands to climate change and implications for Silviculture in West Africa," *Heliyon,* 6, (6), Article ID e04031, 2020

Ansah, P.B., Addo-Danso, S.D., Belford, E.J. *et al.,* (2023) "Temperature and soil nutrients drive seed traits variation in Pterocarpus *erinaceous* (African rosewood) in Ghana," *Plant Environment Interactions.* 4 (4), 215 – 227.

Anthonio, F.A., & Antwi-Boasiako,C (2023). "Biological resistance of Coppiced and non-Coppiced rosewood (Pterocarpus *Erinaceous* Poir.) In the field and their Technological performance,"

Biaou, S., Gouwakinnou, G.N., Noulekoun, F., *et. al.,* (2023). "In-corporating intraspecific variation into species distribution models improves climate change analyses of a widespread West African tree species (*Pterocarpus erinaceous* Poir, Fabaceae)," *Global Ecology and Conservation*. 45, Article ID e02538.

Christine,O.,. Bienvenue, N.K.S., Adigla, A.W., Towanou, H., Yanik, A., & Justin, D (2021) "Traditional uses of African rosewood (Pterocarpus *erinaceous* Poir. Fabaceae) through the sociolinguistic groups and the pathways of conservation and sustainable management in Benin," *International Journal of Biodiversity and Conservation*. 13 (4), 200–213.

Dumenu, W.K., & Bandoh, W.N. (2016). "Exploitation of African rosewood (Pterocarpus *erinaceous*) in Ghana: a situation analysis," *Ghana Journal of Forestry,* 32:1–15

Imarhiagbe, O., Onyeukwu, I. I. Egboduku, W. O. Mukah, F. E. & Ogwu, M. C. (2022). "Forest conservation strategies in Africa: Historical Perspective, status and sustainable Avenues for progress," in Biodiversity in Africa: Potentials, Treats and Conservation, *Springer Nature*, *Singapore*.

Johnson, B. N., Quashie, M.L.A., Adjonou, K., Segla, K.N., Kokutse, A.D., & Kokou, K (2020). "Characterization of germination and growth of Pterocarpus *erinaceous* (Poir.) From Togo," *International Journal of Science and Research*, pp. 1744–1754

Kossi, A., Towanou, H., Habou, R., *et al.,* (2019). "Challenges of conservation and sustainable management of African rosewood (*Pterocarpus erinaceous*) in West Africa. *Natural resources management and biological Sciences,* pp. 289,

Leakey, R.R.B 1998) Agroforestry in Humid Lowland of West Africa. Some Foture Directive in Research. In: Duguma, B. (Ed). *Agroforestry,* (Special Issue) 40**,** 3 – 10.

Obiri, D. B. Abukari, H., Oduro, K. A. *et al.,* (2022). "Rosewood (*Pterocarpus erinaceous*) as a de facto forest common for local communities in Ghana," International Journal of Biodiversity and Conservation, 14 (1), 1–13.

Orwa, C.A., Mutua, A., kindt, R., Jamnadass, R. & Anthony, S. (2009). Agroforestry Tree Database: A Tree Reference and Selection Guide Version 4.0 *http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp*

Rabiou, H., Segla, K.N., Adjonou, K. *et al.,* (2015) "Estimate trees potential and wood cubage in natural stands of Pterocarpus *erinaceous* Poir based on ecological gradient in West Africa," *International Journal of Current Microbiology and Applied Science*s, 4 (5), 1103 – 1117

Sodimu, A.I (1998). *Influence of Granulated Ironstones Overlay Depth on the Growth of Teak (Tectona grandis Linn F.) Seedlings in South Western Nigeria.* A thesis submitted to Department of Forestry and Wildlife Management. University of Agriculture Abeokuta, Nigeria pp. 23

Sodimu, A. I., Olaifa, R.K., Baba, G.O., Lapkat, G. L., Olorukooba, M.M., Olumuyiwa, S.A., Salau, L.O. & Rasheed, F.M. (2021) Effects of Boiled Water On Germination Potential and Early Growth of *Faidherbia albida. (Del.) A. Chev.* Seeds in Kaduna Northern Guinea Savannah Agrological Zone of Nigeria. *Ethiopian Journal of Environmental Studies and Management.* 14 (2):208 – 222.

Usharani, K. V., Roopashree, K. M. & Naik, D. (2019). "Role of soil physical, chemical and biological properties for soil health improvement and sustainable agriculture," *Journal of Pharmacognosy and Phytochemistry.* 8 (5), 1256–1267

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

SOIL NUTRIENTS STATUS AND CROPPING SYSTEM IN PLASTIC HOUSE CONDITION OF CHANDRAGIRI MUNICIPALITY KATHMANDU

Nisha PANTHA[1]and Shova SHRESTHA[2]
[1]Himalayan College of Agricultural Sciences and Technology (HICAST),
[2] National Soil Science Research Centre, Nepal Agricultural Research Council (NARC)
Corresponding Author's email: nisha.pantha159@gmail.com

ABSTRACT

Soil nutrients are essential for plant growth, crop production, and sustainable agricultural development. In recent years plastic house is going popular around peri-urban areas of Nepal, including Chandragiri municipality of Kathmandu district. The research report covered the experience, learning and contribution on nutrient status and cropping system of plastic house of Chandragiri municipality of Kathmandu district. The main goal of the research was to access the nutrient status as well as other farm activities of the farmers to maintain soil fertility and enhance the crop yield for the sustainable agriculture. The research involved different activities like survey, interview and soil sampling. Total 50 plastic houses were visited randomly to achieve the goal and 20 samples out of 50 samples were randomly selected for the laboratory analysis to find out the status of nitrogen (N), phosphorus (P), potassium (P), Zinc (Zn) and Boron (B). The data collected from the interview related to the farm activities involved all 50 farms. The data was analyzed with the help of Microsoft excel and SPSS (version 25). The observed data revealed a range of soil nutrient concentrations, with varying levels of consistency across different variables. Nitrogen showed relatively stable concentrations with low variability. Available Phosphorus and Potassium showed wider fluctuations. Zinc also showed moderate variability. Boron contained the highest variability among the variables, reflecting significant inconsistency in its concentration levels across the samples. According to the survey data, the highly cultivated crop was found to be tomato and its average production was 53.3T/ha which concluded that plastic house farming in Chandragiri has high potential to produce all kind of the vegetable crops and improve their livelihoods if their obstacles such as limited investment, small landholding, lack of subsidies and market facilities are addressed.

Keywords: Cropping Systems, fertilizers, soil fertility, soil nutrient status, subsidies

INTRODUCTION

Nepal is characterized by diverse topography and climatic variations. From the fertile plains of Terai to the rocky terrain of the Himalayas the nation's agricultural productivity is deeply linked to its soil health (Ojha and Panday, 2021). However, the complex interaction of geological, climatic and anthropogenic factors increases the need for detailed examination of micronutrients (Shrestha, 2020). In the present condition, conventional rice-wheat rotations are increasingly replacing the diversified food crop production system with high- value vegetable crops across Nepal. Such systems are likely to enhance the demand for the micro- nutrients, such as boron (B) and Zinc (Zn), which are widely deficient throughout the country (Shrestha, 2021). Following the rice-wheat cropping system, maize-wheat is the second most important cropping system in Nepal, as well as the most prominent cropping system in mid-hills. In peri-urban areas, high value vegetable crops are replacing the cereal crops (Shrestha, 2021). Also, the plastic tunnel technology has become an important alternative technology for year-round crop production and is gaining popularity among farmers in the peri- urban areas of Kathmandu (Gautam, 2019).

According to Bhandari et al. (2016), Nepal has comparative advantages in tomato crop production, as evidenced by year-round production enabled by favorable agro-climatic conditions, an established distribution network, and rising demand. There is considerable potential for increasing tomato area and productivity through the use of appropriate technology. Tomatoes, being a labor-intensive crop, offer great potential for job creation in the country. Activities, such as transplanting, weeding, and harvesting are mostly accomplished manually by women.

While extensive research exists on soil nutrients and cropping systems, this study also examines the use of plastic tunnels in Chandragiri village aiming to address the gap and provide valuable insights for improving agricultural practices.

MATERIALS AND METHODS

Study area

The study was carried out in Chandragiri municipality, Kathmandu, Nepal. It is located at 27˚41' 25" N and 85˚ 13' 13" E. There are total 15 wards in this municipality. Macchegaun, Matatirtha, Bosigaun, Dhaulagiri, Naikap, Thankot and Gurjudhara was covered for the research. The soils are relatively fertile sandy and silty alluvial with some deposit of peat mare (diatomaceous clay). The climate of the study area is subtropical to temperate type. The warm season lasts from April to October and the cold season from December to February. The maximum and minimum average monthly temperature was reported to be in the months of June (28.9 ˚C) and January (18.3˚C) respectively. The highest (341.8 mm) average monthly rainfall was reported to occur in the month of July whereas the lowest (5.5 mm) average monthly rainfall occurred in the month of November (LLRC, 2016).

Sample size and data collection

The list of small farmers and large farmers were used as a sampling framework. 50 farms were randomly chosen from various locations within Chandragiri Municipality for this study. Farmers from all selected farms were interviewed using a pre-tested semi- structured questionnaire to collect primary information on agronomic practices, farm management, and production activities.

For soil analysis, 50 soil samples were collected from the surveyed farms and out of them 20 soil samples were selected randomly to ensure the representation from different parts of the municipality, with at least two samples taken from each area. The collected soil samples were analyzed in the soil testing laboratory to determine important soil properties, including soil pH, nitrogen (N), phosphorus (P), potassium (K), Zinc (Zn) and Boron (B). In addition to the primary data, secondary information was obtained from articles, journals, reports, websites and other relevant publications to support the findings of the study.

Statistical analysis

Data collected from the 50 surveyed farms were organized, coded, and summarized before being analyzed using descriptive statistical methods. The results obtained from the 20 soil samples were used to evaluate the soil nutrient condition of the study area. All statistical computations and data processing were carried out using Microsoft Excel and SPSS (version 25).

RESULTS and DISCUSSION

Soil nutrient status

The analysis of soil samples collected from plastic houses of Chandragiri Municipality revealed significant variation in nutrient status among the sampled farms. Nitrogen content ranged from low to moderate, indicating relatively stable distribution across samples. Available phosphorus showed considerable variation with some farms exhibiting higher concentrations. Potassium levels were generally adequate but varied among locations. Micronutrients such as Zn demonstrated moderate variability, whereas boron showed comparatively higher fluctuation across the sample sites. Overall, the results indicate considerable spatial variation in both macro-nutrients (Nitrogen, Phosphorus, and Potassium) and micro-nutrients (Zinc and Boron) across the plastic house of Chandragiri. While most major nutrients were found in moderate to adequate ranges, boron levels were comparatively low in several farms, suggesting possible micronutrient imbalance in some locations (Table 1).

Nitrogen Levels

Chandragiri's soil samples had a mean nitrogen concentration of 0.238% and a standard deviation (SD) of 0.754%. Nitrogen level showed moderate variation with a CV of 0.32 %

that indicates some variability around the mean. The nitrogen content ranged from 1.40 to 0.14 to 0.43% (Table 1). The narrow range and comparatively low mean suggests that nitrogen levels are often inadequate. For plants to flourish, nitrogen is necessary because it affects activities like protein synthesis and photosynthesis (Hassan et al., 2022). The low levels point to possible nitrogen shortage-related restrictions on crop productivity. This shortage may be caused by a lack of nitrogen-fixing bacteria, poor soil organic matter content, and ineffective fertilization techniques. It is advised to raise nitrogen levels by applying right dose of fertilizers and organic amendments (Pandit et al., 2022).

Table1. Soil Status of nutrients in the plastic house of Chandragiri

Farm No.	Sample Id	Nitrogen (mg^{-1})	Available Phosphorus (μgg^{-1})	Available Potassium (μgg^{-1})	Zinc (μgg^{-1})	Boron (μgg^{-1})
1	Machhegaun	0.227	81.74	121.72	4.88	0.17
2	Machhegaun	0.307	167.43	72.66	5.69	0.35
3	Machhegaun	0.434	219.12	100.21	2.52	0.52
4	Satungal	0.285	393.94	171.11	14.94	<0.10
5	Satungal	0.230	119.42	44.66	2.17	<0.10
6	Satungal	0.187	71.90	98.05	3.60	0.23
7	Satungal	0.179	135.41	170.96	2.06	0.35
8	Satungal	0.277	86.66	76.81	3.99	<0.10
9	Bosigaun	0.173	87.40	40.97	11.38	<0.10
10	Bosigaun	0.214	64.99	104.95	3.30	<0.10
11	Naikap	0.191	194.51	58.15	2.80	<0.10
12	Naikap	0.250	100.95	54.03	1.88	<0.10
133	Dhaulagiri	0.319	445.65	385.20	6.88	<0.10
14	Dhaulagiri	0.237	258.53	290.04	5.76	<0.10
15	Thankot	0.357	96.02	79.44	5.81	<0.10
16	Thankot	0.179	142.80	60.00	7.20	<.0.10
17	Thankot	0.140	105.87	16.05	7.45	0.35
18	Dahachok	0.162	073.87	40.50	3.90	<0.10
19	Matatirtha	0.187	103.41	42.92	3.17	0.14
20	Matatirtha	0.161	66.96	20.96	10.39	<0.10
Mean		0.238	150.83	102.47	5.4885	0.11515
SD		0.750	106.37	92.26	3.46178	0.15581
CV		31.71%	70.52%	90.04%	63.07%	102.84

Available Phosphorus

Significant variation can be seen in the phosphorus levels in the soil samples from Chandragiri which ranged from 64.99 to 445.65kg/ha, with a mean of 150.83kg/ha and an SD of 106.37kg/ha (Table 1). This indicates a wide range of values with some areas showing higher phosphorus level. For plants to transport energy, perform photosynthesis, and produce roots, phosphorus is essential (Fathi and Afra, 2023).
The high mean value implies that there is, on average, enough phosphorus available; nevertheless, the broad range shows that there is unequal distribution, with some locations having insufficient phosphorus. Variations in soil pH, organic matter concentration, and fertilizer application history could be the cause of this heterogeneity. By putting into practice site-specific phosphorus management techniques, such as routine soil testing and customized fertilizer, it will be possible to guarantee balanced phosphorus availability throughout the entire region, which will promote crop productivity.

Available Potassium

The soil samples from Chandragiri had varying potassium levels, with a mean value of 102.47kg/ha, SD of 92.26kg/ha (Table 1). The range of potassium levels was 16.05kg/ha to 385.20kg/ha. Potassium is necessary for a number of physiological processes in plants, such as photosynthesis, enzyme activation, and water management (Pandey and Mahiwal, 2020). The significant variation implies that although certain regions might have adequate potassium, others might not. The soil organic matter level, texture, and inheritance nutrient status could all be contributing causes to this. A focused strategy to potassium management, such as site-specific fertilization and soil amendments, is required to resolve these disparities. By doing this, it will be ensured that potassium levels in all locations are sufficient, encouraging healthy plant growth and raising agricultural yields.

Zinc Level

Soil samples from Chandragiri exhibited a moderate degree of diversity in their Zn contents; ranging from 1.88 to 14.94µg/g, with a mean of 5.4885µg/g, SD of 3.46178µg/g (Table 1). Plants need Zn for the synthesis of proteins and the operation of enzymes (Shrestha et al., 2020). While the moderate variability points to possible inadequacies in some places, the mean result showed that zinc levels are generally adequate. Reduced agricultural yields and stunted growth might result from zinc deficiency. The pH of the soil, the amount of organic matter, and the way zinc interacts with other nutrients are factors that affect Zn availability. To maintain sufficient Zn levels and prevent deficiencies, regular soil testing and proper zinc fertilization are advised. This will support the best possible health and production of plants (Vista and Shrestha, 2019).

Boron Level

Soil samples from Chandragiri had consistently low amounts of boron, with mean values of 0.1515µg/g, SD of 0.15581µg/g and ranges from 0.05 to 0.52µg/g (Table 1). Boron had highest variability suggesting extreme variation and potentially outlier values in the data set. For plants to construct their cell walls, develop their reproductive systems, and expand overall, they need boron (Shrestha et al., 2020). The consistently low levels point to a general B shortage, which may cause irregularities in the growth of flowers and fruits, poor root and shoot development, and decreased crop yields. To improve soil fertility and plant health, targeted boron fertilization is essential.

Fertilizer Application and Production of Tomato in Chandragiri

Overall, the data indicates that there is a heavy reliance on organic fertilizer to improve soil quality. Among the chemical fertilizers used, urea is most common, followed by DAP and potash. This suggests that while organic methods are the main priority, chemical fertilizers are still used in smaller amounts to support crop growth. The result (Table 2) explains the average fertilizer application and production of the 50 farms that were visited for survey in Chandragiri.

The data showed the mean application of the fertilizers (Table 2). According to (PMAMP, 2024) the recommended dose for hybrid tomato in controlled poly house is 200:180:80 NPK kg/ha and hybrid cauliflower is 200:120:100 NPK kg/ha while recommended dose of compost is 15000kg/ha for both crops. This shows the fertilizers applied by the farmers is higher than that of recommended dose but the average production of tomato is 53.3 T/ha and cauliflower is 5000kg/ha, which displays the information that fertilizers application above the threshold level do not increase the production instead production depends on the farm management practices too.

Table2. Mean fertilizer application by farmers in Chandragiri

Fertilizers	Mean Application of fertilizer ($kgha^{-1}$)
Urea	277
DAP	204
Potash	165
FYM	24200
Zinc Sulphate	40
Borax powder	40

This result aligns with the observations of (Bhandari et al., 2016), who observed that Nepalese tomato growers frequently apply surplus nutrients under the mistaken belief that it will guarantee better harvests. In this study, the intensive use of Urea (277 kg/ha) and farm Yard Manure (24,200kg/ha) failed to produce a proportional rise in yield, indicating a clear nutrient disproportion. These findings reinforce the perspective of (Gautam, 2019),

suggesting that crop productivity in plastic tunnels is driven more by precise environmental management than by the sheer quantity of additives. Ultimately, the current approach to soil fertility in the region appears wasteful; shifting toward data-driven, soil-test- base applications could lower expenses while preserving the long-term health of the land. To enhance agricultural productivity in Chandragiri Municipality, several strategic actions are proposed based on direct input from the farming community. Initially, a jointly effort between public and private entities is required to upgrade market infrastructure, provide financial support for inputs, and introduce modern farm equipment. Furthermore, moving away from general fertilizer use towards precise, site- specific nutrition plans derived from soil analysis is vital for ensuring crops obtain the correct nutrient balance. This tailored approach is a key to maximizing plant health and efficiency.

Major Crops Grown in Chandragiri

The bar diagram shows the distribution of cropping system in Chandragiri based on the main crops grown. According to the survey data; 34% of the farmers cultivate and produce tomato only following the cropping pattern: tomato-tomato-tomato; 60% of them produce cauliflower and tomato following the cropping pattern: tomato-cauliflower- tomato; 4% of them produce tomato and broccoli following the pattern tomato- broccoli-tomato and only 2% of the farmers produce tomato along with strawberry following the pattern tomato-tomato/ strawberry-tomato (Figure 1). This clearly shows that most commonly grown crop is tomato whereas least grown item is strawberry.

When comparing to the earlier research conducted in the Kathmandu valley, the 60% adoption of a cauliflower rotation signifies a favorable transition toward diversified cropping. The shift is more effective at disrupting pest life cycles and maintaining soil integrity than traditional monoculture methods. The scientific contribution of this research lies in demonstrating that while the transition to plastic house technology is high, further promotion of diverse crops such as broccoli and strawberry is essential to ensuring the long-term ecological and economical sustainability of these farming systems.

Use of Organic Fertilizers in plastic house

Different kinds of organic fertilizers are used in plastic farms of Chandragiri. Some are used singly and some in combined form. According to the available data, majority of farmers relay on FYM only which is 56% (Figure 2). Second majorly applied organic fertilizer is combination of FYM and poultry which is 8%. Combination of FYM and mustard oil cake and combination of FYM, compost and combination of FYM and vermicompost are applied by 6% of the farmers. 4% of the farmers apply poultry and combination of FYM and jhol maal whereas Combination of FYM and bone meal, combination of FYM, Vermicompost and mustard oil cake, combination of FYM, vermicompost and poultry manure and combination of oil cake and jaggery are applied by 2% of the farmer which is the least applied organic matters in Chandragiri.

The heavy reliance on FYM observed in this study aligns with the findings of (Bhandari et al., 2016), who noted that traditional organic matter remains the primary nutrient source for Nepalese vegetable growers. However, the low adoption rate of concentrated organic inputs like vermicompost and jhol maal suggests an opportunity for improvement in nutrient density. As highlighted by (Fathi amd Melidiniya, 2023), the synergy between diverse organic sources can significantly enhance microbial activity and plant growth resilience compared to single-source amendments. Furthermore, the scientific implication of these results suggests that while farmers are committed to organic practices, the high application volumes, as seen in earlier data may be a response to the lower nutrient concentration of raw FYM. This study supports the economic perspectives of (Gautam, 2019), suggesting that transitioning toward higher-quality organic combinations, such as FYM enriched with mustard oil cake or poultry manure, could optimize yield efficiency in intensive plastic tunnel environments. Promoting these diversified organic strategies is essential for the ling-term ecological sustainability of the Chandragiri agricultural sector.

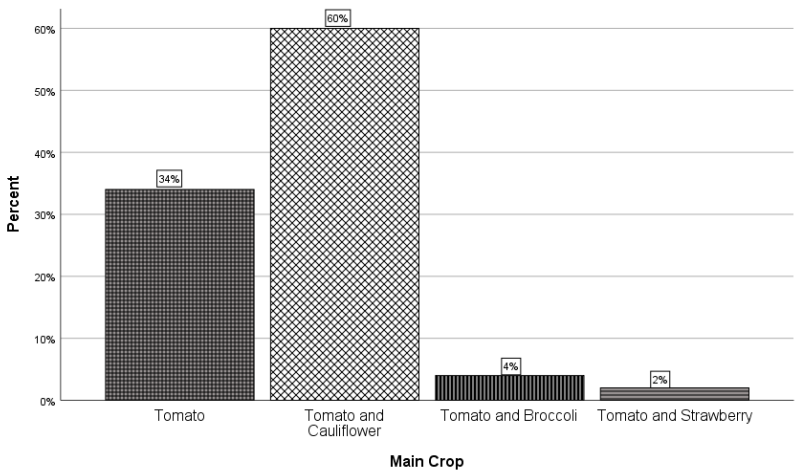


Figure 1. Distribution of farmers growing various crops in Chandragiri municipality under the plastic house

Use of Inorganic Fertilizers

The pie-chart shows the distribution of inorganic fertilizers in plastic farms of Chandragiri municipality. It is divided into three segments which are: Combination of urea, DAP along with potash which is applied by 90% of the farmers (Figure 3): combination of DAP with potash which is applied by 6% of the farmers and no use of any kinds of inorganic fertilizers which means 4% of the farmers do not apply any kinds of inorganic fertilizers. This distribution indicates a heavy reliance on combination of urea, DAP and potash as the primary source inorganic fertilizer. The survey results reveal an overwhelming dependence

on a conventional mineral fertilizer regime, with 90% of respondents utilizing a tri-partial combination of Urea, DAP (Diammonium Phosphate), and Potash. This nearly universal reliance on synthetic inputs suggests a standardized approach to nutrient management among tomato growers in Chandragiri, likely driven by established market availability and historic yield responses. The preference for this specific chemical combination reflects broader agricultural trends across the Bagmati Province. However, as noted by (Bhandari et al., 2021), the continuous application of high- nitrogen fertilizers like urea, without adequate organic supplementation, often leads to long- term soil health degradation, including acidification and a decline in microbial activity. The concentrated use of DAP and Urea carries specific risks for protected plastic tunnels. To strengthen the scientific value of these results, considerations should be given to balance nutrient application, integrated nutrient management and soil testing services.

Tomato cultivars

The diagram displays the distribution of varieties of tomatoes in plastic farms of Chandragiri. Majorly cultivated breed is Srijana which is 62% which is more than half of all types used (figure 4). Mix breed of Srijana along with Samjana is second highly cultivated breed which is 14%. Combination of Sarita, Samjhana, Srijana and Karma77 is cultivated in 8% of the farms. Combination of Srijana and Sarbashrestha is cultivated by the 4% of the farms. The least cultivated breeds are Samjhana, combination of Srijana with Karma777, combination of Karma777, Sarita along with Sarba Shrestha and combination of Sarbashrestha and Karma777 which is 2%. The dominance of the Srijana hybrid in Chandragiri municipality indicates a clear farmer bias toward cultivars characterized by robust yields and resistance to soil-borne pathogens, especially bacterial wilt.

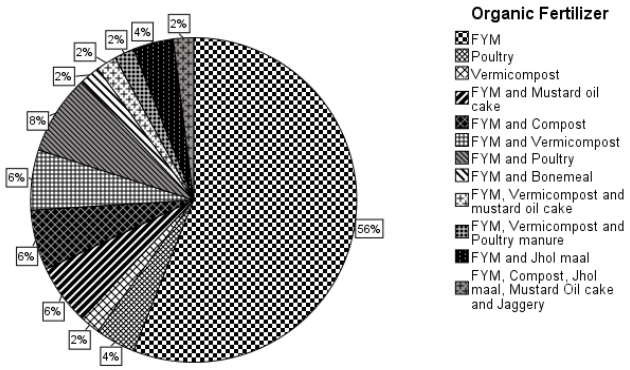


Figure 2. Different Kinds of organic fertilizers used by farmers in Chandragiri

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

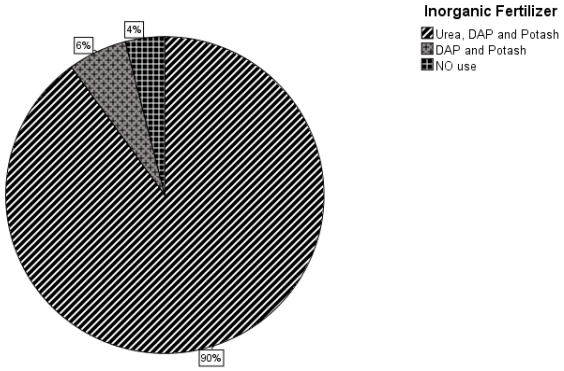


Figure 3. Different inorganic fertilizers used in Chandragiri Municipality?

This trend aligns with observations by (Gautam et al., 2024), who identified Srijana as the premier choice for Nepalese growers due to its extended productive window and post-harvest durability which are essential for maintaining fruit quality during transport to the Kathmandu valley markets.When considering Srijana and its blends, the total adoption exceeds 75%, signaling a significant lack of genetic diversity in local tomato production. While such uniformity ensures predictable market supply, it creates a precarious monoculture environment. Conversely, the marginal use of alternative cultivars such as Samjhana or karma777 (ranging from 2% to 4%) suggests that these varieties may suffer from limited commercial appeal or struggle to adopt to the specific temperature and humidity profiles found in Chandragiri's plastic tunnel systems.

Availability of input subsidies The bar graph reveals the distribution of subsidies especially inputs for the farm activities by the Prime Minister Agriculture Modernization Project (PMAMP) in Chandragiri. Majority of the farmers in Chandragiri were well known about the subsidies but they were not provided because of small land holding and non-registration of farms which is 68% whereas 10% of the farmers are unaware about any kind of subsidies as they were illiterate (figure 6). 14% of the farmers were getting powertiller, plastic and pipe. Only 2% of the farmers were provided by power tiller, plastic and pipe, other 2% were provided by pipe along with drum, also another 2% of the farmers got plastic with pipe and last 2% of the farmers got power tiller along with pipe. These subsidies were granted by PMAMP. The data indicates a significant gap between subsidy awareness and actual utilization within Chandragiri municipality. While a vast majority of the farming population is cognizant of the Prime Minister Agriculture Modernization Project (PMAMP) initiatives, a striking 68% remain unable to access these resources due to structural constraints, especially small land holding sizes and a lack of formal farm registration.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

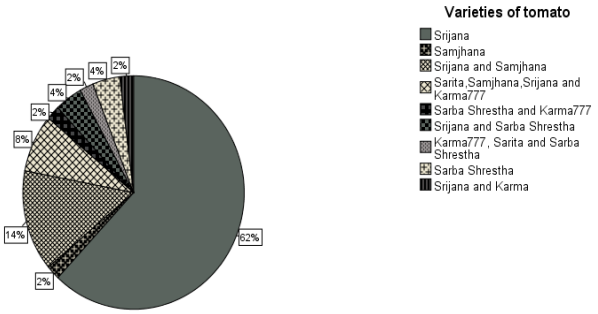


Figure 4. Major breeds of tomato cultivated in Chandragiri

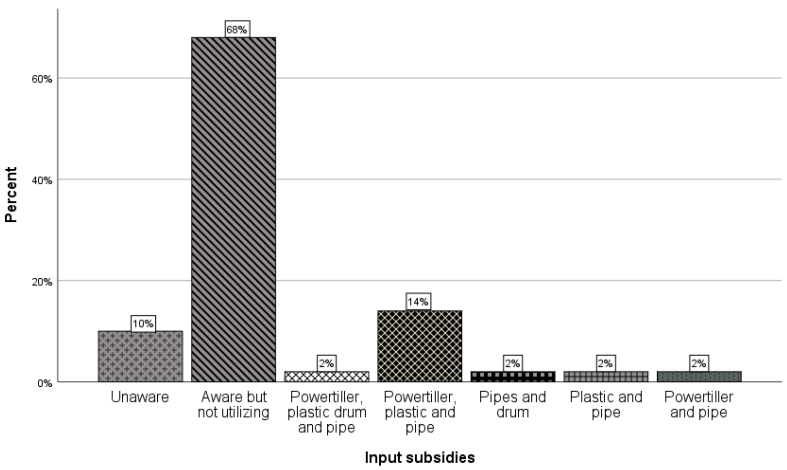


Figure 5. Utilization of subsidies provided by PMAMP

This disparity between knowledge and access resonates highly with the conclusions of (Adhikari et al., 2021), who highlighted that the administrative prerequisites of Nepalese agricultural frameworks frequently create unintended obstacles for smallholder cultivators. The mandatory institutional enrollment functions as a structural barrier, effectively excluding the most vulnerable producers from acquiring essential technological assets, such as protected cultivation structures and mechanized tillers, which are vital for enhancing productivity.

CONCLUSION

The results of this research highlight the pivotal impact of protected cultivation on agricultural modernization in Chandragiri Municipality. Although the 60% prevalence of tomato- cauliflower successions indicates a lucrative shift toward off-season vegetable production, comprehensive pedological evaluations reveal a marked disequilibrium in essential nutrient profiles. Analytical data showed a mean nitrogen concentration of 0.238%, coupled with significant fluctuations in potassium, phosphorus, and boron levels. Such variability suggests an imminent risk of either acute nutrient depletion or potential mineral phytotoxicity within specific farm sites.

Despite these heterogeneous soil profiles, producers continue to apply fertilizers at rates that substantially surpass recommended agronomic thresholds, specifically averaging 277kg/ha of Urea and 24,200kg/ha of Farm Yard Manure. The observation that mean tomato yields (53.3 t/ha) remain stagnant despite such intensive inputs confirms that existing fertilization strategies are mismatched with the actual physiological demands of the crop and the baseline soil status. Therefore, the future sustainability of plastic house enterprises in this region depends upon a transition from broad- spectrum nutrient applications to a precision- based management framework rooted in routine soil analysis.

RECOMMENDATIONS

To optimize agricultural output and ensure the sustainability of farming enterprises within Chandragiri Municipality, several evidence-based strategies are recommended. Initially, a fundamental shift from broad- spectrum fertilization to a precision- based nutrient management framework which is rooted in systematic, Site-specific soil diagnostics is vital. This calibrated approach is designed to provide crops with precise nutritional requirements, thereby mitigating the systematic inefficiencies associated with the current over-application of fertilizers. Additionally, local agricultural extension bodies should launch targeted outreach programs to educate the farming community on how to efficiently access existing subsidies for essential inputs like seeds and fertilizers. Finally, the implementation of a regulated price-support mechanism by the state is essential to insulate producers from the secure equitable financial compensation for their agricultural contributions.

REFERENCES

Adhikari, J., Shrestha, M. and Paudel, D., (2021). Nepal's growing dependency on food imports: A threat to national sovereignty and ways forward. *Nepal Public Policy Review*, *1*, pp.68-86.

Bhandari, N.B., Bhattarai, D. and Aryal, M., (2016). Demand and supply situation of tomato in Nepal, 2015/16. *Agribusiness Promotion & Market Development*

Directorate, Ministry of Agriculture Development, Department of Agriculture, Government of Nepal, Lalitpur, Nepal.

Fathi, A. and Mehdiniya Afra, J., (2023). Plant Growth and Development in Relation to Phosphorus: A review. *Bulletin of the university of agricultural sciences & veterinary medicine Cluj-Napoca. Agriculture*, *80*(1).

Gautam, A., Lamichhane, S., Chapagain, B. and Kattel, R., (2024). An economic study on the production and marketing of tomato (*Solanum lycopersicum)* in Pokhara Metropolitan City, Kaski district of Nepal. *Food and Agrieconomics Review,* 4(2), pp.70-77.

Gautam, P., (2019). Economics of tomato production under plastic tunnel technology in peri-urban areas of Kathmandu valley.

Grzebisz, W., 2021. Site-Specific nutrient management. *Agronomy*, *11*(4), p.752.

Hassan, A., Gulzar, S. and Nawchoo, I.A., (2022). Role of nitrogen in photosynthesis. In *Advances in Plant Nitrogen Metabolism* (pp. 86-95). CRC Press.

Kc, D., Jamarkattel, D., Maraseni, T., Nandwani, D. and Karki, P., 2021. The effects of tunnel technology on crop productivity and livelihood of smallholder farmers in Nepal. *Sustainability*, *13*(14), p.7935.

Ojha, R.B. and Panday, D. eds., (2021). *The soils of Nepal*. Berlin/Heidelberg, Germany: Springer International Publishing.

Pandey, G.K. and Mahiwal, S., (2020). Potassium in plant growth and development. In *Role of potassium in plants* (pp. 37-43). Cham: Springer International Publishing.

Pandit, N.R., Choudhary, D., Maharjan, S., Dhakal, K., Vista, S.P. and Gaihre, Y.K., 2022. Optimum rate and deep placement of nitrogen fertilizer improves nitrogen use efficiency and tomato yield in Nepal. *Soil Systems*, *6*(3), p.72

PMAMP., (2024). *Agriculture Diary 2024,* Ministry of Agriculture and Livestock Development (MoALD), Prime Minister Agriculture Modernization Project.

Shrestha, S., Becker, M., Lamers, J.P. and Wimmer, M.A., (2020). Boron and zinc fertilizer applications are essential in emerging vegetable-based crop rotations in Nepal. *Journal of Plant Nutrition and Soil Science*, *183*(4), pp.439-454.

Shrestha, S., (2020). *Diagnosing and managing zinc and boron deficiencies in emerging crop production systems of Nepal* (Doctoral dissertation, Universitäts-und Landesbibliothek Bonn).

Shrestha, S., Becker, M., Lamers, J.P. and Wimmer, M.A., (2021). Residual effects of B and Zn fertilizers applied to dry season crops on the performance of the follow-up crop of maize in Nepal. *Journal of Plant Nutrition and Soil Science*, *184*(2), pp.238-245.

Vista, S.P. and Shrestha, A., (2019). Availability of micronutrients, PGRS, soil conditioners, enzymes, hormones, etc. in Kathmandu valley of Nepal. *Journal of Pharmacognosy and Phytochemistry*, *8*(1), pp.542-548.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Access to Formal Agricultural Credit and Barriers Among Farmers in Kathmandu Valley, Nepal

Brishti SUWAL and Rojan KARKI
Himalayan College of Agricultural Sciences and Technology (HICAST)
Corresponding Author's Emaiil: karkirojan.ag@gmail.com

ABSTRACT

Agriculture remains one of the key sectors in Nepal's economy. However, many farmers struggle to access formal credit to enhance their farm productivity and sustainability. This study assessed farmers' access to formal credit in Kathmandu Valley and identified the main barriers limiting its use. A sample of 105 farmers from Kathmandu, Bhaktapur, and Lalitpur districts was selected using stratified sampling, based on the proportion of farmers in each district. Data were collected using structured questionnaires. The analysis was conducted using descriptive statistics. The results showed that although 70% of the farmers reported awareness of formal credit institutions, only 27% of them had successfully accessed credit. Among those who accessed credit, most relied on commercial banks and cooperatives with little assistance during the application process. The most significant barriers were long processing times and strict collateral requirements, while high interest was surprisingly not seen as a major issue, possibly due to more pressing concerns. The findings highlight the need to simplify credit procedures, reduce collateral requirements, and provide better guidance and awareness programs for farmers. Addressing these issues is essential for improving financial inclusion and supporting the agricultural sector in Kathmandu Valley.

Keywords: Descriptive statistics, farmers, financial inclusion, formal credit, significant barriers

INTRODUCTION

Agriculture has always been the most important economic sector in the majority of developing countries, not only for its role in supplying food and employment but also as a significant factor in the overall economic development. The sector has changed its role from being passive to being an active partner in industrial expansion (Thorbecke, 1969). In Nepal, agriculture is the backbone of the country's economy and society; it employs 66 percent of the population and contributes 25.8% of the GDP (MoF, 2021). It supports rural livelihoods and continues to impact the country's economic performance (Dahal & Thapa, 2020; Chaudhary & Chaudhary, 2023). Agricultural development, on the other hand, depends on a variety of interrelated factors such as the landholding system, access to credit, availability of modern technologies, socio-economic conditions, and the development of

infrastructure, including irrigation and marketplaces (Dumre et al., 2020). Despite its importance, agricultural productivity in developing countries, including Nepal, remains low due to limited financial capacity among smallholder farmers. According to Oni et al. (2009), smallholder farmers generally do not have enough money to spend on modern technologies, which limits their income potential. In this case, agricultural credit plays a vital role. Access to credit enables farmers to obtain seeds, fertilizers, irrigation equipment, and machinery, thereby strengthening food security and supporting the sustainability of rural livelihoods (Mishra, 2021; Irshad et al., 2021). Formal credit, in particular, has been linked to improvements in agricultural productivity and modernization (World Bank, 2018; Zabatantou et al., 2023). Although formal financial institutions, including banks, cooperatives, and microfinance organizations, are trying to provide credit facilities with lower interest rates and easier application processes (Rastra Bank, 2014; Irshad et al., 2021), access remains limited. Farmers commonly face barriers such as high interest rates, strict collateral requirements, lengthy and complicated loan processes, low awareness of credit schemes, and limited financial literacy (Rastra Bank, 2014; Ali et al., 2023). These challenges are further intensified in the Kathmandu Valley, where rapid urbanization has led to shrinking agricultural land and increasing land prices. Farmland has been replaced by housing, factories, highways, and other construction works (Zurick & Rose, 2010; Bapak, 2017). Because of this, farmers in the Valley face more challenges compared to those in rural areas. Previous reports indicate that farmers in the Valley struggle with high borrowing costs, lack of information, collateral-related issues, and slow loan approval processes (Mishra, 2021; Rastra Bank, 2014). While many studies have examined formal credit access in rural Nepal, little is known about farmers' access and the barriers they experience in the rapidly urbanizing and peri-urban areas of Kathmandu Valley. Understanding farmers' access to credit and the challenges they encounter is essential for improving financial inclusion in these transitioning areas. Therefore, this article concentrates on access to formal credit and the barriers faced by farmers within the study area.

MATERIALS AND METHODS

The study was conducted in Kathmandu Valley, covering the Kathmandu, Bhaktapur, and Lalitpur districts. The sample size was calculated using Cochran's formula (Cochran, 1953), with a 95% confidence level, a 7.5% margin of error. Based on a study by Shakya et al. (2020), it is estimated that 19% of farmers in Nepal have access to formal credit. Given these parameters, the calculated sample size for this study is 104, and a total of 105 farmers were surveyed. A stratified sampling method was used to ensure fair representation of the three districts in Kathmandu Valley, with samples proportionally distributed based on the number of farm holdings: 50 from Kathmandu, 29 from Lalitpur, and 26 from Bhaktapur. Before the main survey, a pilot test with about 10% of the sample was conducted to improve the clarity and relevance of the questionnaire. Primary data were collected through structured and semi-structured interviews. Secondary information was obtained from reports, journals, books, and official publications from sources such as NRB, MoALD, and CBS, which supported the background and analysis of the study.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

RESULTS AND DISCUSSION

Overview of demographic influence on credit access

Gender and credit access

This section highlights the gender composition of the respondents. It provides insight into the participation of male and female farmers in agricultural activities. The result shows, 68 were male (65%) and 37 were female (35%). Thus, the participation of male and female farmers was remarkably unequal. This gap highlights how agricultural decision-making in Nepal is still largely dominated by men. Research backs this up, showing that traditional patriarchal norms often restrict women's financial independence. In most cases, it's men who control the money and make the major decisions (International Organization for Migration, 2018). However, a closer analysis reveals a detailed picture. Women applied for credit more often and had a higher success rate than men. This is possibly due to targeted support from cooperatives and microfinance institutions, as well as policy incentives such as tax exemptions for women-led enterprises (Government of Nepal, 2020). On the other hand, the small number of female respondents means this high success rate should be interpreted cautiously and may not hold with a larger sample.

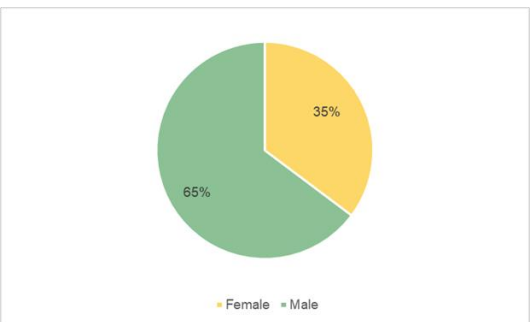


Figure 1. Gender-wise application and access to agricultural credit

Education and credit access

The findings in terms of level of literacy revealed that the majority (49%) had completed their high school, followed by 42 individuals (40%) with education up to SEE (Secondary Education Examination). Only 10 respondents (9%) had no formal education, while just 2 respondents (2%) had a university-level qualification. This finding suggests that most participants had at least a basic level of education. The results show a clear positive relationship between education level and access to agricultural credit. Farmers with no formal education had the lowest application and approval rates, while those with higher

levels of education were increasingly more likely to apply for and receive credit. Overall, education appears to enhance awareness, confidence, and ability to access formal agricultural credit, a finding consistent with Mishra (2021), who reported that higher education significantly increases farmers' use of formal credit.

Age and credit access

The age distribution revealed that 43% of the respondents were aged between 35 and 45 years, highlighting that middle-aged farmers are most active in agriculture. While 30% of the respondents were aged below 35 years, 27% belonged to the age group over 45 years. Farmers aged 35–45 years were the most active in agricultural credit use, with 35.56% applying and 31.11% receiving credit.

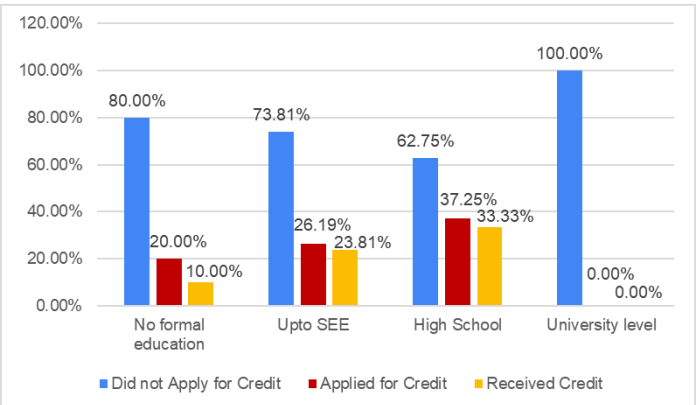


Figure 2. Education-wise application and access to agricultural credit

Younger farmers (below 35 years) had a lower application rate (25%) but a 100% success rate among applicants, suggesting greater awareness of credit procedures. Farmers aged over 45 years were the least involved, with 28.57% applying and only 21.43% receiving credit. Overall, age influences both credit application and approval, though its effect varies across contexts, as supported by Pandey and Timilsina (2024) and contrasting findings by Singh et al. (2023). The chart compares farmers' access to agricultural credit across Bhaktapur, Kathmandu, and Lalitpur districts. In all three districts, around 30% of farmers applied for credit. Bhaktapur showed the most favorable outcome, as all applicants (30.77%) successfully received credit. In Kathmandu, although 30% applied, only 24% of respondents received credit, indicating some rejections. Lalitpur performed moderately well, with 31.03% applying and 27.59% receiving credit. Overall, while application rates were similar across districts, credit approval varied, with Bhaktapur performing best and Kathmandu the weakest, possibly due to lower levels of formal farm registration in Kathmandu.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Annual income of the respondents

The distribution of annual income of respondents shows that 38% of the farmers earned between 3 to 5 lakhs, constituting the largest income group. 23% reported earnings of less than 3 lakhs annually.

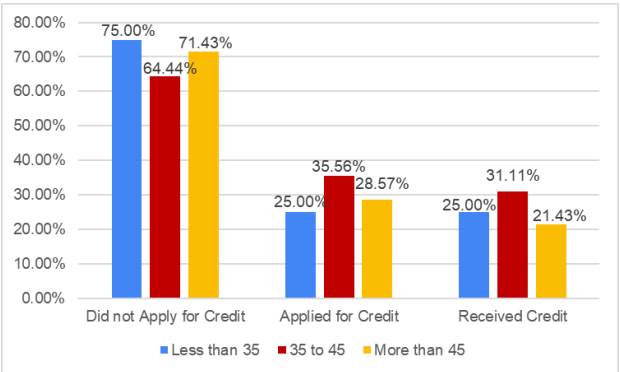


Figure 3. Age-wise application and access to agricultural credit District-wise credit access

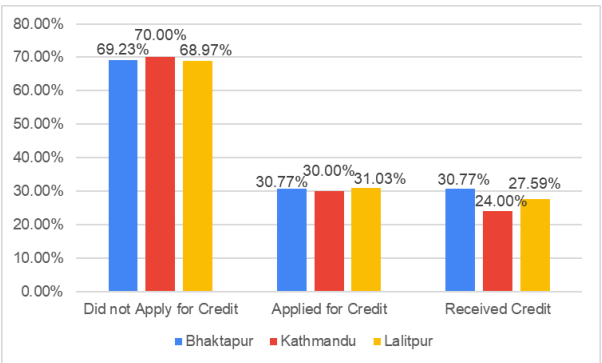


Figure 4. District-wise access to agricultural credi

About 22% and 8% of farmers reported income between 5 to 7 lakhs, and 7 to 10 lakhs respectively while, 9% earned more than 10 lakhs per year. Overall, this indicated that about 61% of respondents had an annual income below 5 lakhs, suggesting that the majority of farmers in Kathmandu Valley operate with limited financial resources. This may restrict their ability to access credit or adopt new technologies. Similarly, Zulfiqar et al. (2020) found that off-farm income had a negative and significant effect on agricultural credit access.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

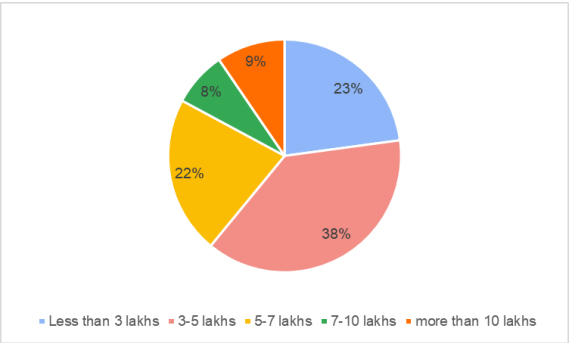


Figure 5. Annual income of the respondents

Land under cultivation

The results show that about 38% of the respondents reported having between 2 to 5 ropani (0.10 to 0.25 ha) of land, making it the most common landholding size among the surveyed farmers. Around 22% of farmers cultivated more than 10 ropani (> 0.51 ha), while another 20% farmers cultivated between 1 to 2 ropani (0.05 to 0.10 ha). 19% of respondents cultivated in the 5 to 10 ropani (0.25 to 0.51 ha) range, and only 1% had less than 1 ropani (< 0.05 ha).

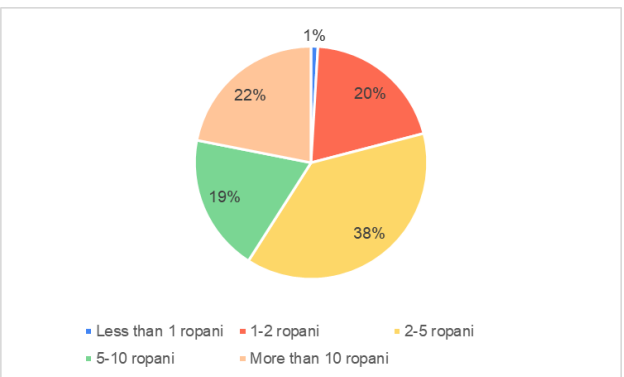


Figure 6. Land under cultivation by respondents

Overall, small to medium landholdings are most common, though some farmers cultivate larger areas. Similar patterns of smallholder dominance have been reported in Nepal. Mishra (2021) noted that most farmers in Western Nepal have less than 0.5 ha, limiting credit access. Pandey and Timilsina (2024) also found that land size affects productivity and access to credit.

Farm registration

The survey results show that 60% of the farms were not registered, while 40% were registered. This shows a gap in formal agricultural documentation among farmers in Kathmandu Valley.

Awareness of formal credit institutions among farmers

The survey revealed that 70% of the farmers were aware of formal credit institutions that provide agricultural credit, while 30% of them were not aware of it. This shows a high level of exposure to formal credit sources among the farming community. This aligns with Campero and Kaiser (2013), who found that awareness is a key factor influencing the use of formal credit. Efforts to improve awareness appear to be effective, but the 30% of farmers who are still unaware need to be reached to improve access to formal credit.

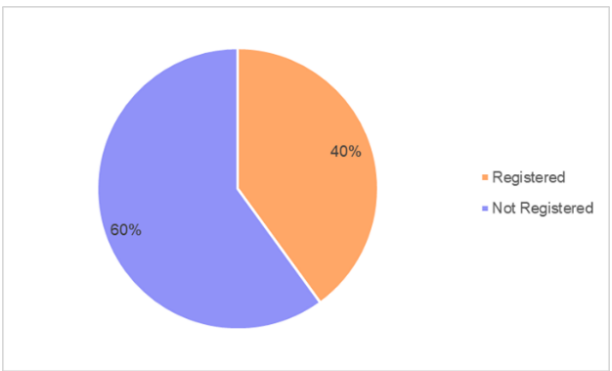


Figure 7. Farm registration *Credit awareness and use*

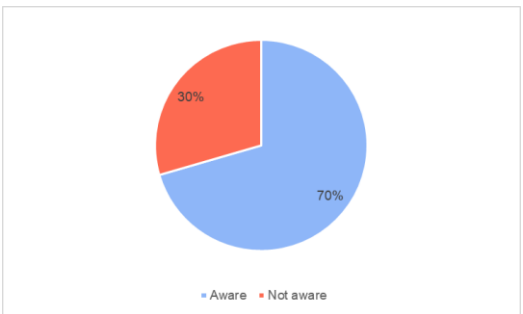


Figure 8. Awareness of Formal Credit Institutions

Access to and ease of formal agricultural credit

The survey shows that out of 105 respondents, only 28 farmers (27%) had access to formal credit, while the majority, 77 respondents, did not. The finding shows a relatively lower level of credit access among the farmers in the Kathmandu Valley, suggesting that formal credit use in the agriculture sector is still at a low level. However, this is slightly higher than the 19% reported by Shakya et al. (2020) for farmers in Nepal, suggesting that while access may be better in Kathmandu Valley, formal credit remains largely underutilized in the agricultural sector. Among those who successfully received credit, perceptions of the application process varied. Most respondents found it challenging: 64% rated it very difficult, 18% difficult, 14% neutral, and only 4% considered it easy, with none finding it very easy. These results highlight that not only is access to credit limited, but the process itself is difficult, reflecting structural barriers within Nepal's agricultural credit system. Such difficulties can directly reduce credit utilization and discourage future applications, consistent with findings from Rastra Bank (2014).

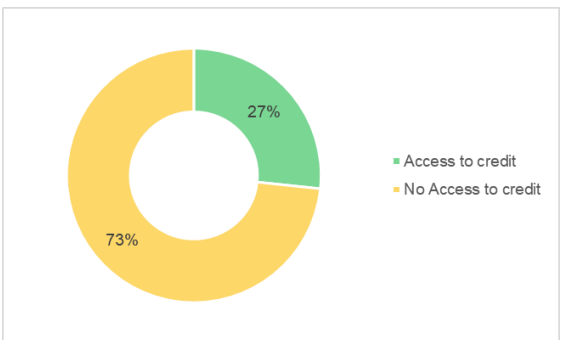


Figure 9. Access to credit

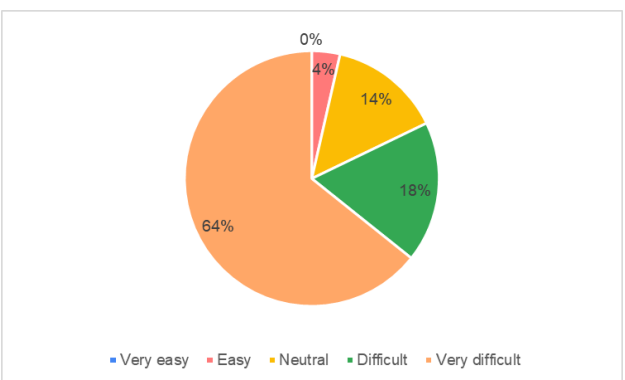


Figure 10. Ease of accessing credit

Source of credit

The survey indicates that among the 28 respondents who had access to credit, the majority of them (57.14%) received credit from formal sources such as commercial banks, cooperative institutions (28.57%), and microfinance institutions (14.29%). None of the respondents reported receiving credit through government schemes or subsidies. This aligns with Gupta et al. (2015), who noted that formal sources of agricultural credit in Nepal included development banks, farmers' cooperatives, and other financial institutions. This shows the important role of banks and cooperatives in supporting agricultural activities and suggests that enhancing farmers' access to these institutions could improve credit availability.

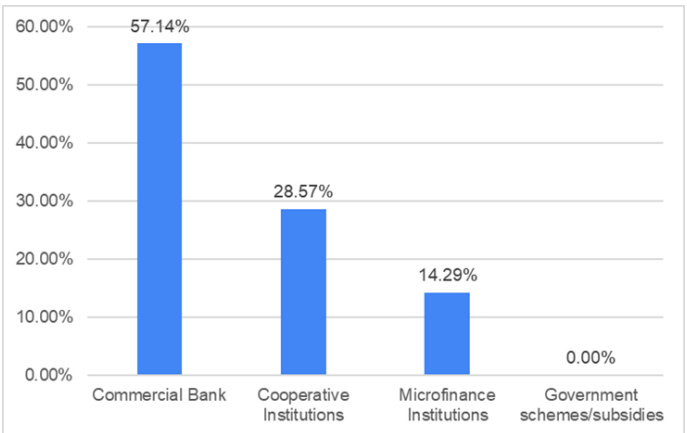


Figure 11. Source of credit

Assistance while applying for credit

Among the respondents who received credit, only 11% received any form of training or guidance during the application process, while 89% did not receive it. This shows that most of the farmers applied for credit without any guidance or support from the institutions. Because of this, many farmers probably struggled to understand the steps involved. This could also explain the reason why many farmers found the process to be very difficult. The findings highlight that assistance is important for easing credit access. This aligns with NRB (2020), which stresses the need for guidance and awareness for financial consumers, including farmers. The low support seen in this study suggests a gap between what policies promote and what farmers actually experience in practice.

Source of information about agricultural credit

The survey reported that 32% of the respondents received information about agricultural credit from friends, family, or neighbors. This was followed by social media (25%) and

radio/TV (18%). A few of them got information from newspapers (14%), while only 11% reported learning about credit through a formal training program. This aligns with Ukwuaba et al. (2020), who reported that farmers mainly relied on informal networks for credit information because it is easier and faster. Few farmers use formal channels, showing that awareness programs are not enough, and many farmers might not be getting complete or reliable information about formal credit. Therefore, enhancing awareness campaigns and educational efforts by credit institutions and government agencies could help improve farmers' understanding and access to formal credit.

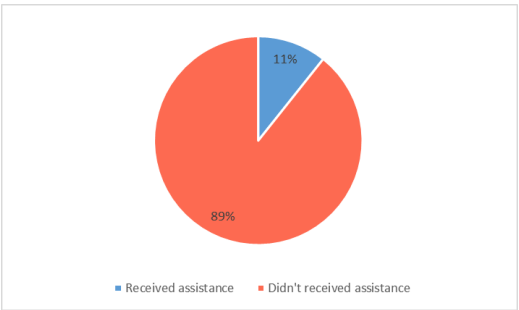


Figure 12. Assistance while applying for credit

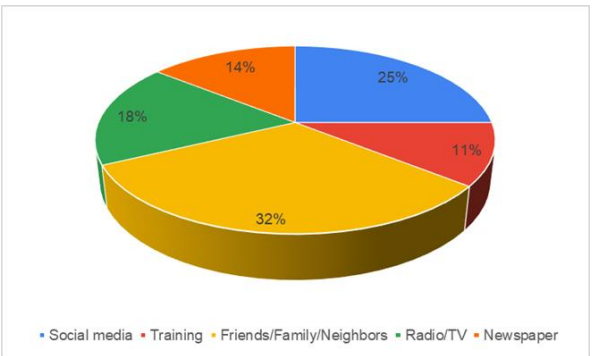


Figure 13. Source of information Perceived barriers to credit access

To analyze the barriers faced by farmers in accessing formal credit, a five-point Likert scale was used, ranging from "Not a challenge" to "Major challenge." Respondents were asked to rate five barriers based on their experience and perception. The results are presented in the table below. Among the barriers listed in Table 1, long processing time was found to be the greatest barrier, with 71.4% citing it as a big challenge and having a high mean score of 4.69, and ranked first. Collateral requirement came second, where 58.1% rated it as a moderate challenge and 31.4% a major challenge (mean = 4.20). Limited

knowledge about credit availability was the third most reported challenge (mean = 3.46), showing that some farmers lack awareness of existing credit options. Fear of repayment burden was ranked fourth (mean = 3.30) and was mostly rated as a moderate or neutral challenge. High interest rates, though frequently cited in more general policy discussions, were lowest (mean = 3.17), and no farmers indicated it as a significant issue.

Table 1. Farmers' perception of barriers in accessing credit

Challenge	Not a challenge	Minor challenge	Neutral	Moderate challenge	Major challenge	Mean	Rank
Long processing time	0	0	3 (2.9%)	27 (25.7%)	75 (71.4%)	4.6857	1
Collateral requirements	0	1 (1%)	10 (9.5%)	61 (58.1%)	33 (31.4%)	4.2	2
Limited knowledge about credit availability	1 (1%)	21 (20%)	34 (32.4%)	27 (25.7%)	22 (21%)	3.4571	3
Fear of repayment burden	2 (1.9%)	16 (15.2%)	45 (42.9%)	33 (31.4%)	9 (8.6%)	3.2952	4
High interest rates	1 (1%)	11 (10.5%)	62 (59%)	31 (29.5%)	0	3.1714	5

(Source: Field Survey, 2025)

The data show that farmers face significant barriers to credit access due to procedural and structural problems such as lengthy processing times and high collateral requirements. Similar challenges have been highlighted in earlier studies, where delays in loan approval and disbursement remain major barriers to effective credit access for farmers (Ayegba & Ikani, 2013; Asogwa et al. 2014). Thus, while credit schemes may exist, access often remains restricted, particularly for those without substantial assets, as lengthy procedures limit timely availability.

A variety of information-related challenges, including limited knowledge and personal concerns such as fear of repayment, contribute to the issue, but their impact is less significant. However, high interest rates were not identified as a major challenge, ranking lowest among the reported barriers, indicating that they may be more urgent access-related issues or that they are relatively manageable. This contrasts with the findings of Pandey et al. (2025), who reported that high interest rates were among the leading constraints faced by farmers in accessing credit. The difference suggests that the nature of challenges varies by context and institutional setting. Overall, the research outcomes show a need to simplify credit procedures while decreasing collateral demands and expanding awareness initiatives to improve credit accessibility for farmers.

CONCLUSION

This study aimed to examine farmers' access to formal credit in Kathmandu Valley and to identify the major barriers that limit their access to credit. The results show that although most farmers are aware of formal credit institutions, only a small proportion actually access credit. This shows a clear gap between awareness and real credit use.

The findings reveal that accessing credit is still a difficult and time-consuming process for many farmers. Long processing times and strict collateral requirements were found to be the most serious obstacles, discouraging farmers from applying for loans even when they need financial support. The fact that most borrowers rely mainly on commercial banks and cooperatives while receiving little to no assistance during the application process shows that credit institutions are still falling short in providing farmer-friendly services. Likewise, farmers' heavy reliance on informal sources such as friends, family, and neighbors for credit information suggests that formal awareness campaigns are not reaching the target groups effectively.

Overall, the study concludes that improving access to formal credit in Kathmandu Valley requires more than simply increasing the availability of loan programs. Credit institutions must simplify procedures, reduce collateral burdens, and provide proper guidance throughout the application process. Strengthening reliable information channels and ensuring supportive, accessible services are crucial steps toward making formal credit more inclusive and responsive to the needs of the farming community in Kathmandu Valley.

AUTHORS'CONTRIBUTIONS

Brishti SUWAL: Investigation; data curation; writing-original draft; software; formal analysis; writing-review and editing; visualization.
Rojan KARKI: Conceptualization; validation, methodology, writing review, and editing

REFERENCES

Asogwa, B.C., Abu, O. & Ochoche, G.E., (2014). Analysis of peasant farmers' access to agricultural credit in Benue State, Nigeria. *British Journal of Economics, Management & Trade*, 4(10),1525–1543.

Ayegba, O. & Ikani, D.I., (2013). An impact assessment of agricultural credit on rural farmers in Nigeria. *Research Journal of Finance and Accounting*, 4(18).

Bapak, R., (2017). Exploring Peri-Urban agriculture and existing farmers in the Kathmandu Valley. *Romanian Review of Regional Studies*, 13(1), 60-70.

Campero, A. & Kaiser, K., (2013). *Access to Credit: Awareness and Use of Formal and Informal Credit Institutions*. Working Papers, No. 2013-07. Banco de México.

Chaudhary, M.K. & Chaudhary, R.K., (2023). Green human resource management for organizational sustainability: Lessons from insurance companies in emerging market. *Journal of Emerging Management Studies*, 1(1), 1–19.

Cochran, W.G. (1953) *Sampling Techniques*. New York: John Wiley and Son.

Dahal, A. K., & Thapa, K. K. (2020). Agriculture sector credit and output relationship in Nepal. *Asian Journal of Economics, Business and Accounting*, 17(2), 33-53.

Dumre, A., Dhakal, S. C., Acharya, M., & Poudel, P. (2020). Analysis of agricultural growth and its determinant factors in Nepal. *Archives of Agriculture and Environmental Science*, 5(1),55-60.

Government of Nepal, 2020. *Industrial Enterprises Act, 2076 (2020). Section 27: Additional facilities for female entrepreneurs*. FAOLEX.

Gupta, V., Gautam, T.K. & Bhandari, B.D., (2016). Choice of agricultural credit sources by Nepalese farmers. Paper presented at the 2016 Annual Meeting, February 6–9, San Antonio, Texas.

International Organization for Migration (IOM), (2018). *Barriers to Women's Land and Property Access and Ownership in Nepal*.

Irshad, M. B., Imran, M., Saleem, M. A., & Wadood, A. (2024) Factors Affecting Agricultural Credit Access to Farmers in the South Punjab Region of Pakistan. *Journal of Business and Management Research,* **3**(3), 320–332

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.

MoF, (2021). *Economic Survey 2020/21*. Kathmandu: Government of Nepal. Ministry of Finance

NRB, (2020). *Financial literacy framework of Nepal Rastra Bank*. Kathmandu, Nepal: Nepal Rastra Bank.

Oni, O. A., Nkonya, E., Pender, J. L., Phillip, D., & Kato, E. (2009). *Trends and drivers of agricultural productivity in Nigeria.* NSSP Report 1. Abuja, Nigeria: International Food Policy Research Institute (IFPRI).

Pandey, P. and Timilsina, R.H. (2024). Factors affecting agricultural credit access of smallholder farmers in Kailali district, Nepal. *Journal of Agriculture and Resource Management*.1(1), 136–147.

Pandey, P., Timilsina, R. H., Paudel, S., Sharma, A. & Pandey, A., (2025). Challenges in agricultural credit access and loan size determinants in Kailali District, Nepal. *Food and Agri Economics Review,* 5(1), 01–06.

Rastra Bank, N. (2014). Agricultural credit and its impact on farm productivity: A case study of Kailali District. Dhangadhi Office.

Shakya, S., Bhaju, S., Shrestha, S., Tuladhar, R. and Tuladhar, S., (2020). The role of data in supporting financial inclusion in Nepal.Cenfri.

Singh, A., Timsina, K.P., Pant, S.R. and Bhatta, G.D. (2023) 'Factors influencing the use and choice of formal agriculture credit sources among rice farmers in Chitwan District, Nepal', *Nepalese Journal of Agricultural Economics,* 45–60.

Thorbecke, E. (ed.), (1969). *The Role of Agriculture in Economic Development: A Conference of the Universities-National Bureau Committee for Economic Research*. New York: National Bureau of Economic Research; distributed by Columbia University Press.

Ukwuaba, A.O., Okezie, C., Mgbakor, M.N. and Osondu, C.K., (2020). *Assessment of agricultural credit sources and accessibility in Nigeria*. *RAAE*, 2(2).

World Bank, (2018). *Breaking down the barriers to regional agricultural trade in Central Africa*. Washington, DC: World Bank.

Zabatantou, L.H., Bouity, C. & Owonda, F., (2023). Impact of agricultural credit on productivity. *Theoretical Economics Letters*, 13, 1434–1462.

Zulfiqar, F., Shang, J., Zada, M., Alam, Q. & Rauf, T., (2021). Identifying the determinants of access to agricultural credit in Southern Punjab of Pakistan. *GeoJournal*, 86(6), pp.2767–2776.

Zurick, D. & Rose, A., (2010). Landscape change in Kathmandu Valley, Nepal. Focus on Geography, 51(4),.7–16.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Determinants of Farmers' Willingness to Grow Potato on a Commercial Scale in Rupandehi District, Nepal

Kriti BHANDARI[1], Sushmita BHATTA[2] & Binayak Prakash MISHRA[2*]

[2]Purbanchal University, Nepal
[1] Agriculture and Forestry University, Rampur, Chitwan, Nepal
***Corresponding Author's Email**: binayakprakash.mishra@gmail.com

ABSTRACT

Despite being an important food and cash crop in Nepal, commercialization of potato is limited. This study was conducted to identify the determinants of farmers' willingness to grow potatoes on a commercial scale, as well as the encouraging and limiting factors, in Rupandehi district, Nepal. Employing a purposive random sampling, 120 farm households were selected from seven municipalities. Primary data were collected in 2025 through household surveys using a pretested semi-structured interview schedule, while Key Informant Interview (KII) and Focus Group Discussion (FGD) were conducted with selected participants. Descriptive statistics and a probit model were used for data analysis. The results revealed that farming experience, access to labor, landholding size and access to subsidy were key determinants that positively affected farmers' willingness to commercialize potato cultivation, while age had a negative effect. Farmers reported better market access, availability of improved seeds, higher selling prices and financial support as major motivating factors for commercialization. Similarly, farmers reported risks of crop failure, lack of capital, small landholdings and unstable prices as major barriers. Thus, the study highlights the need for targeted policy actions such as providing timely access to quality inputs, expanding financial support, stabilizing market prices and promoting collective approaches to address landholding issues to enhance farmers' involvement in commercial potato production.

Key words: Inputs, labor, landholding, market, subsidy

INTRODUCTION

The potato (*Solanum tuberosum* L.) is an important non-cereal crop, grown extensively in more than 125 countries and contributing to food security across

the globe (Bozan et al., 2023; Sahu et al., 2024). Cultivated through the terai to the high mountains in Nepal, in an area of 203,812 hectares, yielding a production of 3,487,816 metric tons and achieving a productivity of 17.11 metric tons per hectare, potato is a major food and cash crop contributing significantly to agricultural GDP, at 6.55% (MoALD, 2024).

Suitability of potato to different agro-ecological zones of Nepal has highlighted this crop for smallholder commercialization. This approach is promoted with the view to accelerate rural income growth, market participation, and structural transformation (Subedi et al., 2019; Timsina et al., 2019).

Agriculture Development Strategy of Nepal defines commercial cultivation as shift from subsistence farming towards market-oriented farming aimed at income generation. Commercialization is promoted because it helps farm household to increase farm income and improves food and nutrition security, with long term benefits of employment generation across the value chain and overall transformation of the agriculture sector into more competitive and sustainable one. The Agriculture Development Strategy highlights that to promote commercialization, enabling factors should be facilitated such as access to quality seeds, fertilizers, irrigation and mechanization, improved storage, transportation and market infrastructure. It also highlights strengthening value chains, encouraging contract farming and cooperatives, providing agricultural finance and insurance, and expanding training and extension services (MoAD, 2016).

However, commercial-scale production is limited as it is still dominated by subsistence production and integration into higher-value market channels is seen uneven across the country (Gairhe et al., 2017). Productivity has only marginally increased from 16.05 Mt/ha in 2018/19 to 17.11 Mt/ha in 2022/23 (MoALD, 2024), indicating unsatisfactory production levels (FAOSTAT, 2023). Nepal imported large quantity of potatoes to meet domestic demand for consumption and cultivation during the fiscal year 2079/80 (2022/23). Record indicates that 29,990 kg of seed potatoes, 306.6 million kg of whether fresh or chilled, and 4.4 million kg of frozen potatoes was imported (MoALD, 2024).

Despite the crop's importance and the focus on commercialization, there is limited studies that looks at both farmers' willingness to grow potatoes on a commercial scale and the various factors that encourage or hinder this across different farming environments. Addressing this gap is important for three main reasons. First, the Government of Nepal continues to prioritize vegetable value chains for growth and food security, with potatoes as a key crop. Second, fluctuations in input and

output markets increase the need for storage, market information, and risk-reduction services when making commercialization decisions. Third, new and renewed investments in improving seed systems and supporting farmer organizations need detailed, location-specific evidence to identify where the main constraints are and which strategies can most effectively increase commercial interest. In this context, the present study offers novel contributions by explicitly examining farmers' willingness to commercialize potato cultivation, rather than focusing solely on adoption or production outcomes, and by integrating econometric analysis with qualitative insights to generate comprehensive, policy-relevant evidence for promoting market-oriented growth in the potato subsector of Nepal. This includes seed system reforms, targeted extension, cooperative development, and investments in market and storage infrastructure.

MATERIALS AND METHODS

The study was conducted in Rupandehi district of Nepal, which represents the terai region. Rupandehi district is a major producer of potato, as it produces 35,945 metric tons of potatoes on 2385 hectares of land, with a productivity of 15.07 metric tons per hectare (MoALD, 2024). Rupandehi has a lot of potential for large-scale potato production because of its fertile, level ground and ideal agro-climatic conditions. To actively encourage commercial growing, the government has established a "potato zone" spanning seven municipalities in Rupandehi as part of the Prime Minister Agriculture Modernization Project (PMAMP). Within the district, the study was carried out in local bodies, namely Tilottama, Sainamaina, Shuddhodhan, Kanchan, Gaindahwa, Mayadevi, and Siyari, covering 19 wards in total which are the potato zones under PMAMP.A purposive random sampling technique was used to select 120 farmers from the PMAMP-potato zone command area. Primary data was collected using pretested semi-structured interview schedule with farm household head. Further, 5 Focus Group Discussion (FGD) were carried out with farmers in a group of 6-8 members and 10 Key Informant Interview (KII) with agriculture officer of PMAMP-PIU Rupandehi, local representatives, cooperatives and farmers group leaders, and progressive farmers. The secondary information was collected from various published sources like journal articles, and publications of the Food and Agriculture Organization (FAO), Ministry of Agriculture and Livestock Development (MoALD), Prime Minister Agriculture Modernization Project (PMAMP), National Potato Research Program (NPRP), Agriculture Knowledge Center (AKC) and other government offices. Purposive random sampling was used to focus on farmers within PMAMP-potato zone command area, which was

appropriate for capturing commercialization dynamics, this approach may limit the generalizability of the findings beyond similar contexts. Nevertheless, the method was suitable for generating in-depth, location-specific insights relevant for policy and program design.

A farmer who cultivates potatoes continuously on 0.5 ha (14.79 katha) or more, sells most of the harvest (>80%), and is linked/registered with market/processing channels or government program is termed as commercial in the study. Descriptive analysis and probit model were employed using Stata/BE 17.0 in order to determine the determinants of farmers willingness to grow potatoes on a commercial scale. The marginal effect on those variables was estimated in the probit model to assess the effect of each independent variable on the willingness.

Model specification:

$$Pr(Y = 1) = f(b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + b_{11}X_{11})$$

Where,

$Pr(Y = 1)$ = Probability of willingness

X_1= Gender (dummy); X_2= Age (continuous); X_3= Education (continuous); X_4= Experience (continuous); X_5= Income (continuous); X_6= Contact (dummy); X_7= Membership (dummy); X_8= Credit (dummy); X_9= Labor (dummy); X_{10}= Land-holding (continuous); X_{11}=Subsidy (dummy)

b_0= Regression coefficient
$b_1, b_2 \ldots\ldots b_{11}$= Probit coefficient
The description of the variables used is presented in Table 1.

RESULTS AND DISCUSSION

Socio-economic and institutional characteristics of the respondents

The socio-economic and institutional characteristics of the respondents is presented in Table 1. As observed, 72.5% of respondent are willing to grow potato commercially and 73.3% of the households were headed by male. The average age of the household head was 53.10 years. On average, respondents have about 4.60 years of formal schooling. Respondents have a 29.87 years of farming

experience on average. On average, 4.32 members of family are involved in farming. Respondents on average had annual household income of NPR 203,916.70. On average, **85.8%** of the respondents have regular contact with extension workers and **87.5%** are members of farmer groups or cooperatives. Similarly, 98.3% of the respondents have access to credit and **81.6%** have access to labor. On average, respondents have 25.74 katha of total farm size, allocated for different commodities, within 3.74 katha under potato farming. On average, **76.6%** have access to subsidy.

Determinants of farmers' willingness to commercialize potato production

Determinants of farmers' willingness to commercialize potato production is presented in Table 2. Results showed that age, farming experience, access to labor, land holding and subsidy were statistically significant in the willingness to commercialize potato production. Keeping other variables constant, the probability of willingness decreases by 2.38% with increase in age by one unit, suggesting that older farmers are less likely to adopt commercial farming practices, possibly due to risks or reduced physical involvement. Result is in line with previous studies (Mdoda et al., 2023; Wakaba et al., 2022).

Table 1. Socio-economic and institutional characteristics of the respondents

Variables	Description	Mean	Standard Deviation
Dependent variable			
Willingness	=1 if the respondent report willingness, 0 otherwise	0.725	0.448
Independent variables			
Gender	Gender of the respondents (1-male, 0-female)	0.733	0.444
Age	Age of the respondent (year)	53.108	12.136
Education	Formal schooling of the respondent (year)	4.60	4.278
Involvement	Family member involved in farming (number)	4.325	3.004
Experience	Farming experience of the respondent (year)	29.875	11.413
Income	Annual income of the household (NPR)	203916.70	231540.50
Contact	=1 if regular contact with extension workers, 0 otherwise	0.858	0.350
Membership	= 1 if member in farmer's groups or agricultural cooperatives, 0 otherwise.	0.875	0.332
Credit	=1 if access to credit, 0 Otherwise	0.983	0.128
Labor	=1 if access to labor, 0 otherwise	0.816	0.388
Land-holding	Total land holding (katha)	25.741	16.918
Farm size	Area under potato farming (katha)	3.741	3.990
Subsidy	=1 if access to subsidy,0 otherwise	0.766	0.424

Similarly, probability of willingness increases by 1.92% with increase in farming experience by one unit, implying that experienced farmers are more confident and informed about commercial opportunities. Result is in line with Wubet et al. (2022).

Probability of willingness increases by 47.41% with access to labor, reflecting the critical role labor availability plays in managing commercial farming. Result is in line with previous studies (Amrullah et al., 2024; Mdoda et al., 2023; Wakaba et al., 2022). Similarly, access to subsidy increase the probability of willingness by 41.73%, highlighting that financial support significantly encourage commercialization. Result is in line with previous studies (Chauhan et al., 2022; Kalwar et al., 2024). Probability of willingness increase by 0.68% with increase in land- holding by one unit, suggesting that land size enables better scale and resource utilization. Result is in line with previous studies (Mdoda et al., 2023; Wakaba et al., 2022). Other variables such as gender, education, income, extension contact, membership and access to credit were not significant, including their limited or indirect influence in this context.

Table 2. Probit model estimation and marginal effect for determinants of willingness to commercialize potato production

Variables	Coef.	Std. Err.	p-value	dy/dx	Std. Err. (dy/dx)
Gender	0.1367	0.3833	0.721	0.0385	0.1103
Age	-0.0870**	0.0375	0.021	-0.0238	0.0098
Education	-0.0306	0.0462	0.507	-0.0084	0.0126
Experience	0.0703*	0.0379	0.064	0.0192	0.0101
Log(income)	0.0683	0.4807	0.887	0.0187	0.1319
Contact	0.9399	0.7253	0.195	0.3176	0.2733
Membership	-0.6866	0.7635	0.369	-0.1465	0.1221
Credit	-0.7850	0.9074	0.387	-0.1462	0.1012
Labor	1.3876***	0.4246	0.001	0.4741	0.1484
Land-holding	0.0250*	0.0134	0.063	0.0068	0.0035
Subsidy	1.2612***	0.4359	0.004	0.4173	0.1537
_cons	0.8977	2.5247	0.722		

Summary statistics: Number of observations=120; LR chi2 (11) =55.20; Prob >chi2 =0.0000; Pseudo R2 = 0.3911; Log likelihood = -42.9792
Note: *, **, *** indicate significant at 10%,5%,1% level of significance, respectively.

Encouraging factors for commercial expansion (among those willing)

The Table 3 shows that better market access is the most significant factor encouraging farmers to grow potatoes commercially, followed by improved seeds and inputs, and higher selling prices. These findings suggest that farmers are encouraged by consistent markets, quality inputs, and better income prospects. Availability of loans, subsidies and training on modern techniques also play important roles by reducing financial risk and improving skills. Although fewer respondents cited cooperative or contract farming, such institutional support still contributes to commercialization. This result is similar to previous studies (Chauhan et al., 2022; Gairhe et al., 2017; Kharel, 2022), which reported that the factors affecting commercialization includes access to quality seed, training and extension, market access and information, irrigation, storage and post-harvest infrastructure, financial services, and membership in farmers organization.

Reasons for not expanding potato farming

Among those unwilling, reasons for not expanding into commercial scale is presented in Table 4. The results revealed that the main obstacles to commercial potato farming are **the** risk of crop failure and lack of capital, suggesting that uncertainty and financial limitations are key concerns for farmers. Land shortage also limits expansion, particularly among smallholders. Additionally, unstable market prices **and** lack of technical knowledge further discourage commercialization.

Table 3. Encouraging factors for commercial expansion (among those willing)

Factors	Frequency (n=87)
Better market access	45
Improved seed and inputs	38
Higher selling price	36
Credit	32
Subsidies	32
Training on modern farming techniques	28
Cooperative/contract farming opportunities	19

Note: Multiple responses were allowed, so the sum of frequencies exceeds the number of respondents.

This finding is further supported by FGD, where a farmer (female, 40 years) stated, *"We know how to grow potatoes, but we don't always know the right fertilizer doses or pest management techniques."* This result is similar to previous

studies who reported major obstacles include a lack of quality seeds, delays in fertilizer supply, labor shortages, and poor market access (Subedi et al., 2019). Additionally, the absence of good post-harvest technologies, inadequate storage facilities, reliance on local collectors to set prices, and a lack of knowledge in pest management make production and marketing even more challenging (Chauhan et al., 2022).

Table 4. Reasons for not expanding potato farming (among those unwilling)

Reasons	Frequency (n=33)
Risk of crop failure	23
Lack of capital	22
Land shortage	17
Unstable market price	10
Lack of technical knowledge	6

Note: Multiple responses were allowed, so the sum of frequencies exceeds the number of respondents.

Desired support for commercial farming

Table 5 presents the desired support stated by farmers for commercial farming. Results revealed that the availability of quality inputs and institutional support such as subsidies, credit and training are desired support the farmers are expecting to grow potato commercially. This finding is similar to the previous studies (Chauhan et al., 2022; Kharel, 2022).

Table 5. Desired support for commercial farming

Type of support	Frequency
Quality/disease-free/graded seed	31
Subsidies (in general, lease-in lands, on seeds, fertilizer, irrigation)	30
Credit at low interest	30
Training	18
Fertilizer availability	12
Irrigation facilities	9
Storage support	7
Better market access	6

Note: Multiple responses were allowed, so the sum of frequencies exceeds the number of respondents.

This finding is also consistent with qualitative evidence from FGD, where a farmer (male, 45 years) stated, "Every year we face delays in getting good seed, and sometimes we are forced to plant whatever is available. If high-quality seed were supplied on time, our production would improve a lot." Similarly, KII with a local cooperative chairperson noted, "Farmers are willing to expand, but the high cost of seed and machinery discourages them. Subsidies would reduce their risk and encourage commercial farming." Similarly, a farmer (male, 50 years) during FGD stated, "Even if we grow more potatoes, where will we store them? Without storage, we are forced to sell at low prices." Similarly, KII with an agricultural officer stated, "Delay in fertilizer distribution creates a big gap between potential and actual yields." Similarly, a farmer (male, 55 years) during FGD stated, "We can grow more, but without water at the right time, it is difficult. And even if we grow, the traders decide the price, not us." Overall, both FGD and KII underscore that improving input delivery systems, strengthening subsidy and credit mechanisms, and investing in irrigation, storage, and market governance are essential to support sustained commercialization of potato farming.

CONCLUSION

The findings from the study showed that young age, experience, labor availability, larger landholdings, and subsidies were factors that influenced farmers' willingness to commercialize potato production. Improved market access, availability of improved inputs and market price seemed to be the encouraging factors for commercial production. Unstable prices, lack of capital, and small landholdings were still important constraints. To address these, policy and programs should target quality seeds on time, subsidies, and programs for improving farmers' capacity. Irrigation and storage facilities should also be invested in to reduce production risks and post-harvest losses. Moreover, improving market systems to provide stable and reliable prices would be important for encouraging continuous engagement in commercial potato production. Measure to combat land shortage should be facilitated by subsidies in lease-in or other collective methods.

SUGGESTIONS

Future studies should consider larger samples randomly selected from different agro-ecological zones, and use longitudinal or panel data. The integration of behavioral studies with value chain studies would be important to develop robust commercialization strategies.

REFERENCES

Amrullah, A., Haerul, A. D., & Salam, M. (2024). Analysis of potato farming production factors. *Potato Journal*, *51*(1), 1-8. https://doi.org/10.56093/potatoj.v51i1.152405

Bozan, I., Achakkagari, S. R., Anglin, N. L., Ellis, D., Tai, H. H., & Strömvik, M. V. (2023). Pangenome analyses reveal impact of transposable elements and ploidy on the evolution of potato species. *Proceedings of the National Academy of Sciences*, *120*(31), e2211117120. https://doi.org/10.1073/pnas.2211117120

Chauhan, B., Joshi, D., Banjade, D., Bhatta, B. D., Awasthi, P., Paneru, M., ... & Chand, P. B. (2022). Economics of potato (Solanum tuberosum L.) production and marketing in Darchula district of Nepal. *Archives of Agriculture and Environmental Science*, *7*(3), 393-401. https://dx.doi.org/10.26832/24566632.2022.0703012

Gairhe, S., Gauchan, D., & Timsina, K. P. (2017). Adoption of improved potato varieties in Nepal. *Journal of Nepal Agricultural Research Council*,*3*,38-44. https://doi.org/10.3126/jnarc.v3i1.17274

Kalwar, S. K., Thapa, K., Sapkota, R., & Sah, P. K. (2024). Economics of production and marketing of potato (Solanum tuberosum) in Rasuwa District, Nepal. *International Journal of Horticulture*, *14*. 10.5376/ijh.2024.14.0021

Kharel, M. (2022). Factors affecting potato marketed surplus in Kavre District of Nepal. *International Journal of Applied Sciences and Biotechnology*, *10*(4), 254-258. https://doi.org/10.3126/ijasbt.v10i4.50882

Mdoda, L., Obi, A., Tamako, N., Naidoo, D., & Baloyi, R. (2023). Resource use efficiency of potato production among smallholder irrigated farmers in the Eastern Cape Province of South Africa. *Sustainability*, *15*(19), 14457. https://doi.org/10.3390/su151914457.

MoAD. (2016). Agriculture Development Strategy (ADS) 2015 to 2035. Part:1. Ministry of Agricultural Development. Government of Nepal.

MoALD. (2024). Statistical information on Nepalese agriculture 2022/2023. Ministry of Agriculture and Livestock Development. Government of Nepal.

Sahu, P. K., Das, M., Sarkar, B., VS, A., Dey, S., Narasimhaiah, L., ... & Raghav, Y. S. (2024). Potato production in India: a critical appraisal on sustainability, forecasting, price and export behaviour. *Potato Research*, *67*(4), 1209-1245. https://doi.org/10.1007/s11540-023-09682-0.

Subedi, S., Ghimire, Y. N., Gautam, S., Poudel, H. K., & Shrestha, J. (2019). Economics of potato (Solanum tuberosum L.) production in terai region of Nepal. *Archives of Agriculture and Environmental Science*, *4*(1), 57-62. https://dx.doi.org/10.26832/24566632.2019.040109

Timsina, K. P., Gaire, S., Ghimire, Y. N., Poudel, H. K., Devkota, D., Subedi, S., & Adhikari, S. P. (2019). Returns to potato research investment in Nepal. *Journal of Agriculture and Natural Resources*, *2*(1), 1-13. https://doi.org/10.3126/janr.v2i1.26002

Wakaba, D., Ateka, J., Mbeche, R., & Oyugi, L. (2022). Determinants of Irish potato (Solanum tuberosum) commercialization and market participation by farmers in Nyandarua County, Kenya. *Journal of Agriculture and Food Research*, *10*, 100382. https://doi.org/10.1016/j.jafr.2022.100382.

Wubet, G. K., Zemedu, L., & Tegegne, B. (2022). Value chain analysis of potato in farta district of south gondar zone, amhara national regional state of Ethiopia. *Heliyon*, *8*(3), e09142. 10.1016/j.heliyon.2022.e09142

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Effect of Vermicompost–Soil–Cocopeat Casing Mixture on Growth, Morphology, and Biological Efficiency of Milky Mushroom (*Calocybe Indica)*

Zenita NEPAL [1], Sundar TIMALSINA [2], Alize Kumar SHAH [1], and Bidur P. CHAULAGAIN [1*].

[1]Himalayan College of Agricultural Sciences and Technology, Kirtipur, Nepal.
[2] Institute of Agriculture and Animal Science, TU, Gauradaha, Jhapa.
***Corresponding Author's email:** bidur@hicast.edu.np

ABSTRACT

The study on the effect of casing materials on *Calocybe indica* was carried out from April 30 to August 1 at the Science Business and Innovation Laboratory of HICAST. The experiment was conducted under ambient environmental conditions, where the temperature ranged between 21–27°C and relative humidity remained within 65–80%. A Completely Randomized Design (CRD) was employed with four treatments Soil + Farmyard Manure (1:1), Soil + Spent Mushroom Substrate (1:1), Cocopeat + Vermicompost (2:1), and Vermicompost + Soil + Cocopeat (2:1:1) each replicated four times to evaluate their influence on yield, number of fruiting bodies, and morphological traits of Calocybe indica. The Vermicompost + Soil + Cocopeat mixture significantly outperformed other treatments, producing the highest number of fruiting bodies (8.5 and 3.25 in first and second harvests), greatest total yield (487.5 g), and highest biological efficiency (97.5%). Soil + FYM followed with 435 g yield and 87% efficiency, while Cocopeat + Vermicompost gave moderate performance (383.75 g, 76.75% efficiency). Soil + SMS consistently resulted in the lowest yield (358.75 g, 71.75% efficiency) and poorest morphological characteristics. In terms of morphology, the Vermicompost based casing produced the longest and thickest stipes and one of the widest pileus diameters. Based on these findings, the Vermicompost + Soil + Cocopeat casing mixture is suggested for improved growth and yield of Milky mushrooms under similar environmental conditions.

Keywords: Biological efficiency, *Calocybe indica*, casing materials, vermicompost, morphological traits

INTRODUCTION

Mushrooms are valued worldwide as a nutritious food source and a reservoir of bioactive compounds with medicinal importance. They are increasingly recognized as functional foods owing to their anti-inflammatory, antioxidant, antibacterial, and immunomodulatory properties (Singh *et al*., 2018; Rijal *et al*., 2021). With low fat content, high-quality protein, essential vitamins (B_1, B_2, B_{12}), and minerals such as potassium, calcium, and iron, mushrooms serve as a healthy dietary component that bridges the nutritional gap between vegetables and meat (Mattila *et al*., 2001; Patel *et al*., 2012). Among the edible species, milky mushroom (*Calocybe indica*) has drawn attention for its ability to grow on a variety of agricultural and industrial wastes, making it an ideal candidate for sustainable farming systems (Chang, 2007). *Calocybe indica*, first identified in 1974 in West Bengal by Purkayastha and Chandra, is now considered one of the most promising tropical mushroom species. After its successful domestication and introduction of the APK2 variety in Tamil Nadu (Krishnamoorthy *et al*., 1998), it has become the third most commercially cultivated mushroom in India after button and oyster mushrooms (Kumar *et al*., 2018). Its robust milky white sporophores, long shelf life, and ability to fruit at higher temperatures (30 ± 2 °C) make it particularly suitable for warm regions where low-temperature mushroom cultivation is difficult (Pani, 2010; Kumar *et al*., 2012). Although *C. indica* is well adapted to tropical climates, commercial production in South Asia including Nepal remains limited. The absence of standardized cultivation techniques, especially concerning casing practices, constrains yield and consistency (Panda and Biswas, 2021). Casing, the application of a surface layer over the colonized substrate, is critical for fruit body initiation and development. It regulates the microenvironment by maintaining moisture, aeration, and microbial activity, while providing mechanical support to developing sporophores (Elangovan *et al*., 2024; Yadav, 2006). The physical and chemical properties of the casing texture, porosity, pH, and water-holding capacity greatly influence the shift from vegetative to reproductive growth, thereby determining yield and biological efficiency (Farsi *et al*., 2011; Tewari, 2005). Traditionally, peat moss has been the preferred casing material in temperate regions, but its cost, limited availability, and non-renewable nature restrict its use in South Asia (Sassine *et al*., 2007). Consequently, sustainable and locally available alternatives such as soil, farmyard manure, cocopeat, vermicompost, and spent mushroom substrate (SMS) warrant evaluation for tropical conditions.

Casing plays a vital role in milky mushroom cultivation, ensuring proper moisture retention and gas exchange, while an unsuitable casing can hinder pinhead formation and reduce yield (MacCanna, 1983; Subbiah and Balan, 2015). The thickness and composition of the casing have also been found to influence productivity, with 2–2.5 cm identified as optimal for *C. indica* (Pani, 2012; Subramanian and Shanmugasundaram, 2015). Vermicompost, in particular, is known to enhance microbial activity and moisture retention, supporting better fruiting body formation (Nagaratna and Mallesha, 2007). Despite this, systematic comparisons among various locally available mixtures remain limited in the Nepalese context. Therefore, the present study was undertaken to evaluate the effect of different casing mixtures Soil + FYM (1:1), Soil + SMS (1:1), Cocopeat + Vermicompost (2:1), and Vermicompost + Soil + Cocopeat (2:1:1) on the growth, yield, and biological efficiency of milky mushroom (*Calocybe indica*) cultivated under ambient Nepalese conditions using polyethylene-bag systems. The results are expected to contribute to the standardization of casing practices for sustainable milky mushroom production in tropical environments.

MATERIALS AND METHODS

Experimental site

The experiment was conducted from April 30 to August 1, 2025, at the Science Business and Innovation Laboratory of the Himalayan College of Agricultural Sciences and Technology (HICAST), Kirtipur, Kathmandu, Nepal (27.6°N, 85.3°E). The site represents a subtropical environment with an annual rainfall of approximately 1025 mm and maximum summer temperatures around 31 °C.

Experimental designs and treatments

A Completely Randomized Design (CRD) was employed with four treatments and four replications (16 units total). Casing mixtures were prepared using locally available materials Soil + FYM (1:1), Soil + Spent Mushroom Substrate (1:1), Cocopeat + Vermicompost (2:1), and Vermicompost + Soil + Cocopeat (2:1:1) selected to compare microbial activity and moisture-retention effects on yield and morphology of *Calocybe indica*. Details of the treatments are presented in Table 1.

Substrate preparation

Paddy straw was used as the substrate for milky mushroom production. It was soaked in water for 19 hours, drained, and pasteurized with hot water steam for

2 hours. The substrate was then cooled on a disinfected surface until it reached 25°C, after which 1% $CaCO_3$ and 2% $CaSO_4$ were mixed in. This prepared substrate was used for spawning.

Table 1. Treatments details

T1	Soil + FYM (SFYM) (1:1)
T2	Soil + SMS (SSMS) (1:1)
T3	Cocopeat + Vermicompost (CPVC) (2:1)
T4	Vermicompost + Soil + Cocopeat (VSCP) (2:1:1)

Inoculation and incubation

Fresh, fully colonized spawn of *Calocybe indica* was inoculated at a 5% rate (wet weight basis) into the substrate using 16" × 24" polypropylene bags. Inoculation was done by alternate layering of pasteurized straw and spawn to ensure uniform distribution. The bags were tightly secured, compressed to remove air pockets, and perforated for aeration. All operations were performed under hygienic conditions to prevent contamination. The inoculated bags were incubated in a dark room under ambient conditions (21–25°C temperature and 65–80% relative humidity) until the substrate was completely colonized by white mycelium, indicating healthy growth.

Casing

After full colonization, casing was applied to stimulate fruiting. Casing mixtures were prepared using garden soil, FYM, vermicompost, cocopeat, and spent mushroom substrate in different ratios to form four treatments. The mixtures were sterilized by autoclaving at 121°C and 15 psi for 2 hours. Once cooled, about 1 inch of casing material was spread evenly over the colonized substrate surface. The cased bags were kept in a well-ventilated area with indirect light and maintained moist through regular watering until pinhead formation and fruiting occurred.

Harvesting

Mushrooms were harvested when the caps were fully expanded by gently twisting and pulling them by hand. Harvested mushrooms were cleaned to remove casing material and dirt before recording yield data.

Observation and data collection

Growth and yield parameters were recorded at regular intervals to assess the effects of different casing mixtures on the performance of *Calocybe indica*. Observations were taken from all replications, and mean values were used for analysis.

The following parameters were measured:

1. **Days to pinhead initiation:** Number of days from casing application to the first visible appearance of pinheads.
2. **Days to first and second harvest:** Number of days from casing to the first and second flush harvests, respectively.
3. **Number of fruiting bodies per bag:** Count of mature mushrooms harvested per experimental unit during each flush.
4. **Stipe length (cm) and diameter (cm):** Measured from the base to the pileus and at the midpoint of the stipe using a digital caliper.
5. **Pileus diameter (cm) and thickness (cm):** Recorded at the widest part of the cap and its center using a vernier caliper.
6. **Fresh weight per fruiting body (g):** Measured immediately after harvest using a digital weighing balance.
7. **Total yield per bag (g):** Cumulative fresh weight of all fruiting bodies obtained per experimental unit from both flushes.
8. **Biological efficiency (BE %):** Calculated using the formula:
   (Total fresh weight of mushrooms / Dry weight of substrate) × 100

All observations were made on freshly harvested mushrooms. Morphological measurements were taken from randomly selected representative fruiting bodies in each replication.

Statistical analysis

Data were compiled in MS Excel (v16.0) and analyzed using ANOVA in R Studio (v4.4.1). Mean differences were compared using the Least Significant Difference (LSD) test at a 5% significance level. Figures and tables were prepared in Excel.

RESULTS AND DISCUSSION

The application of different casing materials significantly influenced all major growth, yield, and morphological parameters of *Calocybe indica* in this study. The Vermicompost + Soil + Cocopeat (VSCP; 2:1:1) casing mixture consistently

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

demonstrated superior performance across nearly all metrics evaluated, establishing itself as the most effective treatment. Specifically, VSCP prompted the most rapid initiation of the fruiting cycle, resulted in the highest production of fruiting bodies, and yielded the greatest total biomass with the highest biological efficiency. Furthermore, mushrooms grown under the VSCP treatment exhibited superior morphological characteristics, indicative of higher quality. The following subsections detail the effects on each parameter, with the performance of the VSCP mixture consistently outperforming the other treatments, including the traditional Soil + Farmyard Manure (SFYM) blend.

Effect of different casing materials on days to pinhead formation and harvest.

The application of different casing materials significantly affected the time required for pinhead initiation and harvest of *Calocybe indica*. The VSCP mixture showed the most rapid fruiting response, initiating primordia within 11.5 days and reaching the first and second harvests at 11.7 and 8.5 days, respectively.

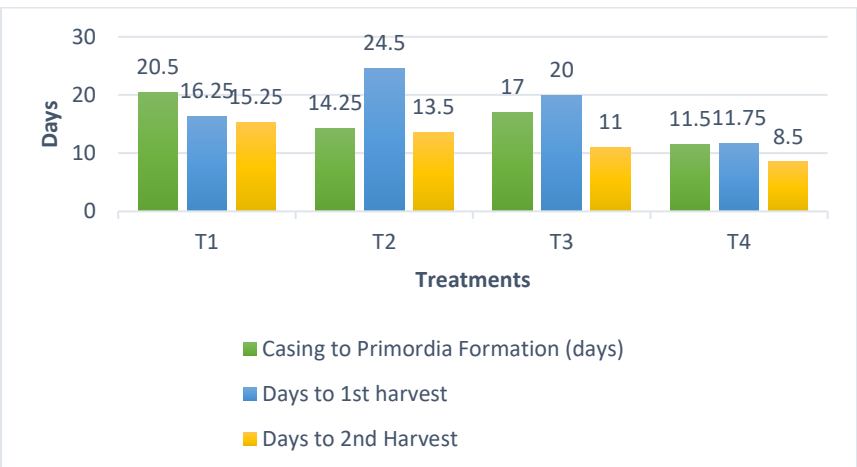


Figure 1. Effect of casing materials on days to primordia formation, days to 1st and 2nd harvest

This accelerated development can be attributed to the optimal physicochemical and biological properties of vermicompost, which harbors beneficial microbes producing growth regulators and volatile compounds that stimulate the transition from vegetative mycelium to reproductive fruiting bodies (Eger, 1961; Nagaratna & Mallesha, 2007). Moreover, the inclusion of cocopeat and soil created a porous,

well-aerated structure that maintained ideal surface moisture while facilitating gas exchange, particularly CO_2 dissipation factors critical for early pinhead initiation (MacCanna, 1983; Subramanian & Shanmugasundaram, 2015). In contrast, the delayed pinning (14.25 days) and harvest (24.5 days) observed in the SSMS treatment suggest nutrient depletion and compaction, leading to poor aeration (Choudhary, 2011). The moderate performance of CPVC (17 days to pinhead formation) and the relatively delayed pinning in SFYM (20.5 days) reaffirm that a balanced combination of physical and microbial properties, as seen in VSCP, enhances mycelial fructification and reduces crop duration (Lambert & Humfeld, 1939; Pandey & Tewari, 1994; Bhatt *et al.,* 2007).

Table 2. Effect of casing materials on number of fruiting bodies

Treatments	Number of fruiting bodies	
	1st harvest	2nd harvest
SFYM (1:1)	6.5±0.288[b]	2.75±0.478[a]
SSMS (1:1)	5±0.408[c]	2.50±0.288[a]
CPVC (2:1)	6.5±0.288[b]	2.25±0.250[a]
VSCP (2:1:1)	8.5±0.288[a]	3.25±0.478[a]
LSD	0.994	1.197
F-value	***	NS
C.V (%)	9.743	28.922
Grand Mean	6.625	2.687

Signif. Codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1 'NS' 1
Non-significant (NS), Significant (*), Highly Significant (**), Very Highly Significant (***) at 95 % level of confidence.

Effect of different casing materials on no. of fruiting bodies

Casing materials markedly influenced the number of fruiting bodies per flush. The VSCP mixture yielded the highest counts (8.5 in the first and 3.25 in the second flush), followed by SFYM and CPVC (6.5 each), while SSMS recorded the lowest (5.0). The superior performance of VSCP reflects its rich microbial population and sustained nutrient availability, both of which stimulate consistent fruiting across flushes (Nagaratna & Mallesha, 2007; Bhatt *et al.,* 2007).

The contrasting performance of CPVC, which produced a strong first flush but declined sharply in the second, highlights the difference between casings that promote initial fruiting and those that sustain productivity. The high water-holding capacity of cocopeat favored initial fruit formation (MacCanna, 1983),

but its lower nutrient and microbial content limited subsequent flushes. In contrast, the biologically active and porous VSCP mixture maintained consistent fruiting through improved aeration and gradual nutrient release (Tandon *et al.,* 2006). These results demonstrate that integrating nutrient-rich vermicompost with soil and cocopeat supports both the initiation and continuity of the fruiting process.

Effect of different casing materials on yield of mushroom

The yield of *Calocybe indica* was significantly influenced by the type of casing material used (Table 3). The VSCP treatment produced the highest yield (325.25 g in the first flush and 162.25 g in the second), indicating its superior ability to support both initiation and sustainability of fruiting. This can be attributed to the biologically active and nutrient-rich nature of vermicompost, which enhances microbial activity and provides sustained nutrient release. Beneficial microbes such as *Trichoderma* and *Azotobacter* in vermicompost secrete growth regulators and enzymes that promote mycelial vigor and continuous fruiting (Nagaratna and Mallesha, 2007; Tandon *et al*., 2006). The combination of soil and cocopeat further improves aeration and moisture balance, providing ideal conditions for sustained yield (Pandey and Tewari, 1994).

Table 3. Effect of different casing materials on yield of mushroom

Treatments	Average yield of mushroom (g)	
	1st harvest	2nd harvest
SFYM (1:1)	285.00±11.669^{c}	150.00±10.700^{a}
SSMS (1:1)	255.75±5.677^{d}	103.00±4.546^{b}
CPVC (2:1)	291.00±3.391^{b}	92.75±3.250^{b}
VSCP (2:1:1)	325.25±23.192^{a}	162.25±22.443^{a}
LSD	0.239	39.264
F-value	*	**
C.V (%)	0.053	20.067
Grand Mean	289.25	127

Signif. Codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1 'NS' 1
Non-significant (NS), Significant (*), Highly Significant (**), Very Highly Significant (***) at 95 % level of confidence.

The SFYM treatment followed with a slightly lower yield (285.00 g and 150.00 g), suggesting that farmyard manure mixed with soil offers sufficient nutrients

and good structure for fruiting but lacks the microbial richness of vermicompost (Krishnamoorthy, 2003). CPVC produced a strong first flush (291.00 g) but a sharp decline in the second (92.75 g), possibly due to compaction and limited microbial support in cocopeat-dominant mixtures (MacCanna, 1983). The SSMS treatment yielded the least (255.75 g and 103.00 g), likely due to nutrient depletion and the presence of inhibitory compounds in spent substrate (Choudhary, 2011). These results highlight that yield performance depends on the synergistic effects of nutrient content, porosity, and microbial activity, with VSCP proving most effective (Bhatt *et al*., 2007).

Effect of different casing materials on morphological traits of *Calocybe indica*

Casing composition markedly affected the morphological characteristics of *C. indica* (Table 4). The VSCP treatment produced mushrooms with the longest (8.06 cm) and thickest stipes (4.29 cm), largest pileus (9.98 cm), and greatest pileus thickness (3.05 cm), indicating robust and compact fruit bodies. This superior morphology can be linked to improved nutrient supply and microbial activity from vermicompost and soil, which promote efficient water uptake and assimilate partitioning, resulting in firm, fleshy structures (Nagaratna and Mallesha, 2007; Tandon *et al*., 2006). Cocopeat's moisture-holding capacity further maintains optimal turgor pressure, supporting healthy tissue formation and dense fruiting bodies. In contrast, the SFYM treatment produced moderately thick and firm mushrooms due to adequate nutrients but less microbial stimulation (Krishnamoorthy, 2003).

Table 4. Effect of different casing materials on morphological traits

Treatments	Avg. Stipe Length	Avg. Stipe Thickness	Avg. Pileus Diameter	Avg. Pileus Thickness
SFYM (1:1)	6.025 ± 0.345^{b}	3.462 ± 0.100^{b}	9.100 ± 0.453^{b}	2.637 ± 0.210^{ab}
SSMS (1:1)	5.300 ± 0.478^{b}	2.737 ± 0.143^{c}	6.562 ± 0.688^{c}	1.125 ± 0.208^{c}
CPVC (2:1)	5.775 ± 0.242^{b}	3.025 ± 0.066^{c}	12.100 ± 0.324^{a}	2.225 ± 0.277^{bc}
VSCP (2:1:1)	8.062 ± 0.408^{a}	4.287 ± 0.154^{a}	9.975 ± 1.007^{b}	3.050 ± 0.219^{a}
LSD	1.167	0.374	2.066	0.711
F-value	**	***	***	*
C.V (%)	12.051	7.190	14.220	18.768
Grand Mean	6.290	3.378	9.434	2.459

Signif. Codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1 'NS' 1

Non-significant (NS), Significant (*), Highly Significant (**), Very Highly Significant (***) at 95 % level of confidence.

The CPVC mixture developed mushrooms with wide caps (12.10 cm) but thinner stipes and pileus an outcome of excess moisture and limited nutrient content favoring cap expansion over compactness (MacCanna, 1983). The SSMS treatment resulted in small, thin fruit bodies, reflecting nutrient exhaustion and poor aeration (Choudhary, 2011). Overall, these morphological responses confirm that the VSCP mixture's aeration, microbial richness, and nutrient availability create optimal conditions for superior fruit quality and marketable traits (Bhatt *et al*., 2007).

Effect of different casing materials on total yield and biological efficiency

The ultimate measures of cultivation success total yield and biological efficiency (BE) were strongly influenced by the choice of casing material (Table 5). The VSCP (2:1:1) mixture achieved the highest BE (97.5%) and total yield (1950 g), confirming its superior performance in converting substrate nutrients into fruiting biomass. Vermicompost's sustained nutrient release and microbial enzymatic activity enhance substrate degradation and nutrient mineralization, leading to high substrate-to-mushroom conversion efficiency (Tandon *et al*., 2006). The soil and cocopeat components stabilize structure and maintain optimal aeration–moisture balance, supporting prolonged fruiting cycles (Pandey and Tewari, 1994). SFYM recorded a BE of 87.0%, showing good but slightly lower efficiency due to limited microbial diversity (Krishnamoorthy, 2003). CPVC achieved 76.75% BE, indicating good initial performance but rapid decline from nutrient depletion and compaction (MacCanna, 1983). SSMS showed the lowest BE (71.75%), confirming its unsuitability as a primary casing due to nutrient exhaustion and toxic residue effects (Choudhary, 2011).

Table 5. Effect of different casing materials on total yield and biological efficiency

Treatments	Total yield (g)	Biological Efficiency (%)
SFYM (1:1)	1740	87.00
SSMS (1:1)	1435	71.75
CPVC (2:1)	1535	76.75
VSCP (2:1:1)	1950	97.50

These findings establish VSCP as the most productive and biologically efficient casing, providing a balanced environment for consistent yield and economic sustainability in *C. indica* cultivation (Bhatt *et al*., 2007).

CONCLUSION

This study conclusively demonstrates that the composition of the casing layer is a decisive factor in the successful cultivation of milky mushroom (*Calocybe indica*). Among the tested formulations, the mixture of Vermicompost + Soil + Cocopeat (2:1:1) proved to be superior, consistently enhancing every critical aspect of production. It significantly accelerated the fruiting cycle, maximized the number and yield of fruiting bodies, and improved key morphological traits, resulting in the highest biological efficiency (97.5%). The success of this mixture is attributed to its synergistic combination of biological activation from vermicompost and optimal physical structure from soil and cocopeat, which together create an ideal microenvironment for pinhead initiation and fruit body development. Therefore, the VSCP mixture is highly recommended as an effective, sustainable, and readily available casing material for commercial and small-scale production of *Calocybe indica* under similar ambient conditions. Replacing traditional materials like FYM alone with this specific formulation can lead to more predictable cropping, higher profitability, and better-quality mushrooms. Future research could focus on fine-tuning the ratios of these components and evaluating the specific microbial consortia within the vermicompost that contribute to its efficacy.

AUTHOR'S CONTRIBUTIONS

Zenita Nepal: designed and conducted the experiment, performed mushroom cultivation, monitored growth parameters, recorded and interpreted the data, and drafted the manuscript.
Sundar Timalsina: performed statistical analysis using R Studio, generated graphs and tables, and validated data interpretation.
Alize Kumar Shah: assisted with substrate preparation, casing application, and watering.
Bidur P. Chaulagain: supervised the study, contributed to conceptualization, provided guidance on cultivation techniques, facilitated access to laboratory and cultivation facilities, and critically reviewed the manuscript.

REFERENCES

Bhatt, B.P., Shukla, P., Sharma, P., Singh, B. & Tiwari, A. (2007). Effect of casing mixtures on yield and yield attributing characters of milky mushroom *(Calocybe indica). Journal of Mycology and Plant Pathology*, 37(3): 201–205.

Chang, S.T. (2007). Mushroom cultivation using the ZERI principle: Potential for Application. *Micologia Aplicada International*, 19(2): 33–34.

Choudhary, D.K. (2011). First preliminary report on isolation and characterization of novel Acinetobacter spp. In casing soil used for cultivation of button mushroom, Agaricus bisporus (Lange) Imbach.

Danny, L.R. (1992). Commercial mushroom production. *Ontario: Horticultural Research Institute of Ontario Vineland Station, Ontario Ministry of Agriculture and Food Publication*, 350(5): 37–38.

Eger, C. (1961). Influence of microflora in casing soil on mushroom fructification. *Transactions of the British Mycological Society,* 44(3): 348–352.

Farsi, M., Malekzadeh, K. and Jalalzadeh, B. (2011). Recycling of mushroom peat casing soil through plastic mesh. *Proceedings of the 7th International Conference on Mushroom Biology and Mushroom Products (ICMBMP7).*

Krishnamoorthy, A.S., Muthusamy, M. & Marimuthu, T. (1997). Substrate evaluation for cultivation of milky mushroom (*Calocybe indica*). *Indian Journal of Mycology and Plant Pathology,* 27(3): 205–210.

Krishnamoorthy, A.S., Muthusamy, M., Marimuthu, T., Narasimhan, V. and Muthusankara Narayanan, A. (1998) *APK2 milky mushroom-Extension Bulletin*. Regional Research Station, TNAU, Aruppukottai.

Kumar, A. (2010). Effect of casing materials on growth and yield of milky mushroom *(Calocybe indica)*. *International Journal of Agricultural Sciences,* 6(2): 140-145.

Kumar, B., Singh, G., Singh, V.P., Patil, J., Mishra, P., Choudhury, D. and Srivastava, S. (2018). Effect of different inorganic additives on spawn run, cropping period and yield performance of oyster mushroom *(Pleurotus species). Plant Pathology Journal*, 17: 19–24.

Kumar, R., Singh, G., Mishra, P. and Singh, R. (2012). Effect of different organic supplements and casing mixtures on yield of two strains of milky mushroom *(Calocybe indica). Indian Phytopathology*, 65: 399–403.

Lambert, J. & Humfeld, W. (1939). Studies on casing soil and mushroom fruit body formation. *American Mushroom Journal*, 11(2): 43–49.

MacCanna, C. (1983). Spawned casing. *The Mushroom Journal*, 129: 329-333.

Marimuthu Elangovan, Gopinath, V., Ganesan Rathinakumar, Madhaiyan Sakthivel and Biswas, M.K. (2024). Assessing the Impact of Casing Material Thickness on Yield and Biological Efficiency of Milky Mushroom *(Calocybe indica P&C). Journal of Advances in Biology & Biotechnology*, 27(10): 556–563.

Nagaratna, B. & Mallesha, S. (2007). Use of vermicompost as casing material for *Calocybe indica* cultivation. *Mushroom Research,* 16(1): 58–63.

Panda, D. and Biswas, M.K. (2021). Impact of sterilization and thickness of casing materials on yield attributes of *Calocybe indica. Research Journal of Agricultural Sciences*, 12(3): 1004–1011.

Pandey, R.C. & Tewari, R. (1994). Evaluation of various casing materials for milky mushroom cultivation. *Mushroom Science,* 13: 135–141.

Pani, B.K., (2010). Evaluation of some substrates for cultivation of white summer mushroom (*Calocybe indica*). *Research Journal of Agricultural Sciences*, 1(4): 357-359.

Pani, B.K. (2012). Sporophore production of milky mushroom (*Calocybe indica*) as influenced by depth and time of casing. *International Journal of Advanced Biological Research*, 2(1): 168-170.

Patel, Y., Narain, R. and Singh, V.K. (2012). Medicinal properties of *Pleurotus species* (oyster mushroom): A review. *World Journal of Fungal and Plant Biology*, 3(1): 1–12.

Purkayastha, R.P. & Nayak, N.K. (1977). In-vitro studies on substrates for *Calocybe indica. Mycological Research*, 81(2): 220–223.

Sassine, Y.N., Ghora, Y., Kharrar, M., Bohme, M. and Abdel Mawgoud, A.M.R. (2005). Waste paper as an alternative for casing soil in mushroom (*Agaricus bisporus*) production, *Journal of Applied Sciences Research*, 1: 277-284.

Shukla, R. (2008). Influence of casing soil ratios on pinhead initiation and yield of milky mushroom. *Journal of Mycology and Plant Pathology*, 38(1): 66–72.

Singh, P., Bhatt, B.P. & Singh, R. (2009). Growth and yield of milky mushroom *(Calocybe indica*) on various solid media and substrates. *Journal of Mycology and Plant Pathology*, 39(2): 144–150.

Singh, R. (2012). Effect of casing thickness and bed height on yield and biological efficiency of milky mushroom. *Journal of Agricultural Research*, 50(1): 33–39.

Singh, V.P., Singh, G., Kumar, B., Kumar, A. and Srivastava, S. (2018). Effect of various chemicals on the mycelial growth and fruiting body of milky mushroom (*Calocybe indica*). *Asian Journal of Crop Science*, 10: 168-173.

Subbiah, K.A. and Balan, V. (2015). A comprehensive review of tropical milky white mushroom (*Calocybe indica* P&C). *Mycobiology*, 43: 184-194.

Subramanian, K. and Shanmugasundaram, K. (2015). Optimization of casing process for enhanced bio-efficiency of *Calocybe indica*, an indigenous tropical edible mushroom. *International Journal of Recent ScientificResearch*, 6(2): 2594-2598.

Sukla, P.K., Jha, A.K. and Singh, T.B. (2007). Effect of Amount of Casing Soil on Crop duration and yield of Milky Mushroom (*Calocybe indica*). *J. Mycol. Pl. Pathol,* 37(1): 192-193.

Tandon, R.N., Kumar, R. & Singh, K. (2006). Physico-chemical properties of casing materials and their effect on milky mushroom production. *Mushroom Science,*14: 98-104.

Tewari, R.P. (2005). From Director's desk. *Mushroom Newsletter*, National Research Center for Mushroom, Chambagat, Solan, p. 8.

Visvanathan, C. and Glawe, U. (2010). Domestic solid waste management in South Asian countries. A comparative analysis, Presented at 3R South Asia Expert Workshop, 2006.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Determinants of Farm Machinery Adoption among Maize Farmers in Khotang, Nepal

Bishal RAWAT[a], Anish Bilash PANTA[b*], Sushmita BHATTA[b] and Binayak Prakash MISHRA[b]

[a]Purbanchal University, Nepal
[b]Agriculture and Forestry University, Rampur, Chitwan, Nepal
Corresponding Author's Email*: anishbilashpanta@gmail.com

ABSTRACT

Agricultural mechanization is crucial in improving productivity and reducing labor dependency. However, the adoption of machinery in Nepal's hilly regions remains limited. The study was conducted to identify the determinants of farm machinery adoption among maize farmers in Khotang, Nepal. Data were collected from 123 randomly selected farm households through a pre-tested semi-structured interview schedule. Focus Group Discussion (FGD) and Key Informant Interview (KII) were conducted with selected participants. In analyzing data, descriptive statistics and a probit regression model were employed. Consequently, 56.09% of the farmers had adopted at least one type of farm machinery. Power tillers, shellers, and maize planters are the commonly adopted machinery. Regular contact with extension workers and membership in either farmers groups or cooperatives had a highly significant positive effect on the adoption of farm machinery. The most common reasons for non-adoption are high rental costs, lack of technical knowledge and small fragmented landholdings. While, women-specific training is the most needed support reported by women farmers. Hence, this study revealed that institutional and social factors are more important than individual characteristics in adopting mechanization. Strengthening extension services together with farmers groups and cooperatives is an issue of priority in promoting mechanization for maize-based hill farming systems in Nepal.

Keywords: Cooperatives, extension, groups, farming system, mechanization

INTRODUCTION

Agricultural mechanization is considered one of the essential elements in agrarian transformation, especially in the developing world, where it catalyzes productivity enhancement, labor-use reduction, and food security (Paudel et al., 2023; Rai et al., 2024). As agricultural mechanization develops, farm machinery is gradually replacing manual labor and draft animals (Quan & Doluschitz, 2021). In the Global South, agriculture is still by and large labor-intensive. However, rising labor wages, seasonal labor shortages, and

out-migration are sending rapid transformations toward mechanized farming systems (Gauchan & Shrestha, 2017).

Agricultural mechanization is an indicator of agricultural modernization, and farm machinery is the carrier of agricultural modernization (Li et al., 2018; Liu & Tian, 2009). The Government of Nepal formulated the Agricultural Mechanization Promotion Policy in 2014 with the objectives of enhancing productivity by appropriate mechanization, enhancing access to agricultural machinery, promoting women-friendly farm machinery, and improving institutions dealing with mechanization (Shrestha, 2022). In addition, the Agriculture Development Strategy (ADS) of Nepal (2015–2035) emphasized the need for adopting appropriate farm technologies to enhance productivity. The ADS encourages a core program that offers different mechanization alternatives to farmers. This adoption is encouraged through activities such as awareness creation, demand stimulation, support for concessionary financing arrangements, capacity building, and implementation of appropriate taxation policies (MoAD, 2016). Along with the government priorities, the existing socio-economic context, such as the scarcity of agricultural labor along with rising daily wage rates, has enhanced the prospects of farm machinery in Nepal. Moreover, the remittance inflow has increased opportunities for commercialization and investment in farm machinery (Shrestha, 2022).

Maize accounts for a 6.63% contribution to Nepal's total agricultural Gross Domestic Product (GDP). Among cereal crops, maize ranks second after rice in terms of both area and production, covering 940,256 ha with a production of 2,976,490 mt and an average yield of 3.17 mt/ha in 2022/23. During the same year, Nepal showed a high dependence on imported maize and maize-based products. The country imported 435.22 million kg of maize (excluding seed) valued at NPR 16.50 billion, mainly to meet the rising demand for food, feed, and industrial purposes. Furthermore, imports included 3.66 million kg of maize seed worth NPR 668.65 million, indicating reliance on external sources for quality planting material. Imports of processed maize products were also significant, comprising maize starch (9.10 million kg; NPR 524.96 million), maize flour (0.31 million kg; NPR 15.47 million), and corn flakes (0.62 million kg; NPR 169.13 million). This import structure highlights structural gaps in domestic maize production, seed supply, and agro-processing capacity, underscoring the need for policies that strengthen local maize value chains, promote import substitution, and enhance food and feed self-sufficiency in Nepal (MoALD, 2024).

In the mid-hills of Nepal, the farming system is exposed to higher productivity, financial and social risks due to increased degradation, outmigration, high cost of production expansion, and marginal fragile landscapes. To reduce these risks and promote sustainable management of landscapes and overall farming system, measures to risk reduction and improved production is desirable (Zepeda et al., 2023). Hilly belt cover 42% of the national area by ecological belt (MoALD, 2024). Suitability of agricultural mechanization is difficult in Hilly and mountainous areas, and considered as weak places for the

development. However, positive impact on resource-use efficiency and food security is observed with adoption of small agricultural machinery suited for hilly and mountainous areas (Li et al., 2023). As, mechanization is critical in accelerating rural revitalization and increasing agricultural competitiveness (Wu et al., 2025).

Khotang district is characterized by a maize-dominant farming system integrated with livestock, where farm households depend on a mixed livelihood strategy combining agriculture with remittance and off-farm income sources. Although maize-based farming remains central to household food security and livestock feeding, a considerable portion of income and labor comes from non-agricultural activities such as wage labor, migration, and remittances. This diversified livelihood strategy reflects both limited agricultural productivity and the need to manage economic risk, influencing farmers' decisions on labor allocation, technology adoption, and investment in agriculture (Zepeda et al., 2023).
From a production standpoint, the yield gap in Khotang is particularly notable. In Koshi province, maize is cultivated on 284,340 ha, yielding 972,073 mt with an average productivity of 3.42 mt/ha. In contrast, Khotang district alone cultivates 31,845 ha of maize but produces only 56,684 mt, resulting in a much lower yield of 1.78 mt/ha. Despite being among the districts with the largest maize cultivation area in the province, Khotang's productivity remains far below that of districts across the terai, hill, and mountain regions (MoALD, 2024). The Government of Nepal initiated Prime Minister Agriculture Modernization Project (PMAMP) with the aim to increase agriculture productivity by ensuring better access to modern machinery via subsidy and credit arrangements, coupled with capability enhancement programs (Rai et al., 2024). However, farm machinery adoption is still found to be low in hill districts like Khotang. Considering Nepal's rugged terrain, especially in the hill regions, there is an urgent need to strengthen and expand the use of locally appropriate technologies that lower time, labor, and production costs while also promoting women's empowerment and reducing gender inequality (Paudel et al., 2020). Most of the available literature on agricultural mechanization in Nepal has focused on other regions of Nepal, while empirical data from Khotang is still missing. This study aims to fill this gap by identifying the factors affecting the adoption of farm machinery among maize farmers, reasons for not adopting farm machinery and support desired by women farmers in the adoption of farm machinery in Khotang, Nepal. Understanding these factors is crucial for creating targeted policies and intervention strategies that speed up the mechanization process and improve agricultural productivity.

MATERIALS AND METHODS

Study area

Khotang is one of the hill districts in eastern region and lies in Province No. 1 (Koshi Province). The farming system in this district is dominated by crops like potatoes, millet, and maize, especially in the mid-hill areas. Agricultural mechanization has been progressively gaining traction in recent years; although traditional farming methods through animal and human power remain predominant.

Sampling technique and sample size

This study focuses on all maize-growing farm households in the chosen Rupakot Majuwagdi municipality and Halesi Tuwachung municipality in the Khotang district. Population was estimated to 1200 farm households. Employing, sample size calculation method by Daniel (1999), 123 households was taken for the study. This sample covers multiple ward of both municipality and includes farm households within PMAMP command area. A random sampling technique was used to select the households for this study. Later divided into two groups of adopters and non-adopters. The primary data were collected from the farmers of the study area through face-to-face interview schedules with semi-structured questionnaire. To add qualitative insights to the survey, four FGDs were conducted. Two groups were for women farmers and two for men in a group of 6-8 members, held separately. Similarly, eight Key Informant Interviews (KIIs) were conducted with people who had institutional or practical knowledge about agricultural mechanization. Informants included: PMAMP officials, Custom Hiring Center (CHC) managers, progressive farmers and executives of farmers group and cooperatives. The secondary data were extracted from publication of statistical information from Ministry of Agriculture and Livestock Development (MoALD), Agriculture Knowledge Center (AKC), and PMAMP and research papers published by different authors.

Empirical method

Probit model (using STATA 17) was employed to identify the determinants of farm machinery adoption among maize farmers in Khotang, Nepal.

Model specification:

$Pr(Y=1) = f(b_0+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6+b_7x_7+b_8x_8+b_9x_9)$
Where,
$Pr(Y=1)$= Probability of adoption of farm machinery
X_1= Gender (dummy); X_2= Age (continuous); X_3= Education (continuous); X_4= Income (continuous); X_5= Contact (dummy); X_6= Membership (dummy); X_7= Credit (dummy); X_8= Labor (dummy); X_9= Experience (continuous)
b_0 = Regression coefficient
$b_1, b_2 \ldots\ldots\ldots\ldots b_9$=Probit coefficient

RESULTS AND DISCUSSION

Descriptive Statistics

Table 1 presents the descriptive statistics of the variables used in the study. The average age of respondent was 44.44 years. On average, farmers had 7.84 years of formal education. The mean annual household income was NPR 491203.3. More than half of the respondents (55.28%) were male and 58.53% of the respondents had regular contact with extension

workers. Similarly, 74.79% of the respondents were members of farmers' groups or cooperatives. Only 18.69% of farmers reported having access to credit, whereas a large majority (88.61%) had access to agricultural labor. The average farming experience in maize cultivation was around 34.13 years, indicating that most respondents were experienced growers. Regarding the dependent variable, about 56.09% of respondents had adopted at least one type of farm machinery.

Adoption status of farm machinery

Table 2 shows the adoption rate of different types of farm machinery among farmers. Among the various machines, the power tiller was the most commonly adopted (55.28%). This was followed by shellers (46.34%) and maize planters (39.83%), which were also relatively common. In contrast, only 17.07% of farmers adopted threshers, and very few (1.62%) had adopted harvesters.

Table 1. Descriptive statistics of variables for adoption of farm machinery in the study

Variable	Description	Mean	SD
Independent variable			
Gender	Gender of the respondent (1 if male, 0 if female)	0.5528	0.4992
Age	Age of the respondent (year)	44.4471	13.1848
Education	Formal education of the respondent (year)	7.8455	4.5539
Income	Annual income of the household (NPR)	491203.3	702320.1
Contact	=1 if respondent has regular contact with extension workers, 0 otherwise	0.5853	0.4946
Membership	=1 if respondent is member in farmer's groups or cooperatives, 0 otherwise	0.7479	0.4359
Credit	=1 if access to credit, 0 otherwise	0.1869	0.3914
Labor	=1 if access to labor, 0 otherwise	0.8861	0.3188
Experience	Respondents experience in maize farming (year)	34.1300	12.5860
Dependent variable			
Farm machinery	=1 if respondent adopt at least one farm machinery, 0 otherwise	0.5609	0.4982

Overall, adoption status of farm machinery revealed that the adoption of farm machinery is mostly limited to land preparation, planting, and shelling, while mechanization in farm operations such as harvesting and threshing remains very low.

Determinants of farm machinery adoption

Probit model estimation on factors affecting the adoption of farm machinery among the maize farmers is presented in Table 3. The model was significant at 1% level of significance, indicating that it had strong explanatory power. Results reveled that the institutional factors such as regular contact with extension workers and membership in an

agricultural cooperative or farmer group positively and significantly affected the probability of adoption of farm machinery.

Table 2. Adoption status of farm machinery used in the study

Machinery	Description	Mean	SD
Maize Planter	=1 if adoption, 0 otherwise	0.3983	0.4915
Sheller	=1 if adoption, 0 otherwise	0.4634	0.5006
Thresher	=1 if adoption, 0 otherwise	0.1707	0.3778
Power Tiller	=1 if adoption, 0 otherwise	0.5528	0.4992
Harvester	=1 if adoption, 0 otherwise	0.0162	0.1269

Probability of adoption of farm machinery increases by 47.93% among farmers with regular extension contact. This is possibly because access to extension service reduces the knowledge gap and perceived risk of new practices among farming communities. This emphasizes how important extension agents are in acting as conduits of information, training, and awareness about new technologies. Result is in line with previous studies (Khanal et al., 2025; Mdoda et al., 2025; Mhango & Chibomba, 2025; Onuwa et al., 2023; Obayelu & Ajayi, 2018). Similarly, probability of adoption of farm machinery increases by 41.98% among farmers with membership in agricultural cooperatives or farmers group.

Table 3. Determinants of farm machinery adoption in the study

Variables	Coef.	Std. Err.	p-value	dy /dx	Std.Err. (dy/dx)
Gender	0.2445	0.3099	0.430	0.0966	0.1220
Age	0.0359	0.0296	0.225	0.0142	0.0117
Education	-0.0096	0.0424	0.820	-0.0038	0.0168
Log(income)	0.3147	0.3256	0.334	0.1245	0.1287
Contact	1.2848***	0.3255	0.000	0.4793	0.1058
Membership	1.1181***	0.4231	0.008	0.4198	0.1361
Credit	-0.4083	0.3603	0.257	-0.1617	0.1408
Labor	-0.0145	0.4660	0.474	-0.1281	0.1721
Experience	-0.0145	0.0291	0.616	-0.0057	0.0115
_cons	-3.9470**	1.9815	0.046		

Summary statistics: Number of observations= 123; LR chi2(9)=58.34; Prob>chi2=0.0000; Pseudo R2= 0.3459; Log likelihood=-55.170.
Note: **, *** indicate significant at 5%, 1% level of significance, respectively.

This is possibly because cooperatives often play a role in disseminating information, joint purchasing or hiring of machines, and even accessing subsidies and credit. They build social capital and trust, which are indeed crucial for collective action in technology

diffusion. This finding informs the approach of various government programs, such as PMAMP, which normally work through farmer groups and cooperatives for technology dissemination. Result is consistent with the previous studies (Blekking et al., 2021; Donkor et al., 2023; Geffersa, 2023; Manda et al., 2020; Olagunju et al., 2021; Pandey & Mishra, 2025). Meanwhile, gender, age, education, income, and credit access did not have a statistically significant effect on adoption in this model. Though counterintuitive, this may indicate that in the Khotang context, institutional factors like extension and social networks are stronger drivers of adoption than individual characteristics of the households. For example, the insignificance of credit access may suggest that PMAMP's subsidy programs are particularly effective in lowering financial barriers to entry, such that personal access to credit is less of a determining factor.

Reasons for not adopting farm machinery

Table 4 presents the reasons stated by farmers for non-adoption of farm machinery. The major barriers are high rental costs, lack of technical knowledge about farm machinery usage and benefits, and cultivation on small fragmented lands. These results are consistent with previous studies (Kandel et al., 2021; Khatiwada et al., 2021; Kalwar et al., 2026; CSISA, 2021), which reported challenges of difficult terrain, small terraces, and limited access compound the economic and knowledge barriers across Nepal's hilly regions in adoption of farm mechanization.

Table 4. Reasons for not adopting farm machinery (n=54)

Barrier	Frequency
High rental costs	45
Lack of technical knowledge	40
Small landholding	38
Machinery not suitable for small farms	26
Non-availability during growing season	16
Lack of repair workshop	14

Overall, the results advocate that to minimize high rental costs, subsidies for initial procurement from custom hiring and agricultural cooperatives and farmers group can be made accessible. Effective extension services and training should be made accessible to reduce the knowledge barriers. Similarly, issue of small landholdings can be minimized by promoting scale-appropriate machinery and institutional innovations like group-based farming.

Desired support by women farmers to adopt farm machinery

Table 5 presents the support desired by women farmers to facilitate their participation in agricultural mechanization. The results revealed that training specified to women is the most desired support, reported by all 55 women farmers. Then, followed by subsidized rental service (54) and promotion of small-scale machinery (40).

Table 5. Desired support by women farmers (n=55)

Desired support	Frequency
Women-targeted training	55
Subsidized rentals	54
Promote small-scale machinery	40

The results emphasized the need for capacity building, skill development, and confidence building for effective adoption of farm machinery. Further, subsidized rental would allow women to overcome their financial limitations and increase access to ownership/rental capacity. In addition, results emphasizes that women farmers prefer farm machinery that is light, cheap, and suitable for small farms and small landholdings. Overall, findings suggest that increasing women's access to agricultural mechanization training, facilitating affordable mechanization services, and promoting gender-friendly technologies is essential for inclusive and sustainable agricultural mechanization in the present context (CSISA, 2021).

CONCLUSION

The results revealed that that adoption of farm machinery is limited to power tillers, shellers, and maize planters, while the adoption of harvesters and threshers is low. Probit model estimates that institutional factors affect the adoption of farm machinery. In the study area, two institutional factors such as regular contact with extension workers and membership in farmers' groups and cooperatives affected the adoption of farm machinery, positively. While, other socio-economic variables such as age, education, income, and access to credit were found to be insignificant. The result highlights that institutional linkages and collective action are significant factors affecting the adoption of farm machinery in the current context. Therefore, efforts should be on strengthening extension services and promoting farmers group/cooperative-based machinery ownership. Similarly, the results revealed that high rental cost is the major barrier to adoption of farm machinery. This is followed by limited technical knowledge among farmers and cultivation on small and fragmented lands. The results also report that women-focused training programs are the most desired need of women farmers, highlighting gender-responsive capacity-building initiatives in advancing mechanization. This is followed by desire for subsidized rental services, which could reduce economic barriers and allow equitable access to farm machinery. Addressing these economic, technical, and structural constraints through inclusive and targeted policy measures is essential for improving mechanization uptake and overall agricultural productivity.

AUTHORS' CONTRIBUTIONS

Bishal Rawat: Conceptualization; Validation; Formal analysis; Investigation; Data curation; Visualization; Writing-original draft.
Anish Bilash Panta:: Writing-original draft; Writing-review and editing.

Sushmita Bhatta: Conceptualization; Methodology; Software; Validation; Formal analysis;

Binayak Prakash Mishra: Investigation; Data curation; Writing-original draft; Writing-review and editing; Visualization.

REFERENCES

Blekking, J., Gatti, N., Waldman, K., Evans, T., & Baylis, K. (2021). The benefits and limitations of agricultural input cooperatives in Zambia. *World Development*, 146, 105616. https://doi.org/10.1016/j.worlddev.2021.105616

Kalwar, P. K. C., Bista, A., Bista, S., & Bista, S. (2026). Status of Farm Mechanization in Maize Farming at Deukhuri Valley of Nepal. *Turkish Journal of Agriculture-Food Science and Technology*, 14(1), 19-28. https://doi.org/10.24925/turjaf.v14i1.19-28.8023

CSISA. (2021). *Online Conference Report. Importance and Role of Scale Appropriate Machinery in COVID-19* Response including Gender Sensitiveness and Awareness. The Cereal Systems Initiative for South Asia (CSISA). Kathmandu, Nepal.

Kandel, S., Poudel, R., Saru, M. T., & Parajuli, T. (2021). Status of farm mechanization and its impact on maize production in Jhapa District, Nepal. *Archives of Agriculture and Environmental Science*, 6(3), 290-294. https://dx.doi.org/10.26832/24566632.2021.060304

Khatiwada, D., Dutta, J. P., Shrestha, K., Adhikari, G., & Paudel, H. (2021). Economic impact of agricultural mechanization in rice farming in Shivasatakshi Municipality of Jhapa District, Nepal**.** *Food and Agri Economics Review,* 1(1), 41–45. http://doi.org/10.26480/faer.01.2024.51.55

Daniel, W.W. (1999). *Biostatistics: A foundation for analysis in the health sciences*. 7th edition. New work: John Wiley & Sons.

Donkor, E., Ratinger, T., & Jiri, H. (2023). The Awareness and Adoption of Environmentally Sustainable Practices by Agricultural Cooperative Members in Zambia. *New Medit*, *22*(1). https://doi.org/10.30682/nm2301e

Gauchan, D., & Shrestha, S. (2017). Agricultural and rural mechanization in Nepal: Status, issues and options for future. In: *Rural Mechanization. A Driver in Agricultural Change and Rural Development*; Mandal, S.M.A., Biggs, S.D., Justice, S.E., (Eds); Institute for Inclusive Finance and Development: Dhaka, Bangladesh.

Geffersa, A. G. (2023). Does cooperative membership enhance inorganic fertilizer use intensity? Panel data evidence from maize farmers in Ethiopia. *Annals of Public and Cooperative Economics*, 95(2), 327-361. https://doi.org/10.1111/apce.12446

Khanal, R., Sushan, K. C., Paudel, A., & Poudel, N. (2025). Assess the Adoption of Improved Maize Production Technologies in Gulmi, Nepal. *The OCEM Journal of Management, Technology, and Social Sciences*, 4(1), 179-193. https://doi.org/10.3126/ocemjmtss.v4i1.74760

Li, H., Chen, L., & Zhang, Z. (2022). A study on the utilization rate and influencing factors of small agricultural machinery: Evidence from 10 hilly and mountainous Provinces in China. *Agriculture*, 13(1), 51. https://doi.org/10.3390/agriculture13010051

Li, W., Wei, X., Zhu, R., & Guo, K. (2018). Study on factors affecting the agricultural mechanization level in China based on structural equation modeling. *Sustainability*, *11*(1), 51. https://doi.org/10.3390/su11010051

Liu, Y., & Tian, Z. (2009). Analysis on Household income levels affects the demand for farm machinery and equipment, Chin. *Rural Econ*, *12*, 44-55.

Manda, J., Khonje, M. G., Alene, A. D., Tufa, A. H., Abdoulaye, T., Mutenje, M., ... & Manyong, V. (2020). Does cooperative membership increase and accelerate agricultural technology

adoption? Empirical evidence from Zambia. *Technological forecasting and social change*, *158*, 120160. https://doi.org/10.1016/j.techfore.2020.120160

Mdoda, L., Tamako, N., Gidi, L. S., & Naidoo, D. (2025). Evaluating the impact of improved maize varieties on agricultural productivity and technical efficiency among smallholder farmers in the Eastern Cape, South Africa: an empirical analysis. *GM Crops & Food*, 16(1), 272-304. https://doi.org/10.1080/21645698.2025.2476667

Mhango, G., & Chibomba, D. (2025). Assessing the effects of agricultural technology adoption on maize productivity in small-scale farming: A case study of Chongwe. *International Journal of Advanced Multidisciplinary Research and Studies, 5*(4), 790–798. https://doi.org/10.62225/2583049X.2025.5.4.4681

Obayelu, A. E., & Ajayi, D. O. (2018). Economic impact and determinants of adoption of improved maize production technologies. *Journal of Agricultural Sciences, Belgrade*, *63*(2), 217-228. https://doi.org/10.2298/JAS1802217O

Olagunju, K. O., Ogunniyi, A. I., Oyetunde-Usman, Z., Omotayo, A. O., & Awotide, B. A. (2021). Does agricultural cooperative membership impact technical efficiency of maize production in Nigeria: An analysis correcting for biases from observed and unobserved attributes. *Plos one*, 16(1), e0245426. https://doi.org/10.1371/journal.pone.0245426

Onuwa, G., Mailumo, S. S., & Oyewole, S. O. (2023). Socio-economic determinants of adoption of maize production technologies among smallholders. *AGRIEKONOMIKA*, 12(1), 83-94. https://doi.org/10.21107/agriekonomika.v12i1.14621

Pandey, J., & Mishra, B. P. (2025). Factors Affecting the Adoption Intensity of Farm Machinery Among Wheat Farmers in Rupandehi District, Nepal. *Journal of the Institute of Agriculture and Animal Science*, 39, 131-140. https://doi.org/10.3126/jiaas.v39i1.88282

Paudel, G. P., Gartaula, H., & Craufurd, P. (2020). Gender differentiated small-scale farm mechanization in Nepal hills: An application of exogenous switching treatment regression. *Technology in Society*, 61, 101250. https://doi.org/10.1016/j.techsoc.2020.101250

Paudel, G. P., Gartaula, H., Rahut, D. B., Justice, S. E., Krupnik, T. J., & McDonald, A. J. (2023). The contributions of scale-appropriate farm mechanization to hunger and poverty reduction: evidence from smallholder systems in Nepal. *Journal of Economics and Development*, *25*(1), 37-61. https://doi.org/10.1108/JED-10-2022-0201

Quan, X., & Doluschitz, R. (2021). Factors influencing the adoption of agricultural machinery by Chinese maize farmers. *Agriculture*, 11(11), 1090. https://doi.org/10.3390/agriculture11111090

Rai, P. B., Singh, O. P., Bhatta, S., & Mishra, B.P. (2024). Factors affecting the Adoption of Farm Mechanization among Rice Farmers in Chitwan District, Nepal. *The Lumbini Agriculture Journal*, *3*, 78.

Wu, Z., Liao, B., Fu, Q., Qi, C., & Liao, W. (2025). Agricultural Machinery Adoption and Farmers' Well-Being: Evidence from Jiangxi Province. *Agriculture*, 15(7), 738. https://doi.org/10.3390/agriculture15070738

Zepeda, A., Cheesman, S., Neupane, N., Shrestha, N., Shrestha, R. N., Amjath-Babu, T. S., ... & López Ridaura, S. (2023). Characterizing farm households in Khotang, Eastern Nepal, through a quantitative farming systems typology. International Maize and Wheat Improvement Center.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Economic Analysis of Dragon Fruit Production in Dang Nepal

Rojan KARKI[1*], Bharat Bikram RAWAT[2*], Rajendra BHARI[1], & Koshila GIRI[1]
[1]Himalayan College of Agricultural Sciences and Technology (HICAST)
[2] Rapti Technical College
Corresponding Author's Emaiil: karkirojan.ag@gmail.com

ABSTRACT

This study assessed the production status, marketing system, and economic viability of dragon fruit cultivation in Dang district from November 2024 to January 2025, based on a survey of 44 purposively selected farmers in Lamahi and Tulsipur. The total production cost per hectare was NRs 3,593,364.90. Despite high initial investment, dragon fruit farming proved economically viable, with a benefit-cost ratio of 2.59, net present value of NRs 760,551.54, and an annual net profit of approximately NRs 1,200,000 per hectare. The payback period was 1.09 years, and the break-even point was 91.81 kg per Katha (3.1 hectares). Direct marketing channels yielded the highest producer share (87.5%), while intermediary-based sales reduced it to 41.2%. Regression analysis identified land preparation, irrigation, and labor as major determinants of costs, whereas subsidies significantly reduced production costs. However, profitability was constrained by weak supply chains, unorganized markets, and post-harvest losses.

Keywords: Benefit-cost, dragon fruit, marketing, productivity, supply chain

INTRODUCTION

Dragon fruit (*Hylocereus undatus* (Haw.) Britton and Rose), an emerging high-value fruit crop in Nepal, is a member of the family Cactaceae, and is a semi-epiphytic climber well adapted to tropical and subtropical climates. Originally native to Central America (Le Bellec *et al.*, 2006), the dragon fruit is now widely cultivated in the warmer regions of Nepal, with commercial plantations expanding from Kavre to the country's eastern and western parts (Atreya *et al*., 2020). Fruit weighs on average in the range of 300-800 grams, containing small black seeds in pulp, and because it flowers at night, the plant is also called the queen of the night. The taste ranges from sweet to sour, and the fruit is consumed both raw and processed, such as in jam, jelly, and wine. This contains a rich volume of Vitamin C and antioxidants that help prevent various diseases such as cancer, diabetes, and high blood pressure, and also improve the digestive system (Chen *et al.*, 2024). Over the past few decades, serious climatic changes have been noted in Nepal; presently, along with the

increase in temperature, the rainfall pattern is erratic, and prolonged dry seasons have dire consequences for agricultural productivity (NPC, 2022). Dang District is particularly hit hard by these changes; it has observed frequent drought events and water scarcity that affect the farming communities of the area (IKI, 2022). Given its low water requirements and adaptability to adverse conditions, dragon fruit presents a viable alternative for marginal farmers in Nepal, offering a sustainable means to maintain livelihoods amidst changing climatic conditions (Wakchaure *et al*., 2023). According to Atreya *et al.* (2020), the growing interest in dragon fruit cultivation in Nepal has resulted from its tolerance of water and nutrient scarcity, ease of orchard management, and the potential for higher annual yields. However, despite the potential, several factors work against the large-scale commercialization of dragon fruit in Nepal: the fruit crop is relatively new, commodity-based technology and high-yielding varieties are not available, and quality grafted saplings are not available. Expansion is dominated by an unknown seedling variety, which may lead to inconsistent yield and fruit quality (Atreya *et al*., 2020). Somewhat, relatively high initial investment costs (Mehta *et al*., 2024) create a financial barrier, especially for small farmers, and thus, institutional and financial support is needed. Uncertainty in market prices and stiff international competition further complicate commercialization efforts. Besides, the lack of appropriate management technologies, post-harvest handling techniques, and processing industries has limited the potential for value addition and storage (Atreya, 2020). Given its agro-climatic suitability for many fruits of high value and increasing demand, dragon fruit cultivation can give a substantial improvement in rural livelihoods, contribute toward economic growth, and assure agricultural diversification in Nepal.

MATERIALS AND METHODS

The study was conducted in Dang District of Lumbini Province, Nepal. A total of 44 dragon fruit farmers were purposively selected, including 34 households from Tulsipur Municipality and 10 from Lamahi Municipality, all engaged in commercial or semi-commercial cultivation. The study applied multiple analytical approaches to evaluate economic viability, financial feasibility, and market performance. Cost and return analysis were used to calculate total cost, gross return, net profit, and return on investment to assess profitability.

Financial feasibility analysis included indicators such as Net Present Value (NPV), Payback Period, Break-even Quantity, and Benefit-Cost Ratio (BCR) to determine long-term viability and investment recovery. Marketing analysis examined price spread and producers' share to understand market efficiency and farmers' earnings. Regression analysis was conducted to identify key factors influencing production costs, while problem ranking using an index method helped prioritize the major constraints faced by farmers.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Table 1. Analysis type, indicators, formulae / methods used in the study

Analysis Type	**Indicators**	**Formula / Method**
Cost & Return Analysis	Total Cost (TC)	TC = TFC + TVC
	Gross Return (TR)	TR = Price × Quantity sold
	Net Profit	Net Profit = TR − TC
	Return on Investment (ROI)	ROI (%) = (Net Profit / Initial Investment) × 100
Financial Feasibility Analysis	Net Present Value (NPV)	NPV = ∑ (Net Cash Flow × Discount Factor)
	Payback Period	Based on cumulative cash flow recovery
	Break-even Quantity	Fixed Cost / (Selling Price − Variable Cost/ kg)
	Benefit-Cost Ratio (BCR)	BCR = Gross Return / Total Cost
Marketing Analysis	Price Spread	Consumer Price − Farm-gate Price
	Producer's Share	(Farm-gate Price / Retail Price) × 100
Regression Analysis	Cost Determinants	$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots + \beta_nX_n + \varepsilon$
Problem Ranking	Problem Index	$I = \sum (S_iF_i) / N$
Cumulative Investment = Initial investment + ∑Annual costs		

Conversion applicable: Note: 1 ha = 28.59 Katha, 20 katha = 1 Bigha)

RESULTS AND DISCUSSION

Economics of dragon fruit

Cost of production

The initial investment for dragon fruit is quite high when compared to other conventional crops due to the requirement of special equipment, such as pillars and tires, which support the growing dragon fruit. Likewise, the working capital is necessary for irrigation, fertilization, plant protection, labor, marketing, and transport, as shown in the table 2. The total cost of production was calculated by combining both fixed and variable costs. The total cost (A), which includes all production-related expenses, was estimated at Rs. 116,662.87 per Katha per year. In addition, the cost of agricultural machinery (B) was considered separately, amounting to Rs. 4,722.45 in the first year. Since machinery costs are distributed over five years, the annualized cost was calculated as Rs. 944.49. Therefore, the overall total cost of production was obtained by adding (A) and the annual machinery cost (B), resulting in Rs. 117,607.36 per Katha per year. This indicates that the average annual cost of dragon fruit production per Katha is Rs. 117,607.36.

Price trend of dragon fruit

The trend of price for dragon fruit can be observed declining according to the information provided by the farmers, which is supported by various reports. From a peak of NRs 900-1000 per kilogram (Rijal, 2019), it declined to NRs 500-900 in different markets of Nepal in the year 2020 (Dhakal *et al.,* 2021). As of 2023, the price ranged from NRs 500-800 in Nawalparasi (The Rising Nepal, 2023), which then plummeted to NRs 300-350 in just a

year (Koirala, 2024). Similarly, as of recently, the price of dragon fruit has been reported to be an average of 350 NRs per kilogram by the respondents. This price decline can be attributed to increased supply, poor storage facilities, and market saturation. The farmers have indicated that initially, dragon fruit was a high-value exotic crop, and therefore, there was high demand and premium prices. However, as production increased and imports from neighboring countries increased at half the price tag, the price stabilized and later declined.

Table 2. Initial Investment for dragon fruit orchard in the study area Dang

Cost components	**Fixed Capital (NRs/Katha)**	**Working Capital (NRs/Katha)**
Land preparation	5,000	-
Trellis and support system (Pillars, wires, Tires, etc.)	40,000	-
Cuttings/Saplings	16,700	-
Irrigation system (Drip irrigation)	8,300	1000
Fencing	6700	-
Storage	3300	-
Fertilizers and Manure	-	3300
Plant protection	-	1700
Labor cost	-	5000
Marketing and Transport	-	2500
Miscellaneous Expense	3300	1700
Total Estimated Cost	**83,300**	**15200**

Average dragon fruit production in the study area, Dang 024/25

Table 3 shows that dragon fruit is cultivated on an average of 1 Katha with 40–50 plants, producing about 400–500 kg per Katha. Overall, 44 Katha with 1,800–2,200 plants yielded 17,000–20,000 kg, indicating good production potential and income generation capacity.

Cash flow and benefit-cost ratio of dragon fruit production

Based on the cost calculation from the initial year, the project seems to be a loss, but it is well known that dragon fruit starts to fruit after year one, and upon proper management, the yield increases (CABI, 2020). The dragon fruit business is undertaken by technically sound farmers, and the production of up to 1500 kg/Katha can be achieved (Goenaga *et al.*, 2020). The selling prices can be raised to Rs. 400/kg in favorable conditions.

The analysis assumes that variable costs increase by 5% annually due to rising input prices, while the initial investment is reduced by 10% through efficient resource management and a one-time subsidy of Rs. 50,000. The total fixed cost is estimated at Rs. 162,744.37, and a salvage value of 20% of this amount (Rs. 32,548.87) is considered at the end of the project. Different production levels (500, 800, 1200, and 1500 kg per Katha) are evaluated using the Discounted Cash Flow (DCF) method, which accounts for costs and returns over multiple years.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Table 3. Total Annual Cost of Production in the study area Dang

S.N.	Description	Quantity	Per unit cost (Rs)	Average cost (Rs/Katha)
A.	**Fixed cost**			
1	Land tax	Lump sump	-	484.62
2	Depreciation (Annual)	Lump sump		8,106
3	Interest on Fixed capital	10%		8330
	Total	**16,920.62**		
B.	**Variable Cost**			
1	Land preparation and transplanting	6	610.27 per day	3679.49
2	Cuttings	40-50 cuttings	180 per cutting	47546.47
3	Manure (Self-made)	Lump sump		5171.31
	Manure (Purchased)	152 Kg	21 per Kg	2692.31
3	Urea	5-6 Kg/ plant	19.03	443.61
4	DAP	5-6 Kg/ plant	48.67	1246.15
5	Potash	3-4 Kg/ plant	34.92	1231.15
6	Irrigation	Lump sump		4137.90
7	Hoeing	Lump sump		3200.00
8	Plant protection	Lump sump		5287.38
9	Harvesting	Lump sump		5200.00
10	Transportation	Lump sump		4500.00
11	Agricultural Tools	Lump sump		6700.00
12	Labor cost	Lump sump		7500.00
	Interest on working capital	10 %		9815.53
Total Variable Cost				**107848.25**

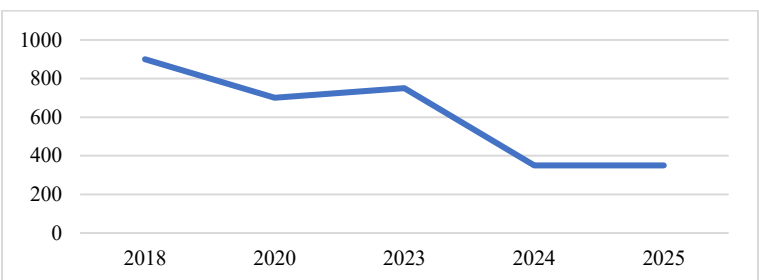


Figure 1. Price of Dragon fruit per kilogram throughout the years in the study sites (Source: Field Study)

Cash flow and return on investment

It can be observed in Table 4 that the ROI in the first year is negative (-8.38%), which implies that the cumulative investment exceeds the net profit. However, by the second year, it reaches 53.84%, showing an increase in recovery of more than half the investment. Continuing the upward trend, by the third year, ROI crossed 100%, *i.e.,* (117.44%),

indicating that the dragon fruit cultivation has fully repaid the investment and is generating profit. A substantial return can be observed by the fourth year with 182.64% ROI.

Table 4. Average Dragon Fruit Production

Total production area (Katha)	Total No. of plants cultivated	Total Production/Yield now (kg)	Avg. production area (Katha)	Avg. No. of plants cultivated per Katha	Avg. Yield per Katha (kg)
44	1800-2200	17000-20000	1	40-50	400-500

Average Return on Investment (ROI)

The average return on investment (ROI) was calculated by dividing the average net profit by the initial investment and multiplying by 100. Using the values from the study, the average net profit of Rs. 128,192.51 was divided by the initial investment of Rs. 98,500, resulting in an ROI of 130.1%. This indicates that dragon fruit cultivation generates returns equivalent to approximately 1.3 times the initial investment annually, reflecting strong profitability.

Table 5. Cash Flow and Return on Investment

Year	**Description**	**Cash Outflow (Rs)**	**Yield (kg/Katha)**	**Gross Income (Rs)**	**Cash Inflow (Rs)**	**Net Profit (Rs)**	**Cumulative Investment (Rs)**	**ROI (%)**
0	Initial Investment	98,500	–	–	–	-98,500	98,500	–
1	Production Year 1	119,778.83	500	200,000	200,000	80,221.17	218,278.83	-8.38
2	Production Year 2	119,778.83	800	320,000	320,000	200,221.17	338,057.66	53.84
3	Production Year 3	119,778.83	1,200	480,000	480,000	360,221.17	457,836.49	118.44
4	Production Year 4 + Salvage Value	119,778.83	1,500	600,000	632,548.87	512,770.04	577,615.32	182.64

Average Return on Investment (ROI)

The average return on investment (ROI) was calculated by dividing the average net profit by the initial investment and multiplying by 100. Using the values from the study, the average net profit of Rs. 128,192.51 was divided by the initial investment of Rs. 98,500, resulting in an ROI of 130.1%. This indicates that dragon fruit cultivation generates returns equivalent to approximately 1.3 times the initial investment annually, reflecting strong profitability.

Discounted cash flow analysis table

The discounted cash flow analysis shows that dragon fruit cultivation is financially viable, with a Net Present Value (NPV) of Rs. 760,551.54. The total discounted benefits (Rs.

1,238,630.85) significantly exceed the total discounted costs (Rs. 468,175.35), resulting in a Benefit-Cost Ratio (BCR) of 2.59. This indicates strong profitability over time, driven by increasing yields, improved market prices, reduced initial investment through subsidies, and efficient resource management.

Table 6. Combined discounted cash flow analysis table

Year	Net Cash Flow (Rs)	Discount Factor (10%)	Discounted Net Benefit (Rs)	Discounted Cost (Rs)	Discounted Benefit (Rs)
0	-98,500	1.000	-98,500	98,500.00	–
1	80,221.17	0.909	72,920.84	106,004.57	181,800
2	200,221.17	0.826	165,382.68	96,365.55	264,320
3	360,221.17	0.751	270,526.08	87,599.98	360,480
4	512,770.04	0.683	350,221.94	79,705.25	432,030.85
Total	–	–	**760,551.54 (NPV)**	**468,175.35**	**1,238,630.85**

Payback Period and Break-Even Point (BEP)

Payback period represents the total minimum time taken to generate enough cash flow to recover the initial investment costs. From Table 7, it is conspicuous that by the end of year 1, the initial investment is still not recovered with a cumulative net cash flow of Rs -18,278.83; meanwhile, by the end of year 2, the cumulative net cash flow is Rs 181,942.34, suggesting the initial investment is fully recovered. In this study, the payback period falls between Year 1 and Year 2. It was calculated using the remaining investment at the end of Year 1 (Rs. 18,278.83) divided by the net cash flow in Year 2 (Rs. 200,221.17), resulting in 0.091 years. Adding this to the first year gives a total payback period of 1.091 years, which is approximately 1 year and 1.1 months. This indicates that the initial investment is recovered quickly, demonstrating strong financial viability.

Table 7. Cumulative Net Cash Flow

Year	Net Cash Flow (Rs)	Cumulative Net Cash Flow (Rs)
0	-98500	-98500
1	80,221.17	-18,278.83
2	200,221.17	181,942.34
3	360,221.17	542,163.51
4	512,770.04	1,054,933.55

Break-Even Point (BEP)

The break-even point (BEP) represents the level at which total revenue equals total cost, resulting in no profit or loss. It can be expressed in terms of time or production quantity. In terms of time, the BEP is equivalent to the payback period, calculated as 1.091 years. In terms of quantity, the BEP was determined using fixed costs and the difference between the selling price and variable cost per kilogram. Using a fixed cost of Rs. 16,920.62, a selling price of Rs. 400 per kg, and a variable cost of Rs. 215.7 per kg, the break-even

quantity was calculated as 91.81 kg. This indicates that a farmer needs to produce and sell at least 91.81 kg of dragon fruit to cover all production costs.

Regression analysis of cost of production

A multiple linear regression analysis was conducted to identify factors that influence the cost of dragon fruit production. The variables, including land preparation, cuttings, irrigation, and labor, are the most significant factors influencing the cost of production.

Table 8. Regression results for cost of production

Variable	Coefficient	Std. Error	t-value	p-value
Intercept	5200	190	27.37	0.000***
Land Preparation	0.5	0.1	5	0.000***
Cuttings	0.3	0.05	6	0.000***
Manure	0.2	0.04	5	0.000***
Fertilizer	0.1	0.03	3.33	0.001**
Irrigation	0.4	0.06	6.67	0.000***
Plant Protection	0.3	0.05	6	0.000***
Harvesting	0.2	0.04	5	0.000***
Transportation	0.1	0.03	3.33	0.001**
Labor	0.5	0.1	5	0.000***
Farming Area	0.2	0.04	5	0.000***
Yield	-0.1	0.02	-5	0.000***
Subsidy	-0.4	0.07	-5.71	0.000*

*(*p < 0.10, **p < 0.05, ***p < 0.01)*

These findings indicate the significant impact that the high initial establishment costs have on the overall cost of production of dragon fruit. Likewise, the subsidy shows a significant negative relationship with the cost of production ($p<0.001$), *i.e.,* a 1 Rs increase in subsidy leads to a 0.4 Rs reduction in the total cost, assuming that other factors remain constant. These highlight the importance of the role of the Agriculture Knowledge Center's subsidy programs that provide financial assistance of up to Rs 2 lakh based on expenditure cost. In addition, the negative coefficient for yield indicates that higher yields reduce the per-unit production cost. Similar findings were reported by Mehta *et al.* (2024) in their study conducted in the southern Terai region of Nepal.

Marketing channel, price spread, and producer's share

Six primary marketing channels were identified in the study area of Tulsipur and Lamahi, Dang. Most of the farmers leveraged the nearby highway area to sell their produce; similarly, consumers also preferred to buy directly from the farm gate. Their dragon fruits were mostly sold at the nearby city, Ghorahi, and within the markets of the study site. The fruits are transported to major cities including Kathmandu, Narayanghat, Pokhara, Butwal, and Nepalgunj. The last channel identified was with the involvement of the Middleman.

Table 9. Marketing channels in the study area

Channels	Actors Involved
Channel I	Farmer-Consumer (Highway area) (F-C)
Channel II	Farm gate sale (F-C)
Channel III	Farmer-Retailer-Nearby Market (F-R-C)
Channel IV	Farmer-Wholesaler-Nearby City-Retailers (F-W-R-C)
Channel V	Farmer-Wholesaler-Big cities (F-W-R-C)
Channel VI	Farmer-Middlemen-Wholesalers (F-M-W-C)

Furthermore, price distribution and market margins were analyzed to understand the economic dynamics across various market channels, which is described in the table 9. The analysis of marketing channels shows that as the number of intermediaries increases, the price spread and market margin also rise, while the producer's share declines. The highest price spread (Rs. 500) and market margin were observed in longer channels like F-M-W-C, indicating higher consumer prices but lower returns to farmers, who still receive a base price of Rs. 350. In contrast, the direct marketing channel (F-C) had the lowest price spread (Rs. 50) and market margin, allowing producers to receive the highest share (87.5%) while consumers pay lower prices. Channels with more intermediaries, such as F-W-R-C and P-M-W-C, showed reduced producer shares of 53.80% and 41.20%, respectively.

Constraints related to production and marketing

Farmers identified the lack of region-specific cultivation practices as the primary production challenge, followed by high initial investment and limited access to high-quality planting materials; irrigation was the least concern due to low water requirements. In marketing, major issues included price fluctuations, declining consumer preference due to mild taste, post-harvest losses, and inadequate storage, transport, and processing facilities. Additionally, competition from imported dragon fruit, especially from Vietnam and Thailand, further reduces the market share of local producers.

Table 10. Pricing structure across market channels

Channel	Producer Price (Rs)	Consumer Price (Rs)	Total Market Margin (Rs)	Producer Share (%)
F-C	350	400	50	87.5
F-C	350	450	100	77.8
F-R-C	350	550	200	63.6
F-W-R-C	350	650	300	53.8
F-W-R-C	350	750	400	46.7
F-M-W-C	350	850	500	41.2

Table 11. Major constraints in Dragon fruit production

S.N.	Production-related Problem	Rank
1	High initial investment costs	II
2	Inadequate irrigation facilities	V
3	Lack of access to quality planting materials	III
4	Pest and Disease outbreaks	IV
5	Lack of region-specific protocols of cultivation	I
S.N.	**Marketing-related Problem**	**Rank**
1	High price fluctuation	I
2	Poor storage and transportation facilities	III
3	Post-harvest losses	IV
4	Competition from imported dragon fruit	II
5	Intermediaries	V

CONCLUSION

Dragon fruit cultivation in Dang demonstrates strong economic potential due to its climate resilience and growing market demand. The study confirms its long-term profitability, with a benefit–cost ratio of 2.59, NPV of NRs 760,551.54, a short payback period (1.09 years), and an average ROI of 130.1%. However, profitability is influenced by high initial investment, labor dependence, and key cost factors such as land preparation, irrigation, and labor. Marketing inefficiencies and longer supply chains reduce producer share, while direct selling enhances farmer returns. Addressing constraints related to input availability, post-harvest management, and market infrastructure through targeted policy support and investment is essential to fully realize the potential of dragon fruit cultivation and promote sustainable agricultural diversification.

AUTHORS' CONTRIBUTIONS

Rojan Karki: Conceptualization; Data curation; Software; Formal analysis; Visualization; Writing-review and editing.
Bharat Bikram Rawat: Investigation; Methodology, Writing-original draft.
Rajendra Bhari: Conceptualization; Validation.
Koshila Giri: Writing-review and editing, Formal analysis.

REFERENCES

Atreya, P. (2020*). Dragon Fruit Cultivation in Nepal. Government of Nepal*, Ministry of Agriculture and Livestock Development, National Fruit Development Center, Warm Temperate Horticulture Center, Kirtipur, Kathmandu.

CABI, (2020). *Economic analysis of dragon fruit production.* CABI Digital Library. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20203429708 [Accessed 12 Nov. 2024].

Chen, S.Y., Xu, C.Y., Mazhar, M.S. and Naiker, M., (2024). Nutritional Value and Therapeutic Benefits of Dragon Fruit: A Comprehensive Review with Implications for Establishing Australian Industry Standards. *Molecules,* 29(23), 5676.

Dhakal, A.R., Mahatara, B., Parajuli, S., Budhathoki, S., Paudel, S. and Regmi, S. (2021). Farmers' knowledge level and readiness in adoption of dragon fruit (Hylocereus sp.) in Chitwan District, Nepal. *Food and Agriculture Economics Review (FAER)*, 1(1), 57-63. Available at: https://doi.org/10.26480/faer.01.2021.57.63 [Accessed 8 Dec. 2024].

Goenaga, R., Marrero, A., and Pérez, D. (2020). Yield and Fruit Quality Traits of Dragon Fruit Cultivars Grown in Puerto Rico. *HortTechnology hortte* 30, 6, 803-808. Available from: < https://doi.org/10.21273/HORTTECH04699-20> [Accessed 12 Jan. 2025]

IKI. (2022). *Clean Energy Initiatives in Dang District, Nepal*. IKI Small Grants. Available at: https://iki-small-grants.de/k1project/clean-energy-initiatives-in-dang-district-nepal/[Accessed 6 Oct. 2024].

Le Bellec, F., F. Vaillant and E. Imbert., (2006). Pitahaya (*Hyloicereus* spp.): A new fruit crop, a market with a future. *Fruits,* 61: 237-250.

Mehta, A., Lamichhane, P., Khatiwada, R., Mandal, A., Chaudhary, P. & Aryal, S., (2024). Dragon fruit cultivation, profitability, and production efficiency in Southern Terai, Nepal. International *Journal of Horticultural Science and Technology*, 11(4), 469-480. Available at: https://www.researchgate.net/publication/378743756 [Accessed 6 Nov. 2024].

NPC. (2022). *Climate Change Related Indicators of Nepal. United Nations Statistics Division.* Available at: https://unstats.un.org/unsd/envstats/compendia/Nepal_ClimateChangeRelatedIndicatorsofNepal_2022.pdf [Accessed 25 Dec. 2024].

Rijal, S. (2019). Dragon fruit in Nepal. *Malaysian Journal of Halal Research (MJHR),* 2(2), 25. Available at: https://doi.org/10.2478/mjhr-2019-0010

The Rising Nepal. (2023). *Dragon fruit cultivation flourishes in Nawalparasi*. Available at: https://risingnepaldaily.com/news/22574 [Accessed 5 Oct. 2024].

Koirala, H.P. (2024). Farmers make good income from dragon fruit farming. *The Rising Nepal,* Tuesday, December. Available at: https://risingnepaldaily.com/news/53439 [Accessed 16 Nov. 2024].

Wakchaure, G.C., Minhas, P.S., Kumar, S., Mane, P., Kumar, P.S., Rane, J. and Pathak, H., (2023). Long-term response of dragon fruit (Hylocereus undatus) to transformed rooting zone of a shallow soil improving yield, storage quality and profitability in a drought prone semi-arid agro-ecosystem. *Saudi Journal of Biological Sciences*, 30(1), 103497.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Comparative Analysis of Technical Efficiency among Smallholder Rice Farmers Using Local and Improved Seeds in North Central Nigeria

Godfrey Ajayi, SUNDAY[1], Olugbenga Omotayo, ALABI[2] and Josephine Bosede, AYOOLA[3]

[1]Plot 1027 Abdul One Mohammed Close, Off Abdulsalam Abubakar Way, Gudu District, Abuja, NIGERIA

[2]Department of Agricultural Economics, Faculty of Agriculture, University of Abuja, PMB 117 Gwagwalada-Abuja, Federal Capital Territory, NIGERIA.

[3]Federal University of Agriculture Makurdi (Now Joseph Surwuan Tarka University Makurdi) PMB 2373 Markurdi, Benue State, NIGERIA

***Corresponding Author's Email**: omotayoalabi@yahoo.com,
(ORCID: https://orcid.org/0000-0002-8390-9775)

ABSTRACT

The research compared technical efficiency among smallholder rice farmers using local and improved seeds in North Central, Nigeria. A multi-stage random sampling to choose a total sample size of two hundred and thirty-four (234) rice farmers which comprises 88 and 146 smallholder farmers who cultivated local and improved rice seeds, respectively. Primary data were used for the study. The data were collected with the aid of well-structured questionnaire which was subjected to validity and reliability tests. Data were analyzed using descriptive statistics, stochastic production frontier model, and t-test statistics. The results show that the mean age of smallholder farmers utilizing local and improved rice seeds were 43 and 42 years, respectively. The average farm sizes were estimated at 2.00 and 1.99 hectares, respectively. The analysis indicates that farm size, fertilizer, and agrochemicals are significant predictors with a positive impact on rice yields for both local and improved seed users. Furthermore, the inefficiency model reveals that increased farming experience significantly enhances technical efficiency across both groups of smallholder farmers. The mean technical efficiency scores of smallholder farmers who cultivated local and improved rice seeds were 50.2% and 77.2%, respectively. This leaves an inefficiency gap of 49.8% and 22.8%, for improvement, respectively. The study recommends that credit facilities should be made available to rice farmers at low-interest rate devoid of bureaucratic processes. Improved rice seed and other farm inputs such as fertilizer should be made available to smallholder farmers at affordable prices to increase productivity and efficiency.

Keywords:, Agrochemicals, farm, fertilizer, labour stochastic frontier model

INTRODUCTION

Rice (*Oryza sativa*) is one of the most significant staple foods in Nigeria, it makes up roughly 10.5% of the average calorie intake of Nigerians and accounts for 6%

of household expenses (Toluwase et al., 2019). Because of the shift in consumer preference towards rice, rising population, rising income levels, and rising urbanisation, rice consumption is rising quickly in Nigeria (Kamai et al., 2020). Rice (*Oryza sativa*) farming in Nigeria is primarily carried out by smallholder farmers, who cultivate both improved and local rice seed varieties across diverse agro-ecological zones. According to the Food and Agriculture Organization (2019), Nigeria produced approximately 8.9 million metric tons of milled rice, positioning it as one of Africa's largest rice producers. If the right steps are taken, Nigeria may generate 14 million tonnes per year, up from the 8.9 million tonnes. Nigeria is currently the second-largest rice importer after China, with an average of 2.4 million tonnes per year, since rice consumption has overtaken domestic production (Durand-Morat et al., 2019; FAO, 2019). According to Durand-Morat et al. (2019), FAO (2019), and USDA-ERS (2019), rice consumption is expected to expand during the following ten years because of urbanisation and population growth. The demand-supply gap is still evident in the economy despite concerted efforts over the years to increase rice production, including the Agricultural Transformation Agenda, agricultural promotion policies, and the closing of borders against rice importation. Despite the efforts, fewer than 10% of the possible 3.4 million hectares are currently being farmed (Oyinbo et al., 2013; Macauley, 2015). According to Kanu et al. (2014), estimates over 96% of African farmers are smallholders and according to Cadoni and Angelucci (2013), 90 percent of domestic rice production is produced by resource-poor, smallholders' farmers. According to Babura et al. (2017), smallholder farmers play a critical role in Nigeria's rice production, contributing substantially to national food security and rural livelihoods. Improved rice varieties, developed through breeding programs, are designed to possess desirable traits such as high yield potential, drought resistance, quick growth, disease resistance, and improved grain quality (Khan et al., 2015). These varieties are the result of concerted efforts by research institutions and breeding programs to enhance rice productivity and resilience to biotic and abiotic stresses. Conversely, local rice varieties in Nigeria are often traditional landraces cultivated by farmers for generations, adapted to local environmental conditions and cultural preferences (Bello et al., 2020). While local varieties may exhibit resilience to certain environmental stressors and cultural significance, they often have lower yields and increased susceptibility to pests and diseases compared to improved varieties (Ojo et al, 2018). Despite the potential advantages of improved varieties, smallholder farmers continue to cultivate local varieties, influenced by factors such as cost, seed availability, lack of extension services and ignorance of perceived performance (Oluwatoyin, 2021).

Technical efficiency means employing the fewest inputs possible to produce the highest level of output possible given the inputs. According to Farrell (1957), a firm's capacity to produce on the isoquant frontier is correlated with technical efficiency (TE). The farm's production function may prevent a firm of its size from reaching the frontier. However, given their levels of inputs, some firms may produce outputs that are closer to the frontier. The measure of technical efficiency for each firm is the idea of how close the individual production plans are to the maximum levels, as defined by the frontier and given input levels (Ouedraogo, 2015). Takele et al. (2020) measured the technical, allocative, and economic efficiency of rain-fed rice production and identify the factors that affect the efficiency of farmers in Fogera Districts of the Amhara Region. For the study, cross-sectional data were collected from a survey of 230 smallholder rice producers. The study used stochastic frontier production (SFA) and cost function to investigate the variations in the efficiency level of rice producers. The result indicated that the technical efficiency (TE) was higher as compared with the economic efficiency (EE) and allocative efficiency (AE). The average TE ranges between 24% and 93% with a mean of 70%. However, the mean of EE was 24.40 % and the AE 37.30%. Therefore, reduction of cost of production (such as improved input supply systems), warehouse facilities to keep produce and prevent the immediate sale of a product, introducing of a contract marketing system would improve the economic efficiency of the rice farming. Interventions on education and training on female-headed households, reducing family dependency, training of older farmers were vital to increase the EE of rice production. Similarly, improving the farmer's education level to boost knowledge about new rice technology applications, and frequent training of farmers would enhance the TE of farmers in the study area. Chikezie et al. (2020) analysed the technical efficiency of rice farmers in Ebonyi State, Nigeria. It specifically analysed the levels and determinants of technical efficiency. A multistage sampling technique was adopted for sample selection. A total of 150 well-structured questionnaires were distributed but only 91 were returned. The Cobb-Douglas production function model was used to predict the farm level technical efficiency. Results from the Cobb- Douglas Regression showed a sigma square ($\sigma 2$) of 0.06584 which was statistically significant at 1 percent. The technical efficiency scores among the rice farmers ranged from 0.012 to 1.000 with a mean of 0.350. Farm size, quantity of rice seedlings, quantity of fertilizer and quantity of agrochemical all were showed positive correlation with coefficients of 0.93511, 0.08310, 0.11200 and 0.14345 respectively while farm labour showed a negative correlation with technical efficiency. The determinants of technical inefficiency were age, household size and extension visits. This paper advocates the

strengthening of existing extension system for timely sourcing of highly improved rice seed varieties and subsidized fertilizer. There is the need to enhance farmers' technical efficiency through adequate training on optimum input mix. The study focused on comparative analysis of technical efficiency among smallholder rice farmers using local and improved seeds in North Central, Nigeria.

MATERIALS AND METHODS

This study was conducted in Niger State and Federal Capital Territory (FCT). Niger state is located between Latitudes 8^0 22' North and $11^0$30' North and Longitudes 30 30' East and 70 20' East. It has a population of 5,556,247 people as estimated by National Bureau of Statistics (NBS), 2016) and is projected to be 7,069,097 in 2023 at a 3.5% growth rate (Population Growth Calculator, 2023). The Federal Capital Territory has a land area of 8,000 square kilometres. It falls within Latitude 9.0765° North and Longitude 7.3986° East. FCT had a population of 3,564,126 people (NBS, 2016) and is projected to be 4,534,563 people in 2023 at a 3.5% growth rate (Population Growth Calculator, 2023).

A multi-stage sampling method was used to select the target respondents. In the first stage, three LGAs from Niger State and three area councils from FCT were randomly selected. In the second stage, two wards each were randomly selected from each of the area councils and LGAs making a total of twelves wards. In the third and final stage, a proportionate simple random sampling was employed to select a total of two hundred and thirty-four (234) rice farmers from a sample frame of five hundred and sixty-five (565) rice farmers in the study area. The sample size (234) comprises eighty-eight (88) and one hundred and forty-six (146) smallholder farmers who cultivated local and improved rice seed was calculated using Yamane (1967) as shown below.

$$n = \frac{N}{1 + N(e^2)} = \frac{565}{1 + 565(0{,}05^2)} = 234 \qquad (1)$$

Where,

n = Sample Size (Units)
N= Sample Frame (Units)
e = Level of Significance (5%)

Primary data were used for this study. A pilot test was conducted prior to the main test to ensure the reliability and validity of the questionnaire used for data collection. The questionnaire applied in the collection of data for this study was subjected to validity and reliability tests by the supervisors of the study. The reliability test statistics made use of Cronbach's' alpha. It is considered a measure

of scale reliability to determine the internal consistency of the questionnaire. The coefficient ranges from 0, implying no reliability, to 1, implying perfect reliability.

$$\propto = \frac{D\bar{H}}{\bar{\gamma} + (D-1)\bar{H}} \qquad (2)$$

Where,

D= Number of Variables,

$\bar{H}$ = Average inter-item Covariance among the Variables, and

$\bar{\gamma}$ = Average Variance.

Validity is the degree to which the test scores from a research study measure what they intend to measure. The survey instrument (structured questionnaire) was face and content-validated by the researcher and supervisors.

The results of the reliability test presented Cronbach's alpha of 0.762 (76%). Cronbach's alpha ranges from zero to one. A reliability coefficient of 0.5–0.7 is considered moderate reliability and hence acceptable (Taherdoost, 2016). The data were analysed using both descriptive and statistics and stochastic frontier production model.

Stochastic frontier production model

The stochastic frontier model following Peter et al. (2020) was used to achieve part of objectives two (ii) and three (iii). The model is expressed thus:

$$W_{ij} = f(X_i, \beta) + \varepsilon_i \qquad (3)$$

Where,

W_{ij}= Output of the Farmer (Local and Improved Rice Seed) (Kg),

X_i= Vector of Actual Quantity Used,

β = Vector of Parameter to be Estimated,

e_i = Composite Error Term; $e_i = v_i - u_i$,

v_i = Decomposed Error Term Measuring Technical Efficiency of the Farmer, and

u_i = The Inefficiency Component of the Error Term.

Stochastic frontier production model is stated explicitly as: -

$$L_n W_{ij} = \beta_0 + \beta_1 L_n X_1 + \beta_2 L_n X_2 + \beta_3 L_n X_3 + \beta_4 L_n X_4 + \beta_5 L_n X_5 + V_i - U_i \qquad (4)$$

Where,

W_{ij} = Output of the Farmer (Local and Improved Rice Seed Farmers) (Kg),

X_1 = Farm Size (Ha),

X_2 = Fertilizer Usage (Kg)

X_3 = Agrochemicals (Liters),

X_4 = Labour (Mondays),

X_5 = Seed Usage (Kg),

β_0= Constant Term,
β_1-β_5 = Regression Coefficients,
V_i = Decomposed Error Term Measuring Technical Efficiency of the Farmer, and
U_i = The Inefficiency Component of the Error Term.
The inefficiency component of the stochastic frontier model is stated thus: -

$$U_i = \propto_0 + \propto_1 Z_1 + \propto_2 Z_2 + \propto_3 Z_3 + \propto_4 Z_4 + \propto_5 Z_5 + \propto_6 Z_6 \quad (5)$$

Where: -
$\propto_0$= Constant Term,
$\propto_1$ - $\propto_7$ = Regression Coefficient,
U_i = Inefficiency Component (Local and Improved Rice Seed Farmer),
Z_1 = Farming Experience of Rice Farmers (Years),
Z_2 = Level of Education of Rice Farmers (Years),
Z_3 = Age of Rice Farmers (Years),
Z_4 = Household Size of Rice Farmers (Number),
Z_5 = Number of Contact with Extension Agent (Number of Contact/Month), and
Z_6= Sex of Rice Farmers (1, Male; 0, Otherwise).

The t-Test of Difference between Means

$$t - Stat = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{{S_1}^2}{n_1} + \frac{{S_2}^2}{n_2}}} \quad (6)$$

Where,
$\overline{X_1}$ = Mean of Improved Seed Users
$\overline{X_2}$ = Mean of Local Seed Users
${S_1}^2$ = Variance of Improved Seed Users
${S_2}^2$= Variance of Local Seed Users
n_1 = Number of observation of Improved Seed Users
n_2 = Number of observation of Local Seed Users

RESULTS AND DISCUSSION

Socio-economic characteristics of smallholder farmers utilizing local and improved rice seeds farmers

Table 1 shows the results of the socio-economic characteristics of Smallholder Farmers Utilizing local and improved rice seeds in the study area. The mean age of Smallholder farmers who cultivated local and improved rice seeds were 43, and 42 years, respectively. This implies that most of the rice farmers were predominantly young, resourceful, and energetic in their economically active age.

This finding is similar to that of Raju et al. (2015), Obot et al. (2022), and Okoro et al. (2023). The mean household sizes were 6 for smallholder farmers who cultivated local and improved rice seeds respectively. This has a direct impact on the supply of labour to the farm because of the potential contributions of these people to the labour available for rice production. The results align with the findings of Antwi and Aborisade (2017), Oloyede et al. (2020), and Mauki et al. (2023). The mean farm size is 2.0 and 1.99 hectares for smallholder farmers who cultivated local and improved rice seeds respectively. This suggests that the farmers were small-scale farmers. The mean experiences were 17, and 14 years for smallholder farmers utilizing local and improved rice seeds respectively. According to Isah and Muhammad (2017), number of years of experience could improve skills and approaches to rice farming practices. The results suggest that the farmers were not new to the rice enterprise, as the majority had over 10 years of experience. The average annual income earned by smallholder farmers utilizing local and improved rice seeds were ₦1,504,886, ₦1, 609,368.8 respectively. This suggests an average monthly income of ₦125,407.17 and ₦134,114.07. The average number of contacts with extension agents within the production seasons were 3 and 4 respectively.

Table 1. Socio-economic characteristics of rice farmers using local and improved seeds

Variable	Unit of Measurement	Local Seeds	Improved Seeds
Age	Years	43	42
Household Size	Number	6	6
Farm Size	Hectares	2	1.99
Faming Experience	Years	17	14
Income from other Farming Activities	Naira	1, 504, 886	1,609,368.8
Contact with Extension Agent	Number	3	2

Source: Computed from Field Data (2024)

Factors influencing technical efficiency of rice production in the study area

Table 2 shows the estimated maximum likelihood results of the stochastic frontier production function for rice farmers in the study area. From the results, farm size ($P<0.01$), fertilizer usage ($P<0.01$), agrochemicals ($P<0.01$), and seeds ($P<0.01$) were significant factors influencing the output of smallholder farmers utilizing local rice seed in the study area. Farm size ($P<0.01$), fertilizer ($P<0.01$),

agrochemicals (P<0.01), and labour (P<0.01) were significant factors influencing the output of improved rice seed variety farmers in the study area.

Farm size had positive coefficients and was statistically significant at 1% probability levels in influencing the technical efficiencies of smallholder farmers utilizing local and improved rice seeds. respectively. This means that a 1% increase in the farm size, while holding other variables constant will lead to a 21.4% and 34.7% increase in the output of smallholder farmers utilizing local rice and improved rice seed respectively. This result is in line with Okello et al. (2019), Takele et al. (2020), and Chikezie et al. (2020), who reported that farm size is one of the major factors influencing rice production. Fertilizer usage had positive coefficients and was statistically significant at 1% probability levels in influencing the output of local rice seed varieties farmers and improved rice seed varieties farmers respectively. This implies that a 1% increase in fertilizer input will result in a 30.9% and 20.7% increase in the rice output of local rice seed varieties' farmers and improved rice seed varieties' farmers respectively. This collaborates with the findings of Ouedraogo (2015), Okello et al. (2019), and Takele et al. (2020), who reported that fertilizer input had a positive effect on rice production.

Agrochemicals had positive coefficients and was statistically significant at 1% level of probability in influencing the output of smallholder farmers utilizing local and improved rice seed. This implies that a 1% increase in agrochemicals, keeping all other factors fixed will result in a 23.2% and 20.7% increase in the output of smallholder farmers utilizing local and improved rice seeds, respectively. Seed input had positive coefficients and was statistically significant at 1% level of probability in influencing the output of smallholder farmers utilizing local rice seed. The result shows that a 1% increase in seed input keeping all other factors fixed will lead to a 10.8% increase in the output of smallholder farmers utilizing local rice seed. In the diagnostic statistics, the variance parameters of the production function, which are represented by Chi-squared, lambda, and gamma, were significant at the 1% probability level. This is in line with the findings of Ouedraogo (2015), Okello et al. (2019), Takele et al. (2020), Chikezie et al. (2020), and Mauki et al. (2023).

From Table 2, the inefficiency component revealed that farming experience, contacts with extension agents, and sex were statistically significant variables influencing technical inefficiency of rice farmers. Farming experience had negative coefficients and was statistically significant at 10% probability levels in

influencing technical influencing of smallholders utilizing local and improved rice seed respectively. The results suggest that a unit increase in farming experience keeping all other factors constant will lead to a 0.129 unit and 0.067 unit increase in the technical efficiencies of smallholder farmers utilizing local and improved rice seeds. This collaborates with the findings of Ouedraogo (2015), Okello et al. (2019), and Takele et al. (2020).

From Table 2, Contact with extension agents had a positive coefficient and was statistically significant at 5% probability level in influencing inefficiencies of smallholder farmers utilizing improved rice seed. The results suggest that a unit increase in contact with extension agents keeping all other factors fixed will lead to a 0.4022 unit decrease in the technical efficiency of the farmers who cultivated improved rice seed. This finding does not conform with the results of Chikezie et al. (2020) and Mauki et al. (2023). From Table 2, Sex had negative coefficients, was statistically significant at 5% probability levels in influencing technical inefficiency of smallholder farmers utilizing improved rice seed. The results suggest that a unit increase in male farmers keeping all other variables fixed will lead to a 0.776 unit increase in the technical efficiency of the farmers who cultivated improved rice seed.

Technical efficiency scores for smallholder rice farmers utilizing local and improved rice seed in the study area

Table 3 presents the technical efficiency scores of rice farmers in the study area. About 62.50% and 93.15% of the smallholder farmers utilizing local and improved rice seeds respectively, were between 51% to 97% efficient. This means that majority of the farmers are technically efficient. Such efficiency distribution conforms to previous studies carried out on rice farming by Okello et al. (2019), Takele et al. (2020), Chikezie et al. (2020), Peter et al. (2020), and Mauki et al. (2023). The mean technical efficiency of the rice farmers was 50% and 77%, for smallholder farmers who cultivated local and improved rice seeds respectively, leaving a gap of 50% and 23% for improvement.

Therefore, for smallholder farmers who cultivated local rice seed, there is substantial room for improvement, with technical efficiency at 50%. This indicates that they are only utilizing half of their potential productivity. There is a 50% gap that can be addressed through various interventions. For smallholder farmers who cultivated improved rice seed, while their technical efficiency is higher at 77%, there is still a 23% gap for potential improvement. The result also

means that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could make 20% and 21% cost savings for smallholder farmers who cultivated local improved rice seed varieties farmers respectively.

Table 2. Maximum likelihood estimates of the stochastic frontier production function for rice farmers in the study area

Variables	Local Rice Seed Farmers (N=88)			Improved Rice Seed farmers (N=146)		
	Coefficient	Standard Error	t-ratio	Coefficient	Standard Error	t-ratio
Technical Efficiency Component						
Farm Size	0.214 ***	0.058	3.67	0.347***	0.062	5.58
Fertilizer	0.309 ***	0.037	8.40	0.207***	0.04	5.22
Agrochemicals	0.232 ***	0.042	5.49	0.207***	0.074	2.80
Labour	0.103	0.065	1.58	-0.143**	0.07	-2.06
Seed	0.108 ***	0.035	3.11	0.019	0.039	0.48
Constant	-1.797 ***	0.463	-3.88	-2.73***	0.515	-5.30
Technical Inefficiency Component						
Constant	-4.151 ***	0.19	-21.84	-4.961***	0.574	-8.64
Farming Experience	-0.129*	0.073	-1.76	-0.067*	0.037	-1.78
Level of Education	0.018	0.388	0.05	0.021	0.123	0.17
Age	0.038	0.096	0.39	0.03	0.025	1.20
Household Size	0.364	0.348	1.05	0.056	0.071	0.79
Contact with Extension Agents	0.304	0.338	0.01	0.4022**	0.2047	1.96
Sex	0.053	1.484	0.04	-0.776**	0.382	-2.03
Constant	-68.279	6772.937	-0.01	-9.632**	4.778	-2.02
Chi-square		1067.808***			913.457***	
Lambda		1.09			4.99	
Gamma		54%			96%	
*** $p<.01$, ** $p<.05$, * $p<.1$						
Source: Computed from Field Data (2024)						

Test of Hypothesis

The data presented in Table 4 leads to a clear rejection of the null-hypothesis, demonstrating that there is, in fact a statistically significant difference between the technical efficiency of local and improved seed users. The calculated t-value

of 14.79 comfortably exceeding the critical t-table value of 1.96, the result indicate that the performance gap is not due to random chance. Farmers utilizing improved seeds achieved a substantially higher mean technical efficiency of 0.772 compared to the 0.502 recorded for local seed users, suggesting that improved variety are a primary driver of productivity. Furthermore, the significantly lower standard deviation for improved seed users (0.017 versus 0.158) implies that the benefits of these seeds are consistent across the larger sample of 146 observations where as local seeds performance is much more volatile and less reliable.

Table 3. Technical Efficiency Scores of Smallholder Farmers Utilizing Local and Improved Rice in the Study Area

Seed	**Local Rice Seed Farmers**		**Improved Rice Seed Farmers**	
	Freq.	**Perc.**	**Freq.**	**Perc.**
0.141-0.50	33	37.50	10	6.85
0.51-0.80	55	62.50	98	67.12
0.81-1.00			38	26.03
Total	**88**	**100**	**146**	**100**
Mean	0.502		0.772	
Min	0.374		0.449	
Max	0.624		0.97	
Standard Deviation	0.069		0.141	
Freq = Frequency	**Perc = Percentage**			
Source: Computed from Field Data (2024)				

Table 4. There is no significant difference between technical efficiency of smallholder rice farmers using local and improved seeds in the study area

Variable	**Technical Efficiency (Values)**
Local Seed Users	0.502
Improved Seed Users	0.772
Standard Deviation (Local)	0.158
Standard Deviation (Improved)	0.017
Number of Observation (Local)	88
Number of Observation (Improved)	146
t-Calculated	14.79
t-Table Critical Value	1.96

Source: Computed from Field Data (2024)

CONCLUSION

The study established that improved seed varieties were significantly more effective in enhancing productivity than local varieties. The farmers utilizing improved seeds achieved the higher mean technical efficiency (0.772) compared to those using local seeds (0.502), a difference validated by a robust t-calculated value of 14.79, which far exceeded the critical threshold. The stochastic frontier model highlighted that while both groups relied heavily on farm size, fertilizer, and agrochemicals, improved seed users benefited more from land expansion (coefficient of 0.347), however they faced challenges with labour management. Furthermore, the inefficiency analysis indicated that farming experience and extension contact played vital roles in reducing waste and improving output. With gamma value for improved seed users, it was evident that 96% all deviations from the maximum potentials output were due to technical inefficiencies rather than random noise. Ultimately, shifting from local to improved seeds, supported by better extension services, remained the most viable pathway for closing the yield gap, and ensuring food security in the region.

RECOMMENDATIONS

To close the 22.8% efficiency gap between local and improved seed users the following recommendations were made:

(i) **Adoption of Improved Seed Varieties**: Smallholder currently using local seeds should shift to using certified improved varieties.

(ii) **Optimization Farm Size and Labour**- Farmers should focus on land size or better land preparation.

(iii) **Enhanced Input Management:** Farmers should adopt precision agriculture techniques, applying the right quantity at the right time.

(iv) **Strengthening Extension Services**. The government should recruit and train more extension officers to provide technical how-to sessions specifically focusing on the management of improved varieties.

(v) **Subsidized Input Distribution Systems**- The government should move beyond general subsidies, and implement a targeted electronic-wallet system in order to ensure access to certified improved seeds and high-quality fertilizer.

(vi) **Gender-Sensitive Agricultural Support**- Policies should specifically target female rice farmers with tailored credit facilities and land tenure security.

AUTHORS' CONTRIBUTIONS

All Authors contributed equally towards the research and manuscript preparation of the article.

REFERENCES

Antwi, K. & Aborisade, O. (2017). Profitability of Rice Production Among Small-Scale Rice Producers in Ghana. *American Journal of Agricultural Science*. 4,13-17.

Babura, B., Isah, S., & Chamo, A. (2017). Role of Smallholder Farmers in Nigeria's Food Security. *Journal of Agricultural Science*, 7(1), 12-19.

Bello, L., Baiyegunhi, L., & Danso-Abbeam, G. (2020). Productivity impact of improved rice varieties' adoption: case of smallholder rice farmers in Nigeria. *Economics of Innovation and New Technology*. 3(1),1-17.

Cadoni P., & Angelucci F. (2013). Analysis of incentives and disincentives for rice in Nigeria. Technical notes series, MAFAP, FAO, Rome.

Chikezie, C., Benchendo, G.N., Ibeagwa, O.B, Oshaji, I.O. & O.A. Onuzulu (2020). Analysis of Technical Efficiency Among Rice Farmers in Ebonyi State of Nigeria: A Stochastic Frontier Approach, *Journal of Agriculture and Food Sciences,* 18(1),40-49.

Durand-Morat, A., Chavez, E., & Wailes, E. (2019). International Rice Outlook, International Rice Baseline Projections, 2018-2028. International Rice Outlook.

Food and Agriculture Organization (FAO) (2019). Retrieved August 20, 2023, From FAOSTAT: http://www.fao.org/faostat/en/#home

Farrell, M.J. (1957). The Measurement of Production Efficiency. *Journal of Journal of the Royal Statistical Society* 120:253-290.

Kamai, N., Omoigui, L.O., Kamara A.Y., & Ekeleme, F. (2020). Guide to rice production in northern Nigeria. International Institute of Tropical Agriculture, Ibadan, Nigeria. 27(1), 35.

Kanu, B.S., Salami, A.O., & Numasawa, K. (2014). *Inclusive Growth: An Imperative for African Agriculture*. Tunis: African Development Bank.

Khan, M. H., Dar, Z., & Dar, S. (2015). Breeding Strategies for Improving Rice Yield—A Review. *Agricultural Sciences*. 06, 467-478.

Macauley, H. (2015). Cereal crops: Rice, Maize, Millet, Sorghum, Wheat. Feeding Africa Conference (21-23 October 2015, Dakar, Senegal), Abdou Diouf International Conference Center, 2015 www.afdb.org/fileadmin/upload..._sorghum_wheat.pdf

Mauki, C. Jeckoniah, B.B., & Massawe, G.D. (2023). Smallholder rice farmers profitability in Agricultural Marketing Co-operative Societies in Tanzania: A case of Mvomero and Mbarali districts, *Heliyon*, 2-9.

Obot, A., Okeke., C., Precious, C., & Onuoha, F. (2022). Factors Influencing the Adoption FARO-44 Rice among Smallholder Farmers in Anambra State, Nigeria," *Canadian Journal of Agriculture and Crops, Online Science Publishing*, 7(1), 30-37.

Ojo, M.A., Mohammed, U.S., Ojo, A.O., Yisa, E.S. & Tsado J.H. (2019). Profit efficiency of small-scale cowpea farmers in Niger State, Nigeria. *International Journal of Agricultural Economics and Rural Development*, 2(2), 40-48.

Okello, D.M., Bonabana-Wabbi, J., & Mugonola, B. (2019) Farm level allocative efficiency of rice production in Gulu and Amuru districts, Northern Uganda. *Agric Econ* **7**, 19 .

Okoro, J.C., Ugah D.E., Aroh, J.A., Obioha, O.G., Udoye, C.E., & Agwu, E.A. (2023). Perceived Factors Influencing Farmers' Preference for Rice Varieties in Enugu State, Nigeria. *Journal of Agricultural Extension*, 27 (1), 86-93

Oluwatoyin, B. C. (2021). Factors influencing adoption of improved maize seed varieties among smallholder farmers in Kaduna State, Nigeria. *Journal of Agricultural Extension and Rural Development*. 13, 107-114.

Oloyede, W.O., Muhammad-Lawal, A., Amolegbe, K. B., Olaghere, I.L., & Joseph, I.A. (2020). Comparative Analysis of the Profitability of Rice Production Systems in Kwara State, Nigeria, *Agrosearch*, 20(2), 82-101.

Oyinbo O., Damisa M.A., & Rekwot G.Z. (2013). Growth trend of rice demand and supply in Nigeria: Opportunity for youth and women empowerment. *Russian J. of Agric. and Soc. Ec. Sc*., 4(6), 31-34

Ouedraogo, S. (2015). Technical and Economic Efficiency of Rice Production on the Irrigated Plain of Bagre (Burkina Faso): A Stochastic Frontier Approach, *Journal of Economics and Sustainable Development*, 6(14), 78-85

Peter, D.O., Olohungbebe, S.A., & Rahji, M.A.Y., (2020). Profitability and Technical Efficiency of Rice Production in Abuja, Nigeria. *Nigerian Journal of Scientific Research*, 19 (1), 21-27

Raju, G., Huang, W., & Rudra, B.S. (2015). Factors Affecting Adoption of Improved Rice Varieties among Rural Farm Households in Central Nepal, *Rice Science*, 22(1), 35-43.

Takele, A., Teferi, E., & Berhanu, A. (2020). Technical and Economic Efficiency of Rice Production in Smallholder Farmers: The case of Fogera District, Amhara Region, Northwestern. 1(1),1-10.

Toluwase, S.O.W., Osundare, F.O., & Adekunmi, A.O., (2019). Economic Analysis of Rice Marketing in Some Selected Local Government Areas of Ekiti State, Nigeria. *European Journal of Food Science and Technology*, 7, 9-23

United States Department of Agriculture, Foreign Agricultural Service (USDA-FAS), (2019). USDAPSDOnlineDatabase.https://apps.fas.usda.gov/psdonline/app/index.html#/app/advQuery

Taherdoost, H (2016). Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research. *International Journal of Academic Research in Management,* (IJARM), 5(3): 28 – 36

Yamane, T. (1967). *Statistics, An Introductory Analysis*, 2nd ed., New York: Harper and Row.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Effect of cow dung and NPK fertilizer on the early growth of Northern Black Wattle (*Acacia auriculiformis* A. Cunn. ex. Benth) in Kaduna Northern Guinea Savanna Eco - zone of Nigeria

Akintunde Isiaka, SODIMU*[1], Fatima Muhammad, RASHEED[2], and David, BAYO[3]

[1]Savanna Forestry Research Station, Forestry Research Institute of Nigeria, PMB 1039, Samaru – Zaria, Kaduna, NIGERIA;
[2]Federal College of Forestry Mechanization, Forestry Research Institute of Nigeria, PMB 2273, Afaka – Kaduna, NIGERIA;
[3]Northern Guinea Research Station, Forestry Research Institute of Nigeria, Nasarawa, NIGERIA
***Corresponding author's email**: tunsod88@gmail.com ; sodimu.ai@frin.ng

ABSTRACT

During the early stages of plant growth, trees are very well dependent on soil nutrient supply, the soil has to be enrich with nutrients (Organic and inorganic) applications for optimal growth and development. This study was aimed at evaluating the effect of cow dung and NPK applications on *Acacia auriculiformis* at early growth stage to ascertain the best means of improving faster seedling growth of the species. The study was conducted in Savanna Forestry Research Station nursery situated in Institute for Agricultural Research (I.A.R) farm Samaru in Kurumi Bomu village. Seeds of matured *Acacia auriculiformis* were collected from plus tree at Savanna Forestry Research Station, Samaru – Zaria; Pre-treated with 50% of sulfuric acid (H_2SO_4) for 60 minutes to break the seed dormancy and sown directly in nursery pots filled with top soil, ten (10) potted seedlings were picked two (2) weeks after germination and divided into three (3) groups of three (3) different levels (3g; 6g and 9g) of cow dung and NPK (15:15:15) fertilizers. The experiment was laid out using Complete Randomized Design (CRD), ring method of fertilizers application were used. measured include seedling height; number of leaves and seedlings diameter the data was collected at 2WBFA, 4WAFA, 6WAFA and 8WAFA and subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) at the end of the experiment the results show that application of cow dung at various doses significantly $P \leq 0.05$ yielded better growth and seedlings quality of Acacia auriculiformis as compared to NPK (15:15:15) fertilizer. NPK applied at 6 grams and 9 grams were significantly $P \leq 0.05$ toxic to the seedlings which led to high mortality rate after

application. However, from the results obtained in this experiment it was recommended that cow dung should be utilized to make nutrient available for optimal growth of *Acacia auriculiformis* seedlings and the application of NPK fertilizers above 3g on *Acacia auriculiformis* seedlings should be discouraged.

Key Words: Cow-dung, eco-zone, growth, NPK, Ring method

.

INTRODUCTION

Northern black wattle, Ear-pod wattle, or Darwin black wattle ***(Acacia auriculiformis*** Cunn ex. Benth - (Family- Fabaceae) is a leguminous and multipurpose evergreen tree, which is found in many tropical zones of Southeast Asia, Africa and Latin America (Das & Alam, 2001; Simons & Leakey, 2004). It grows with a trunk up to 12 m long and 50 cm in diameter. It has dense foliage with an open, spreading crown. The trunk is crooked and the bark vertically fissured. Roots are shallow and spreading. Leaves 10-16 cm long and 1.5-2.5 cm wide with 3-8 parallel nerves, thick, leathery and curved. Flowers are 8 cm long and in pairs, creamy yellow and sweet scented. Pods are about 6.5 x 1.5 cm, flat, cartilaginous, glaucous, transversely veined with undulate margins (Tropical Plants Data Base, 2025). They are initially straight but on maturity become twisted with irregular spirals. Seeds are transversely held in the pod, broadly ovate to elliptical, about 4-6 x 3-4 mm (Amin *et al.,* 1995). The plant has a spreading, superficial and densely matted root system, which makes it suitable for stabilizing eroded land. Plantations of the tree improve soil physio-chemical properties such as water-holding capacity, organic carbon, nitrogen and potassium through litter fall. Its phyllodes provide a good, long-lasting mulch, the dense, dark-green foliage, which remains throughout the dry season, makes it an excellent shade tree. This plant species grows very fast, with the ability to fix nitrogen, thrive on infertile, acid, alkaline, saline and waterlogged soils (Hossain *et al.,* 1997). Successful use of *A. auriculiformis* in agro-forestry programme in Africa and Bangladesh has been reported owing to its rapid growth, short rotation and ability to thrive on degradable soil (Amin *et al.,* 1995). *A. auriculiformis* is a potential plant for erosion control, water conservation and also a source of biomass for fuel generation (Hossain *et al.*, 2009). The bark contains sufficient tannin (13 - 25%) for commercial exploitation, Bark harvested for its tannins should only be taken from mature stems, and only when the sap is rising at the beginning of the growing season - which is when the tannin content is highest and the bark is most easily removed from the wood, however, a natural dye, used in the batik textile industry in Indonesia, is also extracted from the bark (Orwa *et al.,* 2009). The heartwood

is light brown to dark red; it is demarcated from the yellow sapwood. The wood is hard, has a high basic density; is fine and straight-grained; often attractively figured; It is excellent wood for turnery articles, toys, carom coins, chessmen and handicrafts, it's also used for furniture, joinery, tool handles; and for construction if trees of suitable girth are available(Orwa *et al.,*2009). The wood is extensively used for paper pulp; Plantation-grown trees have been found promising for the production of unbleached Kraft pulp and high-quality, neutral, sulfite semi-chemical pulp (Orwa *et al.,* 2009). A major source of firewood, its dense wood and high energy (calorific value of 4500-4900 kcal/kg) contribute to its popularity; it provides very good charcoal that glows well with little smoke and does not spark (Hossain *et al.*, 2009).

A decoction of the root is used to treat aches and pains and sore eyes; an infusion of the bark has been used to treat rheumatism, the bark of all Acacia species contains greater or lesser quantities of tannins and are astringent; Astringents are often used medicinally - taken internally, for example, they are used in the treatment of diarrhea and dysentery, and can also be helpful in cases of internal bleeding and they applied externally, often as a wash, they are used to treat wounds and other skin problems, hemorrhoids, perspiring feet, some eye problems, as a mouth wash and so on (Orwa *et al.,* 2009). Many Acacia trees also yield greater or lesser quantities of a gum from the trunk and stems. This is sometimes taken internally in the treatment of diarrhea and hemorrhoids (Orwa *et al.,* 2009). However, to effectively harness the potentials of this species, emphasis must be made for improving their demand as plantation trees. In this regard, the use of organic (cow dung) and inorganic manure (NPK) applications becomes essential in forest soil management practice. In order to regenerate a forest and maintain it, the soil has to be enriched with nutrients. This enrichment could be in form of fertilizer application, which may be organic or inorganic forms, all of which furnish plants with nutrients necessary for their growth (Offiong *et. al.,* 2010; Eduardo *et. al.,* 2016; Sodimu et al., 2021). Siddhuraju (2007) and Sodimu *et. al.,* (2020) reported that during the early stages of growth, trees are very well dependent on soil nutrient supply. However, failure to manage nursery soil adequately can result in depletion of site quality and a reduction of seedling growth (Hoque *et. al.,* 2004; Sodimu *et. al.,* 2020) The dilemma for the foresters is therefor, how to increase the yield and quality of products for rapidly expanding wood based industries and for use by a rapidly expanding human population and simultaneously maintaining the environmental diversity. However, it is well understood that the loss of diversity may be minimized in a sustainable manner through increasing the number of species used in production forestry through

domestication of indigenous timber species (Rafiqul *et al.,* 2004). In view of this multipurpose function and utility of Black wattle (*Acacia auriculiformis*), it is favored for plantation programs. This study was aimed at evaluating the effect of cow dung and NPK applications on *Acacia auriculiformis* at early growth stage to ascertain the best means of improving faster seedling growth of the species.

MATERIALS AND METHODS

Study area

The study was conducted in Savanna Forestry Research Station nursery situated in Institute for Agricultural Research (I.A.R) farm Samaru in Kurumi Bomu village. Located at Latitude 12°13'and 11°11'N / Longitude 8°39' and 7°38' E and 686m above sea level (Figure 1). It is located in Sabon – Gari Local Government Area of Kaduna State. The vegetation in the local Government Area is the Northern Guinea Savannah woodland type, characterized by short scattered drought resistant trees with undergrowth of grass that serves as fuel for bushfires in the long dry season with mean annual rainfall of 1000mm – 1500mm, temperature of 25.6°C (78.1°F), precipitation of 1,117.6mm and humidity of 69% respectively (Sodimu *et al.*, 2021).

Seed treatment and experimental design

The pods of *Acacia auriculiformis* seeds were collected from Savanna Forest research station, Samaru Zaria. The seeds were extracted from the pods by soaking the pods in water for overnight to soften the coat and then wash in running water to remove the seeds. Seed dormancy was broken by soaking the seeds in 50 % concentration of H_2SO_4 acid for 60 minutes to rupture the hard coat and to enhance the germination of seeds. (Abubakar & Muhammed, 2013). The experiment was laid out in a Completely Randomized Design (CRD) with 2 (two) treatments (Cow dung and NPK) and three levels (3g; 6g and 9g) It was replicated 4 (four) times and a control

Seeds sowing and nutrient application

Treated seeds were sown directly into poly pots filled with sterilized river sand. Two (2) seeds were sown per poly pot, approximately 2cm deep into the pots. The seedlings were allowed for 2 (two) weeks growth before fertilizer application. *Acacia auriculiformis* seedlings were transplanted into poly pots filled with a mixture of top soil and river sand in ratio of 3:1 before the fertilizer application.

Both the cow dung and NPK fertilizers were applied when the seedlings were 2 (two) weeks old using ring method at varying levels of 3 g, 6 g and 9 g were administered into the poly pots.

Data collection and analysis

Observation were made and data were collected for the following early growth parameters; seedling height; diameter and number of leaves produced. The growth parameters were measured at two (2) weeks interval for eight (8) weeks. The height of seedling in each poly pot was measured using a graduated meter rule. Veneer caliper was used to measure the diameter of seedlings. The production of new leaves recorded by visually counting the number of leaves produced. These parameters were measured fortnightly. The data collected were Analyzed using Analysis of Variance (ANOVA) at $P \leq .0.05$ probability level and subjected to Duncan Multiple Range Test (DRMT).

RESULTS AND DISCUSSION

Table 1 shows the chemical analysis of cow dung and physiochemical properties of soil before the experiment. However, from the results the soil properties of the soil sample include sand (93.00%), stilt (1.70) and clay (6.44) this implies that the experimental soil is sandy hence coarse in texture. The experimental soil had a pH of 6.80 which indicates that the soil is neutral while the cow dung had pH of 8.68, which indicate alkalinity.

Seedlings height of *Acacia auriculiformis*

Table 2 shows varying effects of levels of Cow dung and NPK fertilizers applications on the mean height of *Acacia auriculiformis* seedlings. Highest mean height of 22.66cm was observed in the 6g treatment of Cow dung in the 8th week after application while NPK treatment recorded highest height of 19.15cm also at the 8th week after application. The lowest mean value of 0.00 was observed at 6^{th} and 8^{th} Weeks after planting in 6g and 9g dosage of NPK, respectively. However, there were negative responses of NPK fertilizers on survival of *Acacia auriculiformis* when the dosage was increased and this significantly increase the mortality rate at $P \leq 0.05$ when compare with the cow dung. Although, there were no significant difference $P \geq 0.05$ between the height in their initial height. This result is in accordance with the work of Ugese (2010) who observed that organic manure increases the growth of *Tamarindus indica.* The application of little doses

of fertilizer stimulates cell differentiation and multiplication leading to height increments (Afa *et al.,* 2011). Similar results have been reported for *Michelia champaca L* seedlings in which minimal doses of Phosphorus yielded positive effects on height increments (Hoque *et al.,* 2004). Although, high doses of phosphorus application may become toxic to seedlings since absorption of this element may affect regular metabolic processes (Ojeniyi, 2020).

Table 3 Shows effect of the varying levels of cow dung and NPK fertilizers on number of leaves of *Acacia auriculiformis.* Highest mean number of 20.41 was observed with 6g dosage of cow dung treatment in the 8th week after application while the NPK treatment with mean number of leaves of 16.10 recorded in the 8th week after application. Results indicated significant difference $P \leq 0.05$ in the number of leaves which showed increase through the study period.

Table1. Physiochemical properties of experimental soil and cow dung

Physical Properties	**Soil**	**Cow Dung**
Sand (%)	93.00	-
Silt (%)	1.70	-
Clay (%)	6.44	-
Chemical Properties		
pH	6.80	8.68
Elec.-cond.(ppm)	80.4	11970
Organic comp.(g/kg)	10.88	27.75
Organic manure(g/kg)	19.48	69.85
Available P (mg/kg)	41.16	0.129
Total N (g/kg)	0.38	0.74
Exchangeable Cations		
Na (mol/kg)	1.01	2.15
K (mol/kg)	0.41	2.01
Ca (mol/kg)	2.13	0.64
Mg (mol/kg)	10.53	0.153
E.A (mol/kg)	0.00	-
CEC (mol/kg)	14.48	-

There were negative responses of NPK fertilizers on number of leaves of *Acacia auriculiformis* when the dosage was increased (6g and 9g) and this significantly increase the mortality rate at $P \leq 0.05$ and causes burning of the leaves and the whole plant generally when compare with the cow dung. However, the above

finding agrees with the work of Ugese (2010) who obtained higher results in the number of leaves using organic manure on the growth of *Tamarindus indica.* Also, Mbah *et al.,* (2019) recorded better yield performance on crops planted with organic soil.

Table 2. Effect of varying level of Cow dung and NPK Fertilizers on the Mean Height (cm) of *Acacia auriculiformis* Seedlings

Treatment	2WBFA	4WAFA	6WAFA	8WAFA
Cow dung(3g)	10.55a	11.83a	18.31b	20.78c
Cow dung(6g)	10.30a	12.67a	19.90b	22.66c
Cow dung(9g)	11.42a	12.67a	18.71b	20.45c
NPK(3g)	11.44a	12.87a	16.32c	19.15
NPK(6g)	10.52a	11.26a	0.00	0.00
NPK(9g)	10.65b	9.74b	0.00	0.00
Control	-	13.78b	9.42a	9.45a
SE±	1.30	1.53	1.42	1.83

(i) Means in the same column followed by unlike letters are significantly different at
(ii) P≤.0.05 level of probability using Duncan's Multiple Range Test (DMRT)
(iii) WBFA=Weeks before fertilizers application.
(iv) WAFA= Weeks after fertilizers application

Table 3. Effect of varying level of cow dung and NPK fertilizers on the mean number of leaves of *Acacia auriculiformis* seedlings

Treatment	2WBFA	4WAFA	6WAFA	8WAFA
Cow dung(3g)	4.50a	9.04b	13.30a	20.51a
Cow dung(6g)	4.20a	8.63a	12.80a	20.41c
Cow dung(9g)	4.31a	8.95a	12.91a	17.80ab
NPK(3g)	6.00b	8.44a	13.68b	16.10b
NPK(6g)	4.10a	7.13a	0.00	0.00
NPK(9g)	4.50a	6.63a	0.00	0.00
Control	-	9.33b	9.60a	9.40b
SE±	0.84	0.98	1.40	2.6

(i) Means in the same column followed by unlike letters are significantly different at P≤0.05 level of probability using Duncan's Multiple Range Test (DMRT)
(ii) WBFA=Weeks before fertilizers application.
(iii) WAFA= Weeks after fertilizers application

Stem Diameter of *Acacia auriculiformis* Seedlings

Table 4 shows effect of the varying levels of cow dung and NPK on the mean girth of *Acacia auriculiformis* seedlings. Highest mean girth of 0.77cm was observed with 9 g dosage of cow dung treatment in the 6th week after application while the NPK treatment with mean diameter of 0.74cm in 3 g dosage recorded in the 6th week after application. The seedlings in this experiment were not significantlyP≥0.05 different in their initial diameter (at the time of fertilizer application).

Table 4. Effect of varying level of Cow dung and NPK fertilizers on the mean diameter (cm) of *Acacia auriculiformis* seedlings

Treatment	2WBFA	4WAFA	6WAFA	8WAFA
Cow dung(3g)	0.71a	0.72a	0.76a	0.76a
Cow dung(6g)	0.71a	0.71a	0.74a	0.76a
Cow dung(9g)	0.71a	0.72a	0.77a	0.77a
NPK(3g)	0.72a	0.72a	0.74a	0.75a
NPK(6g)	0.70a	0.71b	0.00	0.00
NPK(9g)	0.75b	0.60a	0.00	0.00
Control	-	0.71a	0.71a	0.71a
SE±	0.12	0.14	0.12	0.12

(i) Means in the same column followed by unlike letters are significantly different at P≤0.05 level of probability using Duncan's Multiple Range Test (DMRT)

(ii) WBFA=Weeks before fertilizers application.

(iii) WAFA= Weeks after fertilizers application

NPK applied at 6 g and 9 g were toxic to the seedlings which significantly P≤0.05 led to the high mortality rate in the treatment after application. NPK fertilizer have significant effect on diameter increment of *Acacia auriculiformis* seedlings and that after 6 weeks of application, there were no significant (P≥0.005) difference. This observation is in accordance with work of Rafiqul (2004) who recorded high performance of stem diameter in fertilizer application with *Anthocephalus chinensis.* Offiong *et al,* (2010); Mukhtar (2016) also recorded high performance of stem diameter in organic manure application with *Adansonia digitata* and *Tetrapleura tetraptera.*

CONCLUSION

It is an evident from the results that application of cow dung at various doses yielded better growth at the early stage of *Acacia auriculiformis* as compared to NPK fertilizers. Treatment with NPK was toxic to the seedlings at 6 g and 9 g levels of applications which led to the death of the seedlings.

RECOMENDATIONS

Based on the above results, it is therefore recommended that cow-dung should be utilized for better plant nutrition and faster growth of *Acacia auriculiformis* seedlings, and also, the application of NPK fertilizers above 3g, can affect the growth of *Acacia auriculiformis* seedlings negatively hence p roper application guidelines should be adhered to for optimum growth and development of the species.

AUTHORS' CONTRIBUTIONS

Akintunde Isiaka SODIMU: Investigation; data curation; writing-original draft; software / formal analysis; writing-review part, and editing.
Muhammed Fatima RASHEED: Conceptualization; validation,
David BAYO : Methodology, and editing

REFERENCES

Abubakar, Z.A. & Muhammed, A. (2013) Breaking seed dormancy in Tamarind. *Applied Sciences and Environmental Management* 17(1): 83- 87.

Afa, F., Bechem, E., Andrew, E., Genla, F., Ambo, F.B., & Ndah, N.R (2011) Effects of organic and inorganic fertilizers on early growth characteristics of *Khaya ivorensis Chev* (African mahogany) in nursery. *African journal of Plant Science* 5(12) 722 – 729.

Amin, S.M.R, Ali, M.O, & Fattah, M.I.M (1995). Eucalypts in Bangladesh. In: Proceedings of a seminar held at *Bangladesh Agricultural Research Council* on April 06, 1994. Pp.28

Das, D.K, & Alam, M.K (2001). *Trees of Bangladesh. Chittagong, Bangladesh*: The Art Press. p. 11

Eduardo, C.P., Jose, M.D., Francisco, M.D., Wagner, C.D &Vander, M. (2016). Growth and Level of N, P and K in Root Stocks of Tamarind Trees Using Organic Substrates and Doses of Phosphorus. *Rev. Caatinga, Mossoro*.2:274-282. *http://www.scielo.br/scielo.php.*

Hoque A, Hossian M.K., Mohiuddin M., & Hoque, M.M. (2004). Effect of inorganic fertilizers on initial growth performance of *Michelia champaca Linn*. Seedling in Nursery. *Journal of Biological Sciences* 4: 489-49

Hossain, M.K, Islam, S.A, Zashimuddin, M, Tarafdar, M.A, & Islam, Q.N (1997). Growth and Biomass Production of Some Acacia and Eucalyptus Species in Degraded Sal Forest Areas in Bangladesh. *Indian Forester*. 23(3):211-217

Hossain, L, Huda, S.M.S, & Hossain, M.K (2009). Effects of Industrial and Residential Sludge on Seed Germination and Growth Parameters of *Acacia auriculiformis* Seedlings. *Journal of For. Res*. 20(4):331-336

Mbah, C.N.,Onweremadu, E.U., & Njoku, C. (2019). Evaluation of Cow dung and NPK fertilizer on soil quality and crop productivity. *Nigerian Journal of Agriculture and Rural Development*, 17 (5). 401 – 410.

Mukhtar, R.B (2016) Response of Adansonia digitata seedling to organic manure in Aliero area of Kebbi State. *Nigerian Journal of Agriculture, Food and Environment* 12(4): 120- 122.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. & Anthony, S. (2009). *Agroforestry data base: A tree reference and selection guide version 4.0* (*http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp*).

Offiong, M. O., Udofia, S. I., Owoh, P. W. & Ekpenyong, G. O. (2010): Effects of fertilizer on the early growth of *Tetrapleura tetraptera Del. Nigerian Journal of Agriculture, Food and Environment*, 6(2): 53-59.

Ojeniyi, S.O. (2020). Organic manure: Benefits for sustainable agriculture. *Soil Science Journal.* 12 (3), 48 56.

Rafiqul, H. M., Hossian, M. K., Mpoinddon, M. & Hoque, M. M. (2004): Effect of inorganic fertilizers on the initial growth performance of *Anthocephalus chinensis (Lam*) seedlings in nursery. *Journal of Applied Science,* 4(1):477-485

Siddhuraju, P. (2007). Antioxidant activity of polyphenolic compounds extracted from defatted raw and dry heated *Acacia auriculiformis* seed coat. *LWT*, 40, 982-990.

Sodimu, A.I., Lapkat, G. L, Oladele, N.O., Osunsina, O, Suleiman, R & Awobona, T.A. (2020). Evaluation of Growth Performance of Physic Nut (Jatropha curcas) seedlings on Different Soils in the Northern Guinea Savanna Agrological Zone of Nigeria. *Asian Soil Research Journal.* 3(2):12-17.

Sodimu, A. I., Olaifa, R.K., Baba, G.O., Lapkat, G. L., Olorukooba, M.M., Olumuyiwa, S.A., Salau, L.O. & Rasheed, F.M. (2021) Effects of Boiled Water On Germination Potential and Early Growth of *Faidherbia albida. (Del.) A. Chev.* Seeds in Kaduna Northern Guinea Savannah Agrological Zone of Nigeria. *Ethiopian Journal of Environmental Studies and Management.*14 (2):208 – 222.

Simons, A.J, & Leakey RRB (2004). Tree Domestication in Tropical Agroforestry. *Agroforestry System*. 61:167-181.

Tropical Plants Data Base (2025) Kenfern.tropical.theferns.26-12-25< tropical. theferns. info/viewtropical.php? id = *Acacia auriculiformis*>

Ugese, F. U. (2010): Effect of nursery media on emergence and growth of tamarind *(Tamarindus indica)* seedlings. *Journal of Animal and Plant Sciences,* 8(2): 999–1005.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Role of Beneficial Microbes in Enhancing Potato Vegetative Stage in Sindhupalchwok District

Koshila GIRI[1*], Himal BHUSAl[2], Prashant SAPKOTA[3], and Rojan KARKI[1]

[1]Himalayan College of Agricultural Sciences and Technology (HICAST)
[2] Potato Development Center, Nigale, Sindhupalchok
[3] Ministry of Agriculture and Livestock Development, Kathmandu
Corresponding Author's email: koshilagiri123@gmail.com

ABSTRACT

The study titled "Role of Beneficial Microbial Inoculants in Enhancing Potato Vegetation Growth in Sindhupalchok District" was conducted at the Potato Crop Development Centre, Nigale, from February 21 to July 11, 2025. A Randomized Complete Block Design (RCBD) with five treatments- Control, Trichoderma, Pseudomonas, Phosphate-Solubilizing Bacteria (PSB), and a 1:1:1 mixture was used, each replicated four times. Data on vegetative growth were recorded and analyzed statistically using R Studio. At 45 days after planting, plant emergence was highest under PSB (58.33%), while plant height at 105 DAP was greatest in Trichoderma (83.9 cm). Although several variables showed no statistically significant differences ($p \leq 0.05$), consistent numerical improvements occurred in Trichoderma and mixture treatments, indicating that beneficial microbial inoculants can enhance vegetative growth and quality in the mid-hill regions of Nepal.

Keywords: Biofertilizer, microbial inoculants, sustainable, treatment, yield

INTRODUCTION

One of the primary goals of Nepal's Agriculture Development Strategy (ADS) is to enhance agricultural productivity while ensuring long-term sustainability and food security. In line with this objective, potatoes have been identified as a priority crop under the Prime Minister Agriculture Modernization Project (PMAMP) because of their significant contribution to national food systems, nutrition, and rural livelihoods. Potato cultivation area and production in Nepal have steadily increased since 2016/17, with national productivity rising from 13.94 t/ha to 17.11

t/ha over the last decade until 2022/23 (MoALD, 2079). Despite this progress, Nepal's potato productivity remains substantially lower than the global average. Countries such as the United States and New Zealand achieve average potato yields of 51.45 t/ha and 50.88 t/ha, respectively (FAO, 2025), which are more than three times higher than Nepal's current productivity level. This considerable yield gap highlights the urgent need for sustainable and efficient production technologies suitable for Nepalese agroecological conditions.

Recent advances in sustainable agriculture have emphasized the importance of microbial inoculants as eco-friendly alternatives to excessive chemical fertilizer use. Continuous and imbalanced application of synthetic fertilizers and pesticides has accelerated soil degradation, reduced beneficial microbial activity, and negatively affected agroecosystem health. Soil microorganisms play a crucial role in nutrient cycling, organic matter decomposition, soil aggregation, and plant growth promotion; however, intensive chemical-based farming systems often suppress these beneficial microbial populations (Vessey, 2003). The adverse effects of agrochemical dependency can be observed in areas such as Panchkhal Municipality, once widely recognized for commercial vegetable production. Excessive pesticide use has resulted in pesticide-resistant pests such as "Daduwa," increased production costs, phytotoxicity, soil quality deterioration, and chemical residues in vegetables (Karmacharya, 2012). Farmers are increasingly trapped in a cycle of chemical dependency, where crop performance declines without repeated applications of fertilizers and pesticides.

In this context, beneficial microbial inoculants such as *Trichoderma*, phosphate-solubilizing bacteria (PSB), and *Pseudomonas* spp. have gained increasing attention as sustainable biofertilizer options. These microorganisms play significant roles in improving soil fertility, nutrient availability, plant growth, and disease suppression. Microbial inoculants enhance crop productivity through several mechanisms, including nutrient solubilization, phytohormone production, induced systemic resistance, and antagonistic activity against soil-borne pathogens (Harman et al., 2004; Vessey, 2003). Their application has become particularly important in potato cultivation because of the crop's high nutrient demand and susceptibility to soil-borne diseases.

Trichoderma species are widely recognized for their biocontrol potential and plant growth-promoting abilities. They suppress pathogenic fungi through mechanisms such as mycoparasitism, competition, antibiosis, and induction of plant defense responses. In addition, *Trichoderma* improves root development and nutrient

uptake, thereby enhancing overall plant vigor and yield (Harman, 2006). Similarly, phosphate-solubilizing bacteria (PSB) convert insoluble forms of phosphorus into plant-available forms through the secretion of organic acids and phosphatase enzymes. Since phosphorus deficiency is a common limitation in agricultural soils, PSB can significantly improve phosphorus use efficiency and reduce dependency on synthetic phosphate fertilizers (Rodríguez and Fraga, 1999). Likewise, plant growth-promoting *Pseudomonas* spp. contribute to crop performance through nitrogen fixation, siderophore production, phytohormone synthesis, and suppression of pathogenic microorganisms. Fluorescent *Pseudomonas* strains are particularly important in enhancing rhizosphere activity and promoting healthier root systems, ultimately improving crop growth and productivity (Weller, 2007).

Although biofertilizers and microbial inoculants have demonstrated promising results in several crops globally, limited field-based research has been conducted under Nepalese agroecological conditions, particularly in potato cultivation systems. Most previous studies have focused on laboratory-scale experiments or individual microbial strains, creating a significant research gap regarding the combined application of *Trichoderma*, PSB, and *Pseudomonas* in enhancing potato productivity and soil health under local farming conditions. Furthermore, the interaction of these inoculants with the soils and climatic conditions of Nepal, especially in the Sindhupalchowk district, remains insufficiently understood. Therefore, this study hypothesizes that the application of microbial inoculants, individually or in combination, will significantly improve potato growth, nutrient uptake, soil health, and yield compared to non-inoculated treatments.

MATERIALS AND METHODS

The study was conducted from February to July 2025 at the Potato Crop Development Center (PCDC), located at an elevation of approximately 2,500 meters above sea level in Nigale, Lisankhupakhar Rural Municipality, Sindhupalchok District, Nepal. The site lies within a moderate temperate climatic zone suitable for potato cultivation. PCDC was purposively selected because it is a national government institution engaged in potato research, varietal evaluation, seed production, and technology development in Nepal. During the experimental period, the crop was grown under prevailing field conditions of the site.

Before field preparation and treatment application, representative soil samples were collected from the experimental area at a depth of 0–20 cm using a standard

zigzag sampling method. Several subsamples were taken across the field, thoroughly mixed to form a composite sample, air-dried, and analyzed for major physicochemical properties such as soil texture, pH, organic matter, available nitrogen, available phosphorus, and available potassium. These baseline soil characteristics were used to describe the fertility status of the experimental site and to support the interpretation of the treatment effects.

The experiment was laid out as a Randomized Complete Block Design. A total of five treatments were implemented, each replicated four times, resulting in 20 plots across the experimental field. The entire plot area covered 80 m^2, with each plot measuring 2 m × 2 m (4 m^2). Each plot contained 21 potato tubers, making a total of 420 tubers across all plots. The **Rosita** potato variety, which is popular and well-suited to the agro-climatic conditions of Nigale, was selected for planting due to its high yield potential and local adaptability. Row-to-row spacing was maintained at 70 cm, while plant-to-plant spacing within rows was 25 cm to ensure proper growth and minimize competition among plants. Fertilizer was applied at the recommended N:P: rate of 100:60:60 kg/ha. Nitrogen was applied in split doses to enhance nutrient uptake and reduce potential losses through leaching or volatilization.

The treatments included PSB, *Trichoderma*, *Pseudomonas*, Control, and Mixture. Three products bearing the brand names Ferti P, Psumo, and Tree Devi were used as liquid biofertilizers from Yarsa Agro Research Pvt. Ltd., located in Lalitpur, Nepal. Ferti P is a phosphate-solubilizing biofertilizer containing *Phosphate-Solubilizing Bacteria (PSB)* at a concentration of 2×10^8 CFU/ml. Psumo is a biocontrol agent containing *Pseudomonas fluorescens* (2×10^8 CFU/ml), and Tree Devi is a biofungicide containing *Trichoderma viride* at 2×10^9 CFU/ml.

One liter of water was combined with five milliliters of each biofertilizer for the application. For the entire plot, five liters of solution were made. One of the five treatments was a combination formulation, in which five milliliters of each of the three biofertilizers were combined with five liters of water in a 1:1:1 ratio. First, seed tubers were steeped in the biofertilizer mixture for half an hour before planting. On April 25, right before flowering, a second foliar spray application was carried out. The crop was then sprayed with biofertilizer every 15 days until it reached physiological maturity, which happened 105 days after planting (DAP).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

RESULTS AND DISCUSSION

Germination percentage

At 45DAP, the data revealed that the highest number of plants emerged was recorded in T_4(PSB) with 58.33%, followed by T_2(Trichoderma), 54.76%, T_5(Mixture), 40.48%, and T_3(Pseudomonas), 35.71%, with the least germination on T_1(control), 32.14%. The ANOVA results for germination percentage show that neither the replication nor the treatment effects were statistically significant. The F-value for replication was 1.85 ($p = 0.192$), and for treatment, it was 1.38 ($p = 0.299$), both of which exceed the 5% significance level. This indicates that neither block-to-block variation nor the applied treatments had a statistically meaningful influence on the germination rate of the seeds. The mean square error (Ms error) was 393.62, and the overall mean germination rate was 44.29%. However, the experiment exhibited a high coefficient of variation (CV) of 44.80%, and the least significant difference (LSD) at the 5% level was 30.57%. This high LSD suggests that only differences above 30.57 percentage points between treatment means would be statistically detectable.

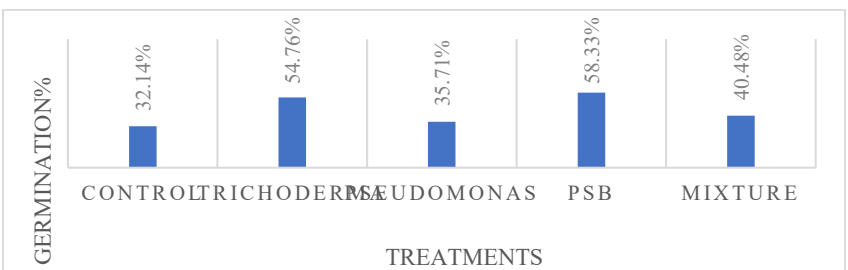


Figure 1. Graph illustrating the germination percentage

The high CV indicates substantial variability in germination performance, possibly due to environmental factors such as uneven moisture content, seed vigor differences, or inconsistencies in seedbed preparation. According to Joshi *et al.* (2020), variability in seed germination across treatments is common in field conditions, especially when seed quality and micro-environmental conditions are not uniform. The non-significant treatment effect implies that the germination differences observed among the treatments are likely due to random variation rather than the treatments themselves. This aligns with the findings of Adhikari *et al*. (2017), who reported non-significant differences in germination among tomato

varieties under similar treatment conditions, attributing it to genetic uniformity and uniform pre-germination conditions.

Plant height

The analysis of plant height across different treatments from 60 to 105 Days After Planting (DAP) reveals a consistent pattern where T_2 exhibited superior vegetative growth, particularly in the later stages. At 60DAP, although T_5 recorded the highest mean plant height (12.75 cm), it was closely followed by T_4 (12.7 cm) and T_2 (12.45 cm), with no significant differences among treatments ($p = 0.3187$). The coefficient of variation (CV%) was relatively high at 45.04%, indicating considerable variability in early growth. According to Sharma et al. (2016), early plant height can often be influenced by seedling vigor and initial soil moisture conditions, which may not necessarily predict final plant performance.

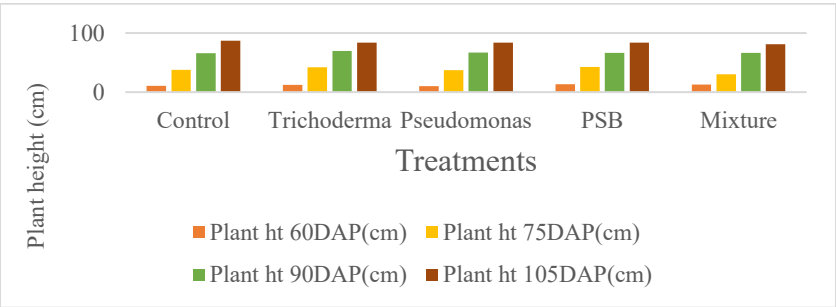


Figure 2. Graph illustrating plant height

At 75DAP, T_4 achieved the highest mean height (42.7 cm), slightly ahead of T_2 (41.85 cm), suggesting that both treatments promoted better vegetative growth than the others. The growth patterns align with findings by Adhikari *et al. (*2020), who noted that mid-vegetative stages are critical in determining overall plant performance, particularly under varied agronomic treatments. However, the differences remained statistically non-significant ($p = 0.1244$), indicating that the variability within treatment groups overlapped.

The superiority of T_2 became more pronounced at 90 DAP and 105 DAP, where it recorded the highest mean plant heights of 69.65 cm and 83.9 cm, respectively. Although these differences were still not statistically significant ($p = 0.6285$ and $p = 0.8004$), the consistent numerical advantage of T_2 suggests its effectiveness in supporting vegetative development in later stages. Similar observations were

reported by Thapa *et al. (*2021), who emphasized that while statistical significance is important, consistent trends over time can still hold agronomic relevance, especially under field conditions where variability is common.

The lack of significant differences could be attributed to environmental variability or limited replication, as suggested by the relatively high coefficient of variation (CV%) values. Nonetheless, T_2's consistent performance supports its potential suitability for robust vegetative growth, even in the absence of statistical confirmation. This is supported by the work of Paudyal and Regmi (2018), who argue that agronomic decisions in field settings often rely on consistent trends rather than solely on statistical thresholds. T_2 demonstrated the most consistent and superior vegetative growth performance across later growth stages, highlighting its promise as a treatment option for improved plant height and vigor. Future studies with larger sample sizes and controlled environments may help confirm the statistical validity of these trends.

Number of stems

The ANOVA results for the number of stems indicate that neither replication nor treatment effects were statistically significant. The F-value for replication was 0.24 ($p = 0.869$), and for treatment, it was 1.24 ($p = 0.345$), suggesting that the variation in stem number among different treatments and across replications was not large enough to be considered significant at the 5% level. The mean square error (MS error) was 0.594, with an overall mean number of stems of 4.83 cm and a coefficient of variation (CV) of 15.96%, indicating moderate variability in the data. The least significant difference (LSD) at the 5% level was calculated to be 1.19 cm, implying that any treatment differences below this threshold are statistically indistinguishable.

The non-significant treatment effect suggests that the tested treatments did not have a notable influence on the number of stems. This may be due to environmental uniformity, limited physiological response, or the short duration of treatment exposure. Similar findings were reported by Pandey *et al*. (2016), who found no significant effect of organic and inorganic fertilizer treatments on stem number in early vegetative stages of tomato due to uniform seedling vigor and initial soil fertility levels. Additionally, the non-significant replication effect suggests consistent conditions across experimental blocks, indicating that extraneous variability such as soil texture or light exposure was well-controlled.

This strengthens the internal validity of the experiment, a feature considered critical in field trials (Gomez and Gomez, 1984).

Table 1. ANOVA for Number of Stems

Response Variable	Source	Df	Sum Sq	Mean Sq	F value	Pr (>F)	M Serror	Mean	CV (%)	LSD (5%)
Stem Length	Replication	3	0.422	0.1407	0.24	0.869	0.594	4.83	15.96	1.19
	Treatment	4	2.952	0.7380	1.24	0.345				
	Residual	12	7.128	0.5940						

Uniformity

The analysis of plant uniformity across different Days After Planting (DAP) reveals important insights into the consistency of treatment effects throughout the crop's growth period. At 60 DAP, significant differences among treatments were observed ($p < 0.001$), with T_2 and T_3 achieving the highest uniformity scores (3.75), significantly outperforming T_4 and T_5 (both 2.75), as supported by the LSD (0.43). The coefficient of variation (CV%) was 21.51%, indicating moderate variability among the experimental units. Uniformity at early growth stages is crucial, as it reflects synchronized development, which can enhance management practices and potentially contribute to better final yield and marketable quality (Gomez and Gomez, 1984). High early uniformity can also reduce intra-plot competition, contributing to more efficient resource use (Adhikari *et al.,* 2021). At 75DAP, all treatments recorded a uniformity score of 4, resulting in non-significant differences ($p = 0.4116$) and a CV% of 0%, signifying complete uniformity across treatments. This uniform growth phase may represent a developmental equilibrium, possibly influenced by favorable environmental conditions and uniform agronomic management. According to Shrestha et al. (2019), such uniformity in mid-growth stages is common in well-managed field trials and indicates physiological stability.

By 90 DAP, although the F-value increased slightly (1.68), the treatment effect remained non-significant ($p = 0.1618$). The highest uniformity (4.5) was noted in T_1 and T_3, while T_2, T_4, and T_5 followed closely with a score of 4.25. The CV% of 10.87% shows mild variation, suggesting that treatment effects were beginning to diverge, but not strongly enough to reach statistical significance. As per Khadka et al. (2022), uniformity in late vegetative or early reproductive stages can be influenced by genotype-environment interactions, which may introduce variability not directly linked to treatment interventions.

At 105DAP, a highly significant treatment effect was once again observed ($p < 0.001$), with T_1, T_3, and T_5 achieving the highest uniformity (4.5), compared to T_2 and T_4 (both 4.0). The LSD at this stage was lower (0.25), and the CV% was 9.24%, suggesting a relatively stable measurement with reduced variability. This stage is critical for evaluating harvest maturity and grading potential. According to Paudel et al. (2020), high uniformity at maturity ensures better post-harvest handling, enhances the market appeal, and reduces sorting losses.

While T_2 showed the best performance at 60 DAP and maintained stable uniformity throughout the growth cycle, its performance slightly declined during the later stages compared to T_1, T_3, and T_5. However, its consistency across all four growth stages still positions it as a reliable treatment for achieving predictable plant development. As argued by Steel and Torrie (1980), stability across time often outweighs peak performance in a single stage, especially in field conditions where uniformity supports operational efficiency and production planning.

The ANOVA results show that treatment impacts on plant uniformity were temporally dynamic, statistically significant in the early and final stages, but not during mid-growth. This pattern emphasizes the importance of stage-specific evaluation in agronomic research, where early and late-stage interventions may exert the most influence. These findings align with the broader principle noted by Steel and Torrie (1980), which advocates interpreting treatment effects in light of developmental phases and environmental interactions.

Table 2. ANOVA for the uniformity

Treatments	**Uniformity (Day 60)**	**Uniformity (Day 75)**	**Uniformity (Day 90)**	**Uniformity (Day 105)**
T_1 (Control)	3	4	4.5	4.5
T_2 (Trichoderma)	3.75	4	4.25	4
T_3 (Pseudomonas)	3.75	4	4.5	4.5
T_4 (PSB)	2.75	4	4.25	4
T_5 (Mixture)	2.75	4	4.25	4.5
LSD (0.05)	0.43			0.25
F	11.08	1	1.68	9.5
p-Value	2.03e-07	0.4116	0.1618	1.67e-06
CV%	21.51	0	10.87	9.24

CONCLUSION

In this study, the treatments applied—*Trichoderma*, *Pseudomonas*, phosphate-solubilizing bacteria (PSB), and their combined mixture—did not produce statistically significant effects on major growth parameters. However, numerical differences were observed among treatments, which were largely influenced by environmental variability.

Despite the lack of strong statistical significance, several consistent agronomic trends were evident throughout the experiment. Microbial inoculant treatments contributed to improved plant uniformity at different growth stages. Significant differences in uniformity observed at 60 and 105 DAP suggest that treatment responses were stage-dependent rather than uniform throughout the crop cycle. Treatments involving *Trichoderma* and *Pseudomonas* performed better during the early stages, whereas the mixture treatment and *Pseudomonas* maintained greater uniformity at maturity.

The study further suggests that microbial inoculants can serve as sustainable and eco-friendly supplements to conventional chemical fertilizers by enhancing nutrient availability, improving rhizosphere activity, and supporting healthier crop growth. In the context of increasing soil degradation, declining microbial activity, and excessive agrochemical dependency in Nepalese agriculture, the use of biofertilizers such as *Trichoderma*, *Pseudomonas*, and PSB offers promising opportunities for sustainable potato production and long-term soil health management.

SUGGESTIONS

Future research should focus on long-term and multi-location trials with larger sample sizes, improved experimental precision, and additional assessments related to soil biological properties, nutrient dynamics, and yield performance. Such studies would help validate the observed trends and provide deeper insights into the interaction of microbial inoculants with local soil and climatic conditions.

AUTHORS' CONTRIBUTIONS

Koshila Giri: Investigation; Methodology; Conceptualization; Data curation; Software; Formal analysis; Visualization; Writing—original draft; Writing—review and editing.
Himal Bhusal: Conceptualization; Validation.

Prashant Sapkota: Conceptualization; Validation.
Rojan Karki: Writing-review and editing, Software; Formal analysis

REFERENCES

Adhikari, B., Bhattarai, D. and Thapa, R.B., (2020). Stolon and tuber development in potato as influenced by varietal and environmental factors. *Nepalese Journal of Agricultural Sciences*, 19(1), pp.50–58.

Adhikari, B., Bhattarai, D. and Thapa, R.B., (2021). Evaluation of growth uniformity and yield traits in potato under different fertilization regimes. *Nepalese Journal of Agricultural Sciences*, 20(1), pp.12–20

Adhikari, D., Subedi, S., and Bhatta, N.R., (2017). Effect of priming on seed germination and seedling growth of tomato (*Solanum lycopersicum* L.). *Journal of Agriculture and Natural Resources*, 1(1), pp.139–147

FAO.org, (2025). Plant Production and Protection Division: What is integrated plant nutrient management? [online].

Food and Agriculture Organization (FAO) (2025). FAOSTAT Statistical Database. Rome: Food and Agriculture Organization of the United Nations.

Gomez, K.A. and Gomez, A.A., (1984). *Statistical procedures for agricultural research*. 2nd ed. New York: John Wiley & Sons.

Harman, G.E. (2006) 'Overview of mechanisms and uses of Trichoderma spp.', Phytopathology, 96(2), pp. 190–194. doi:10.1094/PHYTO-96-0190.

Harman, G.E., Howell, C.R., Viterbo, A., Chet, I. and Lorito, M. (2004) 'Trichoderma species—opportunistic, avirulent plant symbionts', Nature Reviews Microbiology, 2(1), pp. 43–56. doi:10.1038/nrmicro797.

Joshi, B.K., Shrestha, J. and Bhatta, M.R., (2020). Seed quality and field performance of tomato seed lots. *Nepal Journal of Biotechnology*, 8(1), pp.65–70.

Joshi, B.K., Shrestha, J., and Bhatta, M.R., (2020). Seed quality and field performance of tomato seed lots. *Nepal Journal of Biotechnology*, 8(1), pp.65–70.

Ministry of Agriculture and Livestock Development (MoALD) (2079 B.S.) Statistical Information on Nepalese Agriculture 2078/79. Kathmandu: Government of Nepal, Ministry of Agriculture and Livestock Development.

MoALD, (2025). *Statistical information on Nepalese agriculture* २०७९/८०. [online] Ministry of Agriculture and Livestock Development.

Rodríguez, H. and Fraga, R. (1999) 'Phosphate-solubilizing bacteria and their role in plant growth promotion', Biotechnology Advances, 17(4–5), pp. 319–339. doi:10.1016/S0734-9750(99)00014-2.

Shi, Z., Chang, T.-G., Chen, F., Zhao, H., Song, Q., Wang, M., Wang, Y., Zhou, Z., Wang, C., Zhou, S.-C., Wang, B., Chen, G. and Zhu, X.-G. (2020). Morphological and physiological factors contributing to early vigor in the elite rice cultivar 9,311. *Scientific Reports*, [online] 10(1). doi:https://doi.org/10.1038/s41598-020-71913-y.

Shrawasti Karmacharya (2012). Pesticide Use In Agriculture And Its Socio- Economic Contexts, A Case Study of Panchkhal Area, Kavre, Nepal. *ResearchGate*, [online] 1(9), pp.17–29. Available at: https://www.researchgate.net/publication/237065886_Pesticide_Use_In_Agriculture_And_Its_Socio-_Economic_Contexts_A_Case_Study_of_Panchkhal_Area_Kavre_Nepal [Accessed 9 Apr. 2026].

Vessey, J.K. (2003) 'Plant growth promoting rhizobacteria as biofertilizers', Plant and Soil, 255(2), pp. 571–586. doi:10.1023/A:1026037216893.

Weller, D.M. (2007) 'Pseudomonas biocontrol agents of soilborne pathogens: looking back over 30 years', Phytopathology, 97(2), pp. 250–256. doi:10.1094/PHYTO-97-2-0250.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

The Constraints Facing Contract and Non-Contract Rice Farmers: Evidence from Benue and Niger States, Nigeria

Christopher Adava, [1]OHINOYI, Park Odojoma, [2]IDISI, Muhydeen Mobolaji,[3] GIWA, Joy Precious, [4]ALABI, & Olugbenga Omotayo, [2]ALABI*

[1]Federal Ministry of Agriculture and Food Security, Federal Department of Agriculture, FCDA Complex Area 11 Garki, Abu ja, NIGERIA
[2]Department of Agricultural Economics, Faculty of Agriculture, University of Abuja,PMB 117 Gwagwalada-Abuja, Federal Capital Territory, NIGERIA.
[3]Sheikh Gbagba Street, Area 4, Zulqarnain Community Sobi, Ilorin, Kwara State, NIGERIA
[4]Department of Biological Sciences, Faculty of Science, University of Abuja, PMB 117, Gwagwalada-Abuja, NIGERIA.
*Corresponding Author's Email: omotayoalabi@yahoo.com;

ABSTRACT

This study examined the constraints facing contract and non-contract rice farmers: evidence from Benue and Niger States, Nigeria. A multi-stage sampling design was used to select 400 rice farmers comprising 200 contract rice farmers and 200 non-contract rice farmers. Primary data were collected from a well-structured questionnaire survey. Data were analyzed using descriptive statistics, principal component model and Kendall's' coefficient of concordance. The results revealed that contract farmers possess larger average household sizes (17.5 members) and more farming experience (17.3 years) compared to non-contract farmers (6.8 members and 13.5 years). Additionally, contract farmers manage larger landholdings (3.2 hectares) than their non-contract counterparts (2.4 hectares).The principal component analysis (PCA) and Kendall's coefficient of concordance were employed to rank the challenges facing both groups. For contract farmers, PCA identified inadequate capital and discrimination in land access as primary components, while Kendall's rank identified farmer-herder clashes and price fluctuations as the most pressing constraints. Conversely, non-contract farmers are most significantly burdened by rice smuggling, gender inequality in resource access, and high input costs. While contract farming provides a framework for structured production, both groups remain vulnerable to external shocks and systemic inefficiencies. The findings suggest that while

contract arrangements may offer better access to land and experience-sharing, they do not fully insulate farmers from security threats and capital deficiencies. To enhance rice productivity, policy interventions must address broader issues of rural security, credit accessibility, and market protection from smuggled imports.

Keywords: Capital, **c**oefficient of concordance, landholdings, principal component analysis, security threat

INTRODUCTION

Agriculture is the mainstay of the Nigerian economy and it contributes about 29.15% of the Gross Domestic Product in 2017 (National Bureau of Statistics, NBS, 2017), employing about 75% of the Nigerian populace and labor force (Yusuf et al., 2020). Most of these people are small-scale farmers. The small-scale farmers particularly in a less developed country like Nigeria face several production and marketing constraints, such as limited access to services, including effective extension and rural credit, which are crucial pre-conditions for upgrading commodity value chains (Wiggins et al., 2010).

Rice (*Oryza sativa*) is a typical cereal crop that has moved from a ceremonial to a staple food in Nigerian homes. Rice is the second produced cereal in the world after wheat, but first as human consumption is concerned. North Central Nigeria consisting of Benue; Taraba; Plateau; Kogi; Niger; Nasarawa; and Kwara States are some of the most important rice producing state in Nigeria. North Central fertile land and rich climatic condition could easily produce rice to feed the entire country. Total potential land for irrigated rice production in North Central is estimated at 0.9 million hectares out of which only 471, 798 ha is available. There are three rice production environments and their coverage in Nigeria are; rain-fed lowland (having a percentage of 69%), irrigated lowland (taking up 2.7%) and rain-fed upland (accounted for 28.3%). More than 90% of Nigeria's rice is being produced by poor resource small-scale farmers, while the 10% of rice production is by corporate/commercial farmers (FAO, 2019). The market is an important determinant for smallholder farmers and one of the major challenges in developing countries to continue production or to stop.

According to Will (2013), contract farming is regarded as a forward agreement specifying the obligations of farmers and buyers as partners in business, specifying farmers, (sellers) legal obligation to supply the volumes and

qualities as specified, and the buyers, (processors/traders) obligation to off-take the goods and release the payments as agreed and buyers providing embedded services such as: upfront delivery of inputs; pre-financing of input delivery on credit and other non-financial services (eg extension, training, transport and logistics).

Contract farming (CF) a pre-harvest agreement between farmers and buyers is seen as a strategy that can address technology constraints (Swinnen & Kuijpers, 2019), ease adoption of technology (Ragasa et al., 2018), link farmers to marketing agents (Wiggins & Keats, 2013), reduce transaction costs (Bellemare, 2012) and open access to finance (Carletto et al, 2011). Contract farming refers to an institutional arrangement under which agribusiness firms contract the production of agricultural commodities out to farmers and ensure a consistent supply of quality agricultural raw materials (Bellemare & Novak, 2017). Contract Farming has long been prevalent in developed countries and in recent times has spread widely in developing countries (Wong et al., 2014). In the Nigeria there is some emerging evidence of contract farming (Fawole & Thomas, 2014; Iro, 2016; Olusegun, 2016; Miet & Vande, 2017). The existing ones are mostly owned by private companies/individuals as out-grower schemes and a few by the Government such as the presidential anchor borrower program initiated by Federal Government of Nigeria in 2016 (Olusegun, 2016).

A farmer's decision to participate in contract farming is affected by different physical, social and economic factors. The main buyers of rice from smallholder farmers are local collectors/traders, rice processing companies and family, cooperative unions, and individual consumers. Farmers enter different forms of contract mainly with traders, a private processing companies or cooperatives, whenever they think profitable. Therefore, formal or informal agreement are the way of creating a market for smallholder farmers to supply rice to the processors. The study aimed to evaluate the constraints of contract and non-contract rice farmers in Benue and Niger States of Nigeria.

MATERIALS AND METHODS

The study was carried out in Benue and Niger States in the North Central geopolitical zone of Nigeria. Benue State occupies Longitudes 7^0 $47^{||}$ and 10^0 $0^{||}$ East and Latitudes 6^0 $25^{||}$ and 8^0 $8^{||}$ North. It has an estimated population of 5,905,747 inhabitants. The main crops found in Benue State include banana,

cassava, beans, potatoes, maize, finger millet, sorghum, rice, wheat, pulses, oilseeds, fruits, vegetables, and grains. Niger State has a land area of 29484 sq. km. The state falls within latitudes 8^{o} - 10^{0}N and Longitude 3^{0}. - 8^{0}E. Niger State has an estimated population of 6,407,568 inhabitants in 2020 (National Bureau of Statistics [NBS], 2021). Farming is the primary occupation of 85 percent of the state's population; some of the arable crops grown in the state are maize, cassava, vegetables, rice, yam, millet, cocoyam, potato, cowpea, groundnut, guinea corn, fruits, and sugarcane. Livestock reared includes goat, sheep, cattle chicken and donkey.

This study employed a multi-stage sampling technique to select respondents. In the first stage, two agricultural zones were selected through purposive sampling technique from the three agricultural zones in each state. In the second stage, two blocks were selected through a simple random sampling technique from the three (3) blocks in each zone giving a total of 8 blocks. In the third stage, five cells were selected through simple random from each of the 8 blocks giving a total of 40 cells. In the fourth stage, a list of all indigenous rice farmers was compiled by the community leaders in each of the selected cell. From the list, ten (10) respondents comprising of both contract and non-contract rice farmers were selected through stratified random sampling techniques. Thus, the total sample size for the study was 400 respondents. Out of 400 households 200 were independent (non-contracted) rice growers and 200 were contracted farmers. This study employed a field survey method encompassing a designed questionnaire, and primary data were collected from rice farmers. A pilot test was done on the research instrument to detect possible errors in the measurement procedures, identify unclear questions in the questionnaire and determine the validity and reliability of the data.

The data were analyzed using the following descriptive statistics and econometric tools:

Principal Component Analysis (PCA)

The principal component analysis (PCA) following the studies conducted Kashap and Yadav (2020), Niftiyev and Ibadoghlu (2023), and Sruthi et al. (2024). The model of principal component analysis (PCA) is stated as;

For data vector, $X = (X_1, X_2, \ldots\ldots\ldots\ldots, X_P)$ (1)

The ith principal component (Y_i) is define as:

$$Y_i = e_{i1}X_1 + e_{i2}X_2 + e_{i3}X_3 + \cdots \ldots \ldots \ldots \ldots e_{ip}X_p \quad (2)$$

$$= e_i^T X \quad (3)$$

Where,

Y_i = The ith principal component. It is a new variable that represents a portion of the total variance in the original data.

X_j = The jth original input variable (usually centered so the mean is zero and a variance of 1)

e_{ij} = The loading or coefficient. These are the elements of the eigen-vector e_i corresponding to the ith largest eigen-value of the covariance matrix

$Var\ (Y_i) = \lambda_i$= The variance of the ith component, which is equal to the ith eigen -value. Components are ordered such that $\lambda_1 \geq \lambda_2 \geq \cdots \ldots \ldots \lambda_p$

p = The total number of original variables\

Kendalls' Coefficient of Concordance (W)

The Kendalls' Coefficient of Concordance (W) is stated thus:

$$W = \frac{12S}{M^2(n^3 - n) - M\sum T} \quad (4)$$

Where,

n = Number of Objects (Subjects) that is being ranked

M = Number of variables

T = Correction Factor for Tied Ranks

$$T = \sum_{K=1}^{g} (t_K^3 - t_K) \quad (5)$$

Where,

t_K = Number of Tied Ranks in each of 'g' Groups of Ties.

S = The sum of squared deviations of the rank sums from their mean

$$S = \sum_{i=1}^{n} (R_i - \bar{R}^2) \quad (6)$$

Where,

R_i =The sum of ranks assigned to the ith object across all 'm' raters

$\bar{R}^2$ = The mean of the rank sums, this is calculated as:

$$\bar{R} = \frac{m(n+1)}{2} \quad (7)$$

Friedmans Chi Square

$$X^2 = m(n-1)\,W \quad (8)$$

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Contract and Non-Contract Farmers

Table 1 presents the results of the socio-economic profiles of the sampled rice farmers in the study area. The study further revealed that the average age of contract rice farmers was 45years, while the average age of non-contract rice farmers was 44 years. This indicated that both categories of farmers under contract and non-contract farming were still young, energetic and in their active age of productivity. These results imply that the sampled rice farmers could easily adopt innovations and new technology which could lead to an increase in the output yield of rice among both contract and non-contract rice farmers in the study area. This finding aligns with the findings of Igwe-Oscar (2014) but contrary to the findings of Hoang (2021) who reported that rice farmers under contract were older farmers in Vietnam. The average years in schooling for both contract and non-contract rice farmers were 7.2 and 7.5 years respectively. This implies that the sampled rice farmers were able to attain primary level of education, which could enable them to read and write, giving them an advantage in adopting innovation and using improved varieties of seeds, and technical know-how on using productive resources like fertilizer application, and the use of agrochemicals such as herbicides and insecticides effectively. This is in line with the findings of Igwe-Oscar, (2014) who asserted that education enlightened farmers to change and adopt modern opportunities. The study also revealed that the average household size of contract rice farmers was 8 members per family, while for non-contract farmers was 7 members per family. Household size enhances rice production due to the availability of labour that were engaged in farming activities. The farmers under contract farming have an average farming experience of about 17years, while the non-contract rice farmers had an average farming experience of about 14 years. This conforms with the findings of Nazifi et al. (2021) who reported 18 years of farming experience among contract farmers in Kano and Kaduna States, Nigeria. The study further shows that the average farm size cultivated by contract rice farmers was 3.2 hectares, while the non-contract rice farmers cultivated an average farmland size of about 2.4 hectares indicating that category of rice farmers was small-scale rice farmers in the study area. This confirms the findings of Nazifi et al. (2021) who reported similar results on contract farming in Kano and Kaduna States, Nigeria.

Constraints Faced by Contract Rice Farmers in the Study Area

The constraints faced by contract rice producers were subjected to the principal component model or factor analysis and is presented in Table 2. The constraints facing contract rice farmers with higher Eigen-value that are greater than one or unity were retained and used for further analysis by the model. The constraints with Eigen-value less than one were discarded by the model. The retained constraints were inadequate capital, which was ranked 1st with Eigen-value of 2.10178 and this problem explained 17.51% of all the constraints retained in the model.

Table 1. Socio-Economic Characteristics of Contract and Non-Contract Rice Farmers

Variables	Contract Farmers (n=200)	Non-Contract Farmers (n=200)
Age (Years)	44.8	43.7
Education Level (Years)	7.2	7.5
Household Size (Number)	17.5	6.8
Farming Experience (Years)	17.3	13.5
Farm Size (Hectares)	3.2	2.4

Source: Field Survey Data (2024)

Discrimination in terms of access to land input was ranked 2nd among all constraints retained in the model, and this constraint explained 14.68% of all constraints retained in the model. Other constraints were high cost of labour 3rd, inadequate extension services 4th and farmer- herder clashes 5th with percentages of 12.87%, 10.51% and 8.81% respectively. All the retained problems in the model explained a cumulative proportion of 64.4% of all constraints facing contract rice farmers that was included in the principal component analysis. The chi-square value of 350.048 was statistically significant at ($P < 0.01$), this signifies that the model is a good fit. This is line with the findings of Nazifi et al. (2021) who reported that lower pricing was stated by the farmers as because the firm always possess highest power in deciding the price to be paid per bag of harvested rice and is mostly below market price, while the delay in payment of farmers benefits was because after harvesting the farmers are not given their profit after company deducted their services fees and credit in

time.

Table 2. Results of the Principal Components Analysis of the Challenges Faced by Contract Rice Farmers in Production

Component	Eigen Value	Difference	Proportion	Cumulative	Rank
Inadequate Capital	2.10178	0.340544	0.1751	0.1751	1st
Discrimination in terms of access to Land	1.76124	0.216643	0.1468	0.3219	2nd
High Cost of Labour	1.5446	0.283844	0.1287	0.4506	3rd
Inadequate Extension Services	1.26075	0.204111	0.1051	0.5557	4th
Farmer harder clashes	1.05664	0.103747	0.0881	0.6438	5th
Bartlett Test of Sphericity:					
Chi-Square	350.048				
Rho	1.0000				
KMO	0.5354				

Source: Computed from Field Data (2024)

Constraints Faced by Non-Contract Rice Farmers in the Study Area

The constraints facing non-contract rice producers were subjected to the principal component model or factor analysis and is presented in Table 3. The constraints facing non-contract rice farmers with Eigen-value greater than one or unity were retained and used for further analysis by the model. The constraints with Eigen-value less than one were discarded by the model. Rice smuggling and importation was ranked 1st with Eigen-value of 5.45156 and this problem explained 28.69 % of all constraints retained in the model. Gender inequality in access to resources was ranked 2nd among all constraints retained in the model, and this constraint had Eigen-value of about 3.46743 which explained 18.25% of all constraints retained in the model. Other constraints with higher Eigen-value retained in the analysis were policy inconsistency on rice production, 3rd with Eigen value of 2.92805, high cost of labour 4th and inadequate capital 5th with Eigen values of 1.67391 and 1.10252, respectively. All the retained problems in the model explained 76.97% of all constraints facing non-contract rice farmers that were included in the principal component analysis. The chi-square value of 2935.306 was statistically significant at ($P < 0.01$), this signifies that the model is a good fit. This result is in line with Coker et al. (2018) and Alabi et al. (2023) who reported similar problems of rice production faced by farmers in their respective study areas.

Table 3. Results of the Principal Components Analysis of the Challenges Faced by Non-Contract Rice Farmers in the Study Area

Component	Eigen Value	Difference	Proportion	Cumulative	Rank
Smuggling and Importation	5.45156	1.98414	0.2869	0.2869	1st
Gender inequality in access to resources	3.46743	.539379	0.1825	0.4694	2nd
Policy Inconsistency on rice production	2.92805	1.25414	0.1541	0.6235	3rd
High cost of Labour	1.67391	.571385	0.0881	0.7116	4th
Inadequate capital	1.10252	.338784	0.0580	0.7697	5th
Bartlett Test of Sphericity					
Chi-Square	2935.306				
Rho	1.0000				
KMO	0.6883				

Source: Field Data (20 24)

Table 4. Kendalls' Coefficient of Concordance Rank of Constraints Faced by Contract and Non-Contract Rice Farmers

Contract Farmers			**Non-Contract Farmers**		
Constraints	**Mean Score**	**Rank**	**Constraints**	**Mean Score**	**Rank**
Farmer Herder Clashes	7.55	1st	High Cost of Inputs	12.27	1st
Price Fluctuation	6.80	2nd	High Cost of Qualitative Seeds	12.12	2nd
Poor Infrastructure	6.78	3rd	Policy Inconsistency	11.98	3rd
Inadequate Extension	6.76	4th	Bad Roads	11.77	4th
Theft	6.58	5th	Inadequate Price Information	11.62	5th
High Cost of Labour	6.45	6th	Excessive Rainfall	11.50	6th
Discrimination on Access to Resources	6.43	7th	Price Fluctuation	11.44	7th
Inadequate Capital	6.40	8th	Poor Land Tenure System	11.34	8th
Kendalls' W	0.024		Kendalls' W	0.262	
Chi-Square	51.960		Chi-Square	937.704	
Degree of Freedom	11		Degree of Freedom	18	
Asymptotic Significant	0.000		Asymptotic Significant	0.000	

Source: Field Survey Data (2024)

The results showed that the calculated chi-square value for contract and non-contract rice farmers was 51.9 and 937.7, respectively at 5% probability level with degrees of freedom of 11 and 18, respectively, the null hypothesis was rejected since the calculated value was greater than Table critical value. As presented in

Table 4 the farmers ranked the constraints from highest to lowest as reported by the output results of the test.

CONCLUSION

The study evaluated the constraints facing contract and non-contract rice farmers: evidence from Benue and Niger States, Nigeria. The study concluded that contract farming attracts more experienced farmers with larger households and significantly larger farm sizes. This indicates that contract arrangements may currently favor established farmers who possess the labor capacity and land base to meet formal production requirements. However, the analysis of constraints revealed a complex environment where both groups face distinct yet equally debilitating challenges. For contract farmers, the primary constraints are systemic and security-oriented. The high ranking of farmer-herder clashes and price fluctuations suggests that even within a structured contractual agreement, the lack of physical security and market stability undermines productivity. The principal component analysis further highlighted that inadequate capital remained the most significant underlying factor for contract participants, suggesting that current credit facilities provided within these contracts may be insufficient to cover the rising costs of modern rice production. Non-contract farmers, on the other hand, operate in a more volatile environment characterized by external market distortions. The prominence of rice smuggling and importation as their leading challenge indicated that local smallholder farmers are struggling to compete with cheaper, often illegally imported rice. This is compounded by high input costs and gender-based inequalities in resource distribution, which limit the expansion and efficiency of non-contracted farms. The significant difference in household sizes also suggests that non-contract farmers may lack the "free" family labor available to larger contract households, forcing them to rely on hired labor, which is increasingly expensive. The contract farming offers a degree of organizational advantage; it is not a panacea for the broader structural failures in the agricultural sector. The persistence of capital inadequacy across both groups and the looming threat of insecurity (clashes) and market instability (smuggling) represent significant barriers to achieving national rice self-sufficiency. For the rice sub-sector to thrive, a dual approach is required: one that strengthens the internal mechanisms of contract agreements while simultaneously providing a protective and secure environment for independent smallholders. This shall include strengthening rural security and conflict resolution, credit accessibility and input subsidies and trade policy enforcement and market protection. Without addressing these fundamental constraints, security, capital, and trade policy, the gap between potential and actual rice yields will continue to persist.

AUTHORS' CONTRIBUTIONS

All Authors contributed equally towards the research and manuscript preparation of the article.

REFERENCES

Alabi, O.O., Safugha, G.F., & Aluwong, J.S. (2023). Cost Efficiency and Profitability Analysis of Rice (*Oryza sativa*) Production among Smallholder Farmers in Federal Capital Territory, Nigeria. *Australian Journal of Science and Technology*, 7(1): 21 – 29

Bellemare, M. F; & Novak, L. (2017). Contract farming and food security. *American Journal of Agricultural Economics,* 99(2), 357–378.

Carletto, C., Kilic, T., & Kirk, A. (2011). Nontraditional crops, traditional constraints: the long-term welfare impacts of export crop adoption among Guatemalan smallholders. *Agri. Econ.* 42, 61– 76.

Coker, A., Aimola, A., Sanni, L. & Mathew, M. (2018). Effect of agricultural trade openness on the producer prices of rice in Nigeria: Implications for agricultural trade policies. *Agro-Science.* 16. 15. https://doi.org/10.4314/as.v16i3.3

Fawole, P. & Thomas, K. A. (2011). Effects of Contract Farming Scheme on Cassava Production Enterprise in Oyo State, Nigeria. *Journal of Rural Economics and Development*, 20 No. 1, Pp. 1 – 7.

FAO (2019). *Building Climate Resilience for Food Security and Nutrition* (Food and Agriculture Organization, 2018)

Hoang, V. (2021). Impact of Contract Farming on Farmers‟ Income in the Food Value Chain: A Theoretical Analysis and Empirical Study in Vietnam. Agriculture 11, 797. https://doi.org/10.3390/agriculture11080797

Iro, I.K. (2019). Empirical evidence on contract farming in Northern Nigeria: case study of tomato production. *Asian Journal of agriculture and rural development*. Volume 6(12), 240-253

Igwe-Oscar, O. (2014). Effects of Contract Farming on Productivity and Welfare of Cassava-based Farmers in South Eastern Nigeria. *European Journal of Business and Management*, 6(7), 334- 339

Kashap, A & Yadav, V.K. (2020). Principal Component Analysis and Character Association for Yield Components in Rice (*Oryza sativa* L) Genotypes of Salt Tolerance under Alkaline Condition. *International Journal of Current Microbiology and Applied Sciences*, 9 (10): 481 – 495. https://doi.org/10.20546/ijcmas.2020.910.059

Miet, M & Vande, V.K. (2017). Contract-farming in Staple Food Chains: The Case of Rice in Benin, *World Development*, 95, (C), 73-87. https://doi.org/10.1016/j.worlddev.2017.02.011

NBS (2021). National Population Estimates. Demographic Statistics Bulletin. National Bureau of Statistics Retrieved from www.nigerianstat.gov.ng on 20/02/2025.

Nazifi, B., Bello, M., Suleiman, A. & Suleiman, M.S. (2021). Impact of contract farming on productivity and food security status of smallholder maize farmer„s households in Kano and Kaduna States, Nigeria. *Journal of Agriculture and Environment*, 17(1), 1-13.

Niftiyev, I & Ibadoghlu, G. (2023). Longitudinal Principal Component and Cluster Analysis of Azerbaijans Agricultural Productivity in Crop Commodities. *Commodities*, 2 147 – 167. https://doi.org/10.3390/commodities2020009

Olusegun, O. (2016). Production efficiency and profitability of certified rice seed production among out-growers in Katsina state, Nigeria. MSc Thesis, school of postgraduate studies Ahmadu Bello University Zaria, Nigeria 2016.

Ragasa, C; Lambrecht, I; & Kufoalor, D.S. (2018). Limitations of contract farming as a pro-poor strategy: The case of maize outgrower schemes in upper West Ghana. *World Development* 102:30-56.

Sruthi, S.R., Laleeth, K.N., Kishore, D., Ivin, J.S., & Anbusdvam, Y. (2024). Principal Component Analysis in Rice (Oryza sativa L) Varieties for three Seasons in Annamalai Nagar, an East Coast Region of Tamil Nadu. *Plant Science Today*, 11 (4), 634 – 639. https://doi.org/10.14719/pst.4105

Swinnen, J., & Kuijpers, R. (2019). Value chain innovations for technology transfer in developing and emerging economies: Conceptual issues, typology, and policy implications. *Food Policy.* https://doi.org/10.1016/j.foodpol.2017.07.013

Yusuf, T.M. (2022) Profit Efficiency of Small-scale Rice Farms in Patigi Local Government Areaof Kwara State, Nigeria. *International Journal of Innovative Research and Advance Studies.* 9(1): 1-9

Wang, H. H; Wang, Y; & Delgado, M. S. (2014). The transition to modern agriculture: Contract farming in developing economies. *American Journal of Agricultural Economics,* 96, 1257–1271

Wiggins, S. & Keats, S. (2013). Smallholder agriculture‟s contribution to better nutrition. Overseas Development Institute. 203 Blackfriars Road, London, SE1 8NJ https://media.odi.org/documents/8376.pd

Wiggins, S., Johann, K., & Luis, L. (2010). The future of Small Farms, *World Development*, 38, (10), 1341-1348

Will, M. (2013). *Contract farming handbook: A practical guide for linking small-scale producers and buyers through business model innovation*, Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany, 1-116

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Diagnosing Nepal's Fertilizer Crisis: Governance Failures and Systemic Bottlenecks in the Fertilizer Supply Chain

Kamana KAFLE[1], Bidur Prasad CHAULAGAIN[2]*, and Nanu JHA[2]
[1]Arkansas State University, Arkansas, USA
[2]Himalayan College of Agricultural Sciences and Technology (HICAST), Kirtipur, Kathmandu, Nepal
***Corresponding author's email**: bidur@hicast.edu.np

ABSTRACT

Chemical fertilizer is a critical input for enhancing agricultural productivity and ensuring food security in Nepal. However, the sector is plagued by chronic supply insecurity, characterized by persistent demand–supply gaps, untimely delivery, and inequitable distribution. This study employs a mixed-methods institutional analysis, guided by Ostrom's Institutional Analysis and Development (IAD) framework, to diagnose systemic bottlenecks in Nepal's fertilizer supply chain and assess their impact on end-user farmers. Primary data were collected from February to August 2022 from key institutional actors (n=20), 15 agricultural cooperatives, and 60 farmers in the Kathmandu Valley the central hub for fertilizer import and distribution. Secondary data from government reports and policy documents were analyzed to contextualize the findings. Results reveal a profound disconnection between policy intent and field-level reality. An estimated national demand of 600,000 metric tons (MT) is met with less than half through official channels, with procurement delays averaging 8–11 months. The state-controlled duopoly of the Agricultural Inputs Company Limited (AICL) and the Salt Trading Corporation Limited (STCL) have marginalized private sector participation, creating a rigid and inefficient supply system. At the farmer level, 86% reported untimely access, 74% found subsidized fertilizers unaffordable, and 28% were unaware of the subsidy program itself. Distribution is highly inequitable, favoring the Terai region over remote hills ($p < 0.001$). Qualitative findings reveal four core themes: bureaucratic procurement paralysis, political interference, cooperative-level failures, and farmer coping strategies. The study concludes that the fertilizer crisis is fundamentally a governance failure, stemming from institutional monopolies, flawed procurement logistics, weak distribution networks, and poor policy communication. To achieve a resilient

fertilizer supply system, policy reforms must prioritize decentralized distribution, strategic buffer stocks, revitalized public–private partnerships, and enhanced farmer-centric extension services.

Keywords: Access constraints, chemical fertilizer, institutional bottlenecks, subsidy policy, supply chain

INTRODUCTION

Agriculture remains the cornerstone of Nepal's economy, contributing approximately 25.8% to the national GDP and providing livelihoods for about two-thirds of the population (MoALD, 2022). To meet the food demands of a growing population amidst shrinking arable land, enhancing crop productivity through improved inputs is imperative. Fertilizer, along with seed and irrigation, is a major input for agricultural production (McArthur et al., 2017). With the commercialization of agriculture, demand for fertilizer has been continually increasing (FAO, 2019). Fertilizers (organic or inorganic) are among the most important agricultural inputs, and their unavailability in time and required quantity hampers crop production to a great extent (Panta, 2018). Historically, Nepal's fertilizer consumption has been low relative to its South Asian neighbors, averaging about 60–96 kg of nutrients per hectare far below the recommended levels for intensified cropping systems (FAO, 2023; The Rising Nepal, 2023).

The governance of fertilizer supply in Nepal has undergone significant policy oscillations. Prior to 1997, a subsidized public monopoly prevailed. This was replaced by a deregulated market (1997–2008), which improved supply but led to price volatility and quality issues. In 2009, the government reintroduced subsidies, creating a state-controlled duopoly that persists today. Despite fertilizer subsidy allocation from NPR 15 billion to NPR 18.5 billion (FY 2023/24), increased budgetary allocations reaching NPR 15.85 billion in FY 2021/22, systemic inefficiencies remain. Nepal's import of agricultural goods reached Rs. 250 billion in FY 2019/20, with fertilizer subsidy allocations rising from NPR 8.99 billion (FY 2018/19) to NPR 15 billion (FY 2020/21) (MoF, 2020). However, the formal supply meets only a fraction of national requirements, forcing farmers to rely on informal cross-border markets (Gautam et al., 2022). The Agriculture Perspective Plan (APP, 1995–2015) aimed to increase fertilizer consumption to 150 kg/ha by 2015. Yet consumption declined from 1999 to 2008, largely due to subsidy removal, which made fertilizers unaffordable. Private sector participation has been constrained by high costs and risks. The 2009 subsidy reintroduction

temporarily boosted applications, but demand–supply gaps persist. Paudel and Cargo (2017) report that despite rising subsidy expenditure, the supply system remains inefficient, with significant delays and mismatches between demand periods and distribution. International assessments reveal a widening nutrient supply gap, particularly for nitrogen, phosphorus, and potassium (Chakraborty et al., 2024). Shrestha (2010) emphasizes that Nepal's fertilizer system is an institutional governance issue, shaped by political transitions, bureaucratic delays, and weak coordination across federal, provincial, and local levels.

While the Terai region accounts for most cereal production, this study focuses on the institutional node where national procurement, import authorization, and distribution mandates originate. The Kathmandu Valley serves as the administrative epicenter, allowing the study to trace governance failures from policy formulation to implementation. While existing literature documents the demand–supply gap, few studies integrally analyze the institutional architecture and link its failures to quantifiable farmer-level constraints. This study addresses the gap using IAD framework, which examines how rules, actors, and institutional arrangements shape governance outcomes. The IAD framework conceptualizes institutional performance as shaped by the interaction of action situations (the procurement and distribution context), actors (state agencies, cooperatives, private dealers, farmers), rules-in-use (procurement regulations, subsidy mechanisms, allocation criteria), and outcomes (supply gaps, price distortions, informal market reliance). By examining how these elements interact, the IAD framework enables a systematic diagnosis of why policy intentions consistently fail to translate into field-level outcomes (Ostrom, 2011). We ask: (1) What are the key institutional and procedural bottlenecks in Nepal's official fertilizer procurement and distribution system? (2) How do these systemic failures translate into access and affordability constraints for end-user farmers?

MATERIALS AND METHODS

Study area

Kathmandu Valley was purposively selected as the study site for institutional rather than agricultural reasons. As the location of the Ministry of Agriculture and Livestock Development (MoALD), the Customs Department, and the headquarters of both AICL and STCL, the valley is the central node where national procurement policies, import authorizations, and distribution mandates originate. By focusing on this institutional hub, the study traces governance

failures from their source policy formulation and import authorization to their manifestation in distribution networks and farmer access.

While the study is geographically confined to the Kathmandu Valley, the institutional pathologies identified procurement latency, centralized decision-making, and information asymmetry are structural features of the national distribution framework. However, the magnitude of farmer-level impacts may vary across regions, and future research should extend the analysis to Terai and hill districts.

Research design and sampling rationale

A descriptive, single-case study design with a convergent parallel mixed-methods approach was adopted. Purposive sampling identified three stakeholder groups: (a) Institutional Actors (n=20): Senior officials from MoALD (n=8), AICL (n=5), STCL (n=4), and the Customs Department (n=3); (b) Supply Chain Intermediaries (n=15): Representatives from agricultural cooperatives (n=10) and private input dealers (n=5); (c) End-User Farmers (n=60): Active fertilizer-using farmers were selected across Kathmandu, Lalitpur, and Bhaktapur districts..

This study utilized the Kathmandu Valley as an institutional proxy for the national supply chain. While the Terai region is the primary cereal-producing heartland, the institutional pathologies identified here procurement latency, centralized decision-making, and systemic information asymmetry are structural governance failures that originate at the administrative hub. By isolating these bottlenecks at the source, this research identified the root causes of supply failures that manifested across the country.

The sample size of 60 farmers was selected to provide an exploratory depth that captured the governance failures (weaknesses) at the distribution hub; while not statistically exhaustive, it generated critical qualitative and quantitative insights into systemic bottlenecks. Furthermore, the single Focus Group Discussion (n=10) served as a supportive qualitative mechanism to triangulate individual survey data and capture shared experiences among cooperative members, rather than aiming for full theoretical saturation. Within each district, farmers were selected purposively to ensure a diverse mix of landholding sizes, crop types, and varying proximity to cooperative distribution centers.

Data Collection (February–August 2022)

Key Informant Interviews (KIIs): Semi-structured interviews lasting 45–90 minutes were conducted with 20 institutional actors covering procurement procedures, subsidy mechanisms, distribution logistics, and policy challenges.
Focus Group Discussion (FGD): One FGD was conducted with 10 cooperative members and progressive farmers (6 male, 4 female) to explore shared experiences and systemic bottlenecks. The discussion lasted approximately 120 minutes and was audio-recorded with consent.

Household Survey: A structured questionnaire was administered to 60 farmers to collect quantitative data on demographics, fertilizer access (timing, quantity), affordability, subsidy awareness, and satisfaction.

Secondary Data: National import/export statistics, AICL/STCL annual reports, policy documents, audit reports, and peer-reviewed literature were systematically reviewed.

Data Analysis
Quantitative Analysis: Survey data were analyzed using descriptive statistics (frequencies, percentages, means) in Microsoft Excel 2016. One-way ANOVA was used to compare provincial supply variations, with statistical significance set at $p < 0.05$.
Qualitative Analysis: Interview and FGD transcripts were analyzed using inductive thematic content analysis. Transcripts were manually coded by two researchers to identify recurring patterns, themes, and narratives. Inter-coder agreement was 87%, with discrepancies resolved through discussion.
Institutional Analysis: A supply chain map was developed to visualize actors, linkages, and critical nodes. Time-series data on national fertilizer imports and prices were analyzed to identify historical trends and supply gaps.

RESULTS AND DISCUSSION

National annual demand for chemical fertilizer in Nepal is approximately 600,000 MT (MoALD, 2022). However, official supply in FY 2020/21 was only 269,482 MT, meeting less than half of the total requirement, a demand-supply gap exceeding 50%. Officials interviewed for this study estimated that informal cross-border channels may account for up to 70% of total fertilizer consumption. Survey

data from the Kathmandu Valley indicated that 86% (52 out of 60) of farmers did not receive fertilizers during the critical pre-planting period, highlighting the severity of access constraints even in the central distribution hub.

Figure 1 illustrates the magnitude of the demand-supply gap across Nepalese provinces. The widest gaps are observed in Madhesh Province, followed by Bagmati and Lumbini Provinces, where agricultural production intensity is highest. In contrast, Karnali Province, designated as an organic farming zone, exhibits the smallest gap due to lower chemical fertilizer demand**.**

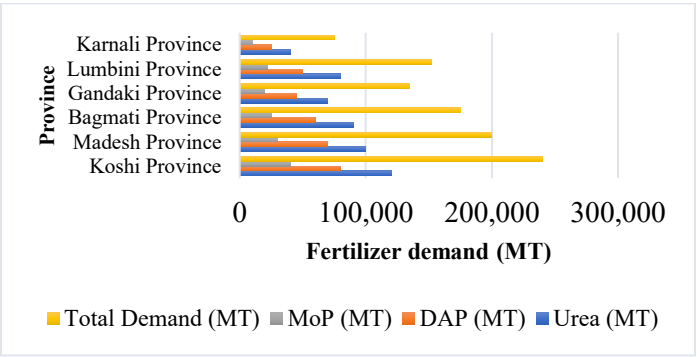


Figure 1. Fertilizer demand-supply gap by province in Nepal (FY 2020/21)

Fertilizer demand for cereal crops varies considerably across the provinces of Nepal. Koshi Province records the highest demand, reflecting its favorable conditions and extensive area devoted to cereal cultivation. Madhesh and Lumbini Provinces also show substantial demand, with cash-crop production estimated at 2.228 million MT and 2.200 million MT, respectively, while Koshi leads at 2.434 million MT. In contrast, Karnali Province has the lowest fertilizer demand, which corresponds with its relatively low cash-crop production (0.582 million MT) and its stronger orientation toward organic farming practices (Figure 2). The persistent gap between demand and official supply forces farmers to seek alternatives. As shown in subsequent sections, this shortfall drives reliance on informal markets, where farmers prioritize availability over price, a critical insight for policy design.

Over the past 17 years, Nepal's fertilizer supply has remained highly inconsistent, marked by repeated fluctuations rather than steady growth. Although supply increased during several periods, these gains were often interrupted by sharp declines, most notably the drop from 298,677 MT in FY 2071/72 to 259,061 MT in FY 2072/73. Such irregularity reflects persistent institutional and logistical

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

weaknesses in maintaining a stable fertilizer supply system, a concern also highlighted by Panta (2018) as illustrated in Figure 3.

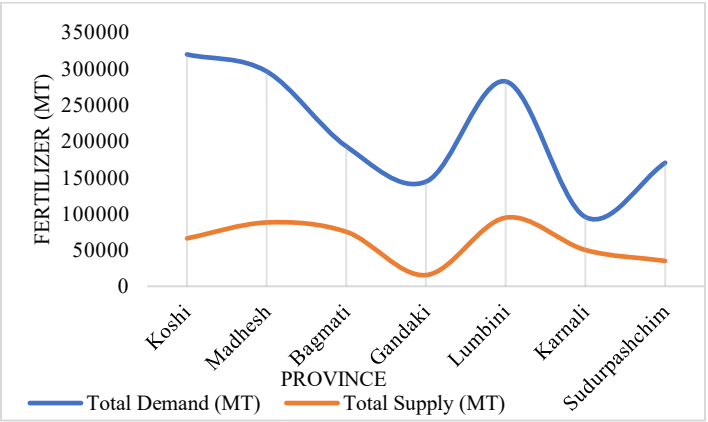


Figure 2. Province-wise estimation of fertilizer demand for cereals in Nepal

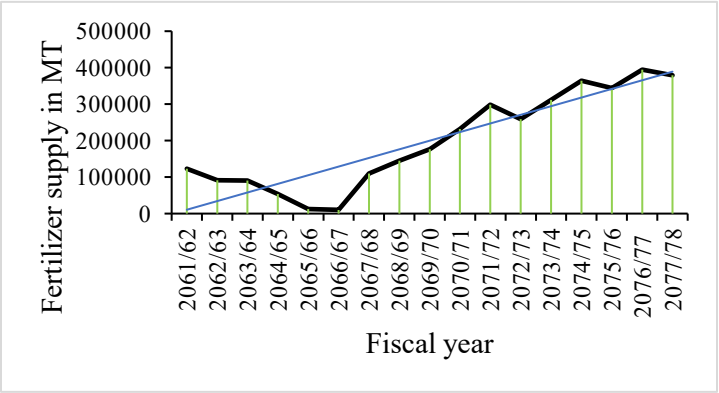


Figure 3. Fertilizer supply trend of Nepal over 17 years (FY 2061/62–2077/78)

This study confirms that Nepal's fertilizer supply insecurity is driven by structural, institutional, and policy-level weaknesses, not temporary logistical disruptions. The persistent demand–supply gap less than half of national needs met officially, aligns with Gautam et al. (2022), who found that chronic shortages force reliance on informal markets. The finding that up to 70% of consumed fertilizer may be

informal (based on expert estimates from officials interviewed) reinforces this structural dependency.

Institutional structure and supply trends

An analysis of fertilizer distribution trends from FY 2061/62 to FY 2077/78, as presented in Figure 4, underscores a persistent reliance on a duopolistic state structure, with AICL serving as the primary provider and STCL playing an auxiliary role. The pronounced year-on-year volatility observed throughout this period highlights an inherent lack of procurement resilience and suboptimal institutional responsiveness to demand surges. By maintaining a highly centralized distribution framework, the system suffers from strategic inflexibility; this concentration exposes the national supply chain to critical failure points, including administrative bottlenecks, import interruptions, and recurring coordination deficits.

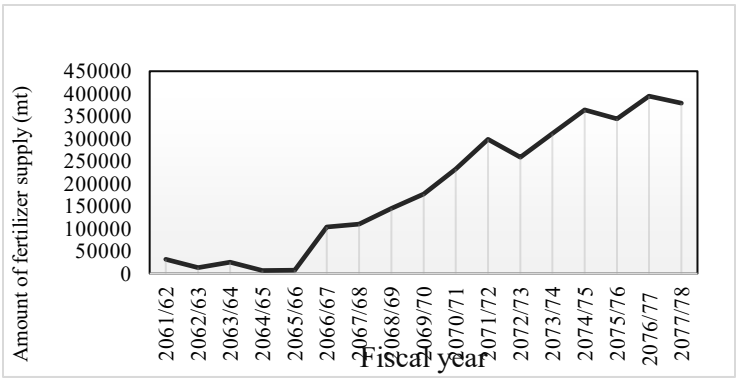


Figure 4. Fertilizer supply trend of AICL and STCL (FY 2061/62–2077/78)

Provincial-Level Distribution Inequities

Table 1 summarizes province-wise fertilizer supply status in Nepal during FY 2020/21. A one-way ANOVA revealed significant inter-provincial differences ($p < 0.001$) for urea, DAP, MOP, and total fertilizer supply. Madhesh Province received the highest total allocation (108,978 MT), followed by Lumbini and Bagmati, reflecting larger cultivated area, intensive cereal production, proximity to the Indian border, and better road connectivity. In contrast, Karnali Province received the lowest total supply (4,011 MT), indicating persistent geographical and logistical constraints. Across all provinces, urea accounted for the largest share of fertilizer supply, followed by DAP and MOP.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Farmer-level access and affordability constraints

The survey revealed important farmer-level constraints related to fertilizer access, affordability, awareness, and informal market use (Table 2). A large majority of respondents (86%) reported untimely access to fertilizers, indicating recurring seasonal delays in supply. Limited availability from AICL and STCL outlets was identified as the principal constraint, whereas transportation was considered less problematic due to Kathmandu Valley's relatively favorable market access.

Table 1. Fertilizer supply status (MT) by Province in Nepal, 2020/21

Province	Urea (MT)	DAP (MT)	MOP (MT)	Total (MT)	CV (%)
Koshi	38,332	20,871	1,917	61,120	20.79
Madhesh	62,033	44,321	2,624	108,978	22.33
Bagmati	42,731	19,191	2,118	64,040	13.30
Gandaki	8,693	3,973	387	13,053	24.95
Lumbini	55,098	33,096	1,719	89,913	12.79
Karnali	2,482	1,427	102	4,011	21.54
Sudurpaschim	18,200	10,461	666	29,327	21.96
F-value	***	***	***	***	
p-value	<0.001	<0.001	<0.001	<0.001	

*Note: *** indicates highly significant at $\alpha = 0.001$. CV: Coefficient of variation

It is important to note that the farmer-level data presented here reflects conditions in the Kathmandu Valley, the institutional hub of the distribution system. While these findings highlight systemic access constraints at the administrative center, they may not represent the more severe challenges faced by farmers in remote hill or Terai regions. Despite subsidy support, 74% of respondents considered fertilizers expensive overall. Urea (NPR 25 kg^{-1}) was generally perceived as affordable, whereas DAP (NPR 57 kg^{-1}) and MOP (NPR 44 kg^{-1}) were widely

viewed as costly. This price differential may encourage imbalanced nutrient use, with greater reliance on nitrogen relative to phosphorus and potassium.

More than one-quarter of respondents (28.3%) were unaware of the government subsidy program, suggesting gaps in farmer outreach and extension communication. Among farmers using informal channels (n = 38), better availability during planting season (68%) was the main reason for purchase, followed by reduced paperwork or rationing (45%) and access to dealer credit (32%). Only 18% cited lower price, indicating that timely availability was more important than cost savings**.** The institutional governance of fertilizer distribution explains these deficits. The 2009 subsidy reintroduction, while intended to protect farmers, created a non-competitive market that stifled private investment. This outcome consists of Shrestha (2010) and Raut and Sitaula (2012), who documented how subsidy-driven price controls made private competition impractical. The AICL/STCL duopoly, handling nearly all subsidized distribution, lacks operational flexibility and accountability.

Table 2. Farmer-Level Access, Affordability, Awareness, and Informal Market Use (n = 60)

Category	**Indicator**	**Result**
Access & Availability	Untimely access	86% of farmers
	Procurement sources	AICL (23), Distributors (20), Agro-vets (17)
	Main access constraint	Purchasing power due to limited supply from AICL/STCL
	Other issues	Quality concerns: moderate Transportation: Accessible
Affordability	Farmers finding fertilizers expensive	74%
	Urea price perception	NPR 25/kg – Affordable
	DAP price perception	NPR 57/kg – Expensive
	MOP price perception	NPR 44/kg – Expensive
	Resulting behavior	Imbalanced nutrient application
Awareness	Unaware of subsidy program	28.30%
Informal Market Use (n = 38)	Better availability during planting	68%
	No paperwork/rationing	45%
	Credit availability	32%
	Lower price	18%

Distributor-level challenges

Based on semi-structured interviews with 15 distributors and cooperative input dealers in the Kathmandu Valley, delayed procurement from AICL and STCL emerged as the most frequently cited operational challenge. Respondents reported uncertainty in stock release schedules, limited seasonal allocation, and administrative delays that disrupted retail planning. Transportation and local distribution mobility were the second most common constraints, particularly during peak demand periods. In contrast, most respondents considered the physical quality of government-supplied fertilizers satisfactory. Several distributors recommended streamlining procurement procedures and exploring domestic fertilizer production to reduce dependence on imports.

Qualitative themes explaining fertilizer supply constraints

Thematic analysis of key informant interviews (KII) and focus group discussions (FGD) generated four recurring themes that help explain the quantitative findings presented in Tables 1 and 2. These themes clarify why fertilizer shortages persist despite subsidy support.

Theme 1: Procurement Delays and Administrative Bottlenecks. Respondents from public agencies consistently described lengthy tendering, budget approval, import processing, and customs clearance as major causes of delayed fertilizer arrival. Several officials noted that procurement timelines frequently extended beyond the main planting season, supporting survey findings on untimely farmer access One respondent noted, *"By the time approval is completed, the planting season may already be over."*

Theme 2: Allocation Inequity and Political Influence. Cooperative representatives and farmers reported that local allocation decisions were not always perceived as transparent. Some respondents believed political connections influenced access priority, which may contribute to unequal local distribution. Several respondents perceived local allocation as inconsistent and politically influenced. One cooperative member stated, *"Those with connections often receive fertilizer first."* This suggests trust deficits in local distribution systems.

Theme 3: Storage and Cooperative-Level Management Constraints. Interviewees identified inadequate warehouse facilities, poor stock handling, and weak inventory management at some cooperative outlets. Such constraints were

reported to reduce fertilizer quality and availability during peak demand periods. An AICL official noted that many cooperatives lack basic storage facilities, resulting in improper exposure of fertilizer to environmental conditions: *"Fertilizer bags are left in the open, exposed to rain. By the time farmers receive it, the urea has caked and the DAP has lost potency"* (KII-AICL-07). This reflects operational deficiencies at the last-mile distribution level that may reduce input effectiveness.

Theme 4: Farmer Coping Responses. Farmers described adaptive responses including reduced fertilizer application, crop switching, delayed planting, and purchases through informal markets. These responses indicate that uncertainty in official supply directly affects farm productivity and decision-making. One farmer stated, *"It costs more, but at least we get it when needed."*

Core institutional pathologies

Applying Ostrom's Institutional Analysis and Development (IAD) framework, the fertilizer governance system in Nepal exhibits four interlinked institutional pathologies. First, in the action situation, procurement cycles (8–11 months) are misaligned with agricultural planting seasons, leading to recurrent seasonal shortages. Second, at the level of actors, a duopoly of state-owned enterprises (AICL and STCL) dominates the system, while private sector participation remains constrained, reducing competition and responsiveness. Third, within rules-in-use, subsidy allocation favors state agencies, with weak performance-based accountability or incentive mechanisms. Finally, these conditions result in persistent outcomes, including an estimated 50% demand–supply gap, ~70% reliance on informal markets, and uneven provincial distribution. Fertilizer importation is concentrated through three customs points—Bhairahawa, Biratnagar, and Birgunj—via global tenders or government-to-government procurement. After entry, prices are administratively fixed following subsidy adjustment, and distribution proceeds through AICL/STCL depots, cooperatives, and agro-vet networks. Farmers bear additional costs for transport and handling at the final stage.

Figure 5 illustrates this institutional supply chain structure**.** It depicts a system where procurement and pricing remain centralized, while distribution becomes progressively layered and weakly coordinated downstream. This fragmentation generates cumulative delays, reduced accountability, and leakage into informal fertilizer markets. The institutional pathologies identified in this study

procurement latency, centralized decision-making, and systemic information asymmetry are structural governance failures that originate at Kathmandu.

Provincial supply patterns reveal systemic imbalances. The disproportionate supply of urea over DAP and MOP ($p < 0.001$) reflects a long-standing nutrient imbalance, consistent with Chakraborty et al. (2024) findings on widening phosphorus and potassium gaps. Madhesh Province's higher supply corresponds with cultivated area, infrastructure, and border proximity, but the significant variation across provinces indicates weak federal–provincial–local coordination, supporting Mishra and Paudel (2023). Farmer-level evidence demonstrates the consequences of institutional failure. The 86% reporting untimely access and reliance on informal sources at higher prices reflects chronic systemic failure. The 28% unawareness of the subsidy program indicates critical extension service failures. Farmers' primary reason for using informal markets better seasonal availability rather than price suggests that supply timing is more critical than subsidy levels. This finding has important policy implications: improving logistics may matter more than increasing subsidy budgets. Distributor challenges procurement delays from AICL/STCL as the most severe constraint align with Raut and Sitaula (2012).

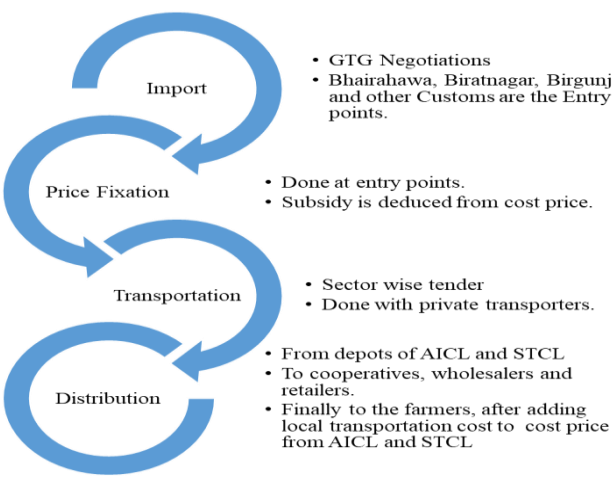


Figure 5. Flow chart of chemical fertilizer supply system in Nepal

Valley's administrative hub. By isolating these bottlenecks at the source, we identify root causes that manifest across the country. Thapa et al. (2019) argued

that Nepal's crisis is fundamentally a policy and governance issue, a conclusion strongly supported here. Applying Ostrom's IAD Framework: Nepal's Fertilizer Governance with explicit mapping of framework components to empirical findings reveals that the current institutional arrangement creates perverse incentives. The duopoly faces no competition, procurement rules favor bureaucratic processes over seasonal responsiveness, and no performance metrics link institutional behavior to farmer outcomes. The result is a system that reliably produces shortages.

CONCLUSION AND SUGGESTIONS

This study demonstrates that Nepal's fertilizer crisis is driven not by mere supply shortages, but by structural failures (weaknesses) in governance, procurement, and distribution. Despite increased subsidy allocations, the system remains constrained by persistent demand–supply gaps, procurement delays averaging 8–11 months, and inequitable access. The centralized duopoly of AICL and STCL has constrained systemic efficiency, limited market competition, and stifled private sector agility. Empirical evidence confirms that the disconnect between policy intent and field-level reality is rooted in a rigid institutional architecture, which this study has diagnosed as a failure of institutional design rather than failure of agricultural inputs. It has been suggested for a reform at Palika-level forecasting, integrating real time digital audit tools for stock and visibility, and introducing regulated competition by enabling vetted cooperatives and private entities to participate in the supply chain. That may ensure transition of Nepal's fertilizer system toward a more responsive, equitable, and resilient structure.

AUTHORS' CONTRIBUTIONS

Kamana Kafle: Conceptualization, Literature review, methodological support, and data collection methodology, data collection, statistical analysis, manuscript writing,
Bidur Prasad Chaulagain: Manuscript reviewing, and editing,
Nanu Jha: Interpretation of findings, manuscript review and academic guidance.

ACKNOWLEDGMENT

We would like to express sincere gratitude to all the respondents, MOALD, SALT and AICL representatives, for their continuous guidance, encouragement, and support throughout this research

REFERENCES

Chakraborty, D., Sherpa, S.R., Koirala, P., Baral, B.R., Karki, S., Sapkota, S., Gathala, M. and Krupnik, T.J. (2024) *Mind the (nutrient supply) gap: an assessment of demand and supply limitations for nitrogen, phosphorus and potassium for major crops in Nepal*. Kathmandu, Nepal: The Cereal Systems Initiative for South Asia (CSISA), Nepal Seed and Fertilizer (NSAF) Project and Transforming Agrifood Systems in South Asia (TAFSSA). Available at: https://hdl.handle.net/10883/35104

FAO. (2019). *World fertilizer trends and outlook to 2022*. Rome: Food and Agriculture Organization of the United Nations. Available at: https://openknowledge.fao.org/server/api/core/bitstreams/42d5a668-f44c-4976-8540-8efdb0f4d17b/content

FAO. (2023). *Fertilizer consumption (kilograms per hectare of arable land) – Nepal*. Food and Agriculture Organization / World Bank data series. Available at: https://www.indexmundi.com/facts/nepal/indicator/AG.CON.FERT.ZS

Forsyth, T. and Johnson, C., (2014). Elinor Ostrom's legacy: governing the commons, and the rational choice controversy. *Development and change*, *45*(5), pp.1093-1110.

Gautam, S., Gaihre, Y.K., Acharya, G.D., Dongol, P. and Choudhary, D., (2022). Fertilizer demand-supply gap and avenues for policy revisits in Nepal: fertilizer deman supply gap in Nepal. *SAARC Journal of Agriculture*, *20*(2), pp.223-234. Available at: https://doi.org/10.3329/sja.v20i2.63583

Government of Nepal, Ministry of Finance (2022) *Economic Survey 2021/22*. Kathmandu: Ministry of Finance. Available at: https://www.mof.gov.np (Accessed: 21 April 2026).

McArthur, J.W. and McCord, G.C., (2017). Fertilizing growth: Agricultural inputs and their effects in economic development. *Journal of development economics*, *127*, pp.133-152. Available at: https://www.sciencedirect.com/science/article/pii/S0304387817300172 (Accessed: 21 April 2026).

Ministry of Agriculture and Livestock Development (MoALD) (2022) *Statistical Information on Nepalese Agriculture 2020/21 (2077/78).* Planning & Development Cooperation Coordination Division, Statistics and Analysis Section, Singha Durbar, Kathmandu: Government of Nepal. Available at: https://centralaglab.gov.np/sites/default/files/publication-file/ STATISTICAL-INFORMATION-ON-NEPALESE-AGRICULTURE-2077-78-82136.pdf

Ministry of Agriculture and Livestock Development MoALD (2024) *Statistical Information on Nepalese Agriculture 2022/23*

Ministry of Finance. 2020. *Budget Speech of Fiscal Year 2020/21*. Kathmandu: Government of Nepal, Ministry of Finance. Available at: https://demo.mof.gov.np/uploads/document/file/1674635120_Economic_Survey_2022.pdf

Mishra, R.P. and Paudel, I.H. (2023) *Agribusiness and supply chain development policies in Nepal: A review from temporal dynamics*. *Nepal Public Policy Review*, 3(1), Special Issue: Agricultural Policies and Practices in Nepal: Pathways for Transformation. Available at: https://doi.org/10.59552/nppr.v3i1.60

National Soil Science Research Centre (NSSRC) / Nepal Agricultural Research Council. (2023). *New fertilizer doses recommended after nearly half century*. Available at: https://risingnepaldaily.com/news/28030

Ostrom, E., (2011). Background on the institutional analysis and development framework. *Policy studies journal*, *39*(1), pp.7-27.

Panta, H.K., (2018). Supply chain of subsidized chemical fertilizers in Nepal. *Journal of the Institute of Agriculture and Animal Science*, *35*(1), pp.9-20. Available at: https://doi.org/10.3126/jiaas.v35i1.22509

Paudel, J. and Crago, C.L., (2017). Fertilizer subsidy and agricultural productivity: Empirical evidence from Nepal.https://ageconsearch.umn.edu/record/258464/files/Abstracts_17_05_22_10_27_57_86__73_4_114_253_0.pdf

Raut, N. and Sitaula, B.K., (2012). Assessment of fertilizer policy, farmers' perceptions and implications for future agricultural development in Nepal. *Sustainable Agriculture Research*, *1*(2). Available at: https://doi.org/10.22004/ag.econ.231372

Shrestha, R. K. (2010) "Fertilizer Policy Development in Nepal", *Journal of Agriculture and Environment*, 11, pp. 126–137. Available at: doi: 10.3126/aej.v11i0.3660.

Thapa, G., Kumar, A. and Joshi, P.K., (2019), *Agricultural Transformation in Nepal: Trends, Prospects, and Policy Options.* Singapore: Springer Nature. doi: 10.1007/978-981-32-9648-0.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Temporal Dynamics of Physical, Chemical and Biological Properties of a New *Panchagavya* During Preparation and Storage stage

Sabita Aryal KHANNA*, and Janardan LAMICHHANE*
School of Science, Kathmandu University, Dhulikhel, Nepal *****
Corresponding author's email: ljanardan@ku.edu.np [1], sabita@ku.edu.np [2]
ORCID ID: 0000-0001-8020-9143 [1], 0000-0003-4672-9297 [2]

ABSTRACT

Panchagavya is a traditional liquid formulation which has been used since Vedic period for medicine and ecosystem health in Indian subcontinent. This study evaluated the dynamics in its physical characters (texture, colour, odour, temperature, EC and pH), chemical characters (macro- and micro- plant nutrients), and biological characters (organic matter, bacteria, fungus and actinomycetes) in its preparation and subsequent storage stage. Objective of the study was to prepare New *Panchagavya* following a standard protocol with some change in substitution of ingredient with locally available materials; and analyzed the New *Panchagavya* to find out days of maturity and expiry. New *Panchagavya* was sampled from 17th to 81th DAM in a regular interval bought for physical (odour, colour, texture, temperature, EC and pH) test, chemical test (macro and micro nutrients: P, K, Ca, Mg, Fe, Zn, Cu and Mn) and biological (organic matter, Bacterial, Fungi and Actinomycetes loads) analysis. Three quality windows were observed. The **New *Panchagavya*** 17-22 DAM was found with maximum nutrients and microbes while 36-51 DAM was with balanced nutrients and stable biological characteristics and 51-81 DAM was with highest humic substances and persistent microbes. The 17-22 DAM best suited for early growth period of crop. 36-51 DAM is a sustained growth period and 51-81 DAM is good for mature flowering and fruiting plants to control the pest attach and provide resistance to the diseases. The study concluded as a match application of ***Panchagavya*** should be made with timing to crop development and need.

Keywords: Ayurvedic agri-input, formative day, microbial dynamics, nutrient dynamics, stock period

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

INTRODUCTION

Green revolution fed the large population but ruined the soil health and ecosystem (Shiva, 1991). Consumer are now more concerned about finding safe and environmentally friendly products produced using novel farming techniques. Many indigenous farming techniques have been found to be in par with modern techniques. One such technique is the use of ancient cow-based amendment called *Panchagavya*. The term "*Panchagavya*" stems from Sanskrit, where "*Panch*" translates to five, and "*gavya*" implies cow-derived products such as cow dung, cow urine, cow milk, cow ghee, and cow curd. *Panchagavya,* the combination of these five ingredients creates a potent blend with diverse characteristics such as nutrient-rich, antimicrobial, purifying, and nourishing properties(Khanna *et al.*, 2025). This makes *Panchagavya* a versatile substance that can be used in agriculture, *Ayurveda*, and spiritual practices for promoting environmental sustainability, well-being and health.

Vedic and Cultural Background

Panchagavya, a traditional formulation of *Bharat Varsha* (the Indian subcontinent), is believed to have originated from the wisdom of *Maharshi* Dhanvantari and has been valued for its spiritual, medicinal, and agricultural significance since ancient times. The *Rig Veda* and *Atharva Veda* describe the sacredness of cows and the use of cow products in rituals and healing practices (Batra, 1986), while the *Puranas* and *Dharma Shastras* (1st century BCE–6th century CE) emphasize nature-based agricultural traditions. Classical Ayurvedic texts, including the *Charaka Samhita, Sushruta Samhita,* and *Ashtanga Hridaya*, document the therapeutic uses of cow urine, dung, milk, and ghee (Balakrishnan and Shukla, 2018);(Chandra, Geetha and Vidyanath, 2021) . Likewise, ancient agricultural texts such as the *Krishi Parashara* and *Nighantu Sangraha* recommend cow products for improving soil fertility, crop growth, and plant protection (Chaudhary, Darji and Kachchhava, 2025); (Knapp, 2005). These historical records demonstrate that *Panchagavya* has long served as an integral component of the cultural, medicinal, and sustainable agricultural heritage of India and Nepal, where its ritual and practical uses continue today (Valpey, 2019).

Table 1 provides the detailed characteristics of each *gavya* (component) of *Panchagavya* (Khanna, Bajracharya and Rinu Karmacharya, 2018; Rawal *et al.*, 2024). In Vedic rituals and ceremonies, *Panchagavya* is used as a sacred offering

to deities and is believed to purify the environment and bring positive energy. It is also used in traditional practices like *Agnihotra* (fire ritual) for spiritual purification and healing (Abhang and Pathade, 2017), (Kaushal, 2025)). These ancient references to *Panchagavya* reflect the deep-rooted cultural, spiritual, and agricultural significance of cow products is a part of traditions for centuries and continues to be valued in contemporary times for sustainable living and well-being (Khanna, 2016).

Time immemorial this miraculous liquid has been used in the health and farm of the Indian continent. It is the single organic input that can act as a fertilizer, pesticide, growth promoter, and immunity booster for plants. It has demonstrated its potential to serve humankind in the dilemma of a sustainable agro-ecosystem and food production.

Table 1. Five components (*gavya*) of *Panchagavya* and their properties

Cow Dung (Gomaya)	Cow Urine (Gomutra)	Cow Milk (Ksheera)	Cow Ghee (Clarified Butter)	Cow Curd (Dahi)
Nutrient-rich: such as nitrogen, phosphorus, and potassium, which are essential for plant growth. Antibacterial properties: contains beneficial bacteria that help in breaking down organic matter and improving soil health. Purifying: cleanse the environment and neutralize negative energies	Antimicrobial: fights off harmful bacteria and viruses. Detoxifying: promote overall health and well-being of body. Insect repellent: use for protecting plants from pests.	Nutritious :rich source of protein, calcium, vitamins, and minerals Nourishing: growth, and overall vitality. Soothing-cooling: reduce inflammation or acidity. used in Ayurveda	High in antioxidants: boost immunity and fights free radicals. Digestive aid: improve nutrient absorption Nourishing: *sattvic* food that for body and mind.	Probiotic: improve digestion. Cooling: reduce inflammation. Rich in calcium: which are essential for plant growth.

Its traditional roots and modern applications underscore the significance of this ancient remedy as a remarkable gift to humankind. While traditional knowledge lauds the benefits of *Panchagavya*, efforts such as the Scientific Validation and

Research on *Panchagavya* (SVAROP) program in India are initiated to substantiate these claims through modern scientific validation (Bajaj *et al.*, 2022)

Rediscovery of *Panchagavya* for agricultural use

Professor (Natarajan, 2002) formally brought modern *Panchagavya* where he added several herbs such as jaggary, banana, tender coconut, and water besides all five *gavyas* (Selvaraj *et al.*, 2007). *Panchagavya* is used as a natural fertilizer and pesticide. It helps improve soil fertility, enhance plant growth, and protect crops from pests and diseases (Varsha and Thamaraiselvi; Varsha and Thamaraiselvi, 2025). Farmers use *Panchagavya* as an organic alternative to agro chemical, promoting sustainable and eco-friendly farming practices(Srinivasan and Aithal, 2025). In modern time research has revealed the optimal efficacy is observed with a 3% solution of *Panchagavya*, and recommended for various applications such as spray systems, seed treatments, and irrigation water mixing(Kumar *et al.*, 2025). It acts as a viable growth promoter and immune booster for plant systems, aiding in enhanced flowering, fruit quality, and shelf life (Selvaraj and Rana, 2025).

Scientists have detailed the experimentations of the product and tried to validate composition, physical, chemical, and biological behavior, and response in agricultural use. Still there is much of an immense need for scientific efforts to validate the standard formulation process, characterization, authentication, and use in Agriculture agroecosystem. This study is also an attempt to substitute the ingredient prescribed by Professor (Natarajan, 2002) with suitable but locally available ingredient ()and formulate *New Panchagavya*. Tender coconut water is a rear herb for land locked hill country like Nepal. Tender coconut water can be substitute with locally available herb like aloe vera gel. Instead of yeast with *marcha* (sourdough) can be used. Tender coconut water contains growth factors which stimulate the growth of microorganism (Naik *et al.*, 2022). Similarly Aleovera increases the population of growth-promoting Bacillus sps and Pseudomonas sps in soil (Jaramillo *et al.*, 2025); such Indigenous microorganism enhanced the phosphorous content of organic cow manure(Novia *et al.*, 2025) It also inhibit the gram positive bacteria and make safe use in agriculture(Danish *et al.*, 2020). *Marcha* a traditional starter to make home based alcohol by several ethnic community in Nepal (Sharma *et al.*, 2019) is used since it holds many yeast strain some are high amyolytic and some produces ethanol (Tsuyoshi et al., 2005). In this experiment *marcha* from Tamang community is used. This marcha have multi species of yeast, Saccharomyces sps, and non-Saccharomyces, amyolytic

yeast and bacteria Bacillus sps and mold aspergillus sps (Karmacharya *et al.*, 2024). Objective of the study is to identify the quality of the product and its maturity and expiry days. This finding will make the *Panchagavya* as a potent agricultural input which can be scientifically prescribed for nontoxic farming. If this product can substitute agro-chemical use, tremendous resource, money and fuel not only saves but the pristine hill farm from ill of chemicals contamination (Wangchu *et al.*, 2024). While Panchagavya is widely used, no systematic study has tracked its physical, chemical and biological properties over time using a locally adapted formulation. This study therefore tested the hypothesis that New *Panchagavya* exhibits distinct quality during formulation and storage period. The results of this study could be used to identify the correct timing of application of *Panchagavya* for different use case.

MATERIALS AND METHODS

Formulation of New *Panchagavya*

A modified Panchagavya formulation was prepared by replacing tender coconut water with locally available aloe vera gel and yeast with marcha (traditional sourdough starter), while following the standard preparation protocol described by (Natarajan, 2002). The experiment was conducted at the Aquatic Ecology Laboratory, Kathmandu University, Dhulikhel. Fresh cow dung and cow ghee were thoroughly mixed in a clean, sterilized, sun-dried, wide-mouthed plastic bucket on first day of mixing (DAM) and ilet it formented for three days. On the fourth DAM cow urine, cow milk, curd, jaggery, ripe banana, aloe vera gel, and marcha were added(Plate 1). The mixture was stirring twice-daily (12 clockwise and 12 anticlockwise rotations). while letting furthure fermention under aerobic conditions for 15 DAM. On 19 days 30 lit of New Panchagaya was measured , if a litere of panchgavya should be made the ingredients needed is calculated in Table 2.

This final product with new locally available ingredients is called a new *Panchagavya* and was stored further for 90 DAM (days of mixing). Throughout the period of preparation and storage the bucket was covered with a thick cotton, placed in shade to protect it from insect, rodent, rain and sun light, stir 12 time clock-wise and 12 time anti clock-wise direction twice a day with a wooden stick as the metal contact was prohibited. We collected 300 ml sample at day 17, 18, 19 20, 21, 36,51,61,71 and 81DAM in a sanitized plastic bottle and stored at the Aquatic Ecological Laboratory and Microbiological Laboratory of Kathmandu

University, Dhulikhel, Nepal for further analysis. Physical characteristics colour, odour, texture and temperature were instantly observed, felt and measured with temperature probe. EC meter and pH probe used to measure the salinity, acidity of *Panchagavya* samples.



Plate 1. *Panchagavya* preparation in Lab

Table 2. Proportion of New *Panchagavya*

SN	Ingredients	Quantity (30 lit)	1 lit
1	Dung	5 kg	97ml
2	Ghee	1 kg	42 ml
3	Urine	3 lit+10 lit water	503ml
4	Milk	2 lit	77ml
5	Curd	2 kg	75ml
6	Jaggary	100 g+1 lt water	39ml
7	Banana	2 dozen	46ml
8	Aleo vera Juice	3 lit	116ml
9	*Marcha*	100 g+1 lt water	7ml

Total Nitrogen is measured by Kjeldahl method, in which wet oxidation procedure is followed, available phosphorous is measured by Vanadomolybdate phosphoric yellow colour methods and Potassium by Flame photometry methods (Jackson, 2005). We estimated Ca, Mg , Fe, Zn, Cu and Mn by the use of Atomic Absorption Spectrometer(de Oliveira, Raposo Jr and Neto, 2009). Organic matter was quantified by using dry combustion method (Nelson and Sommers, 1996). Microbial loads was calculated from colony count methods (Waksman, 1922). A Serial jump dilution technique is performed for the dense *Panchagavya* solution

into a more usable concentration. Fermentation dynamics was studied by using R programming (R Development Core Team, 2023). Nutrient dynamics during storage stage can be extrapolated to understand the usable shelf-life of the quality product.

RESULTS AND DISCUSSION

Physical Properties of *Panchagavya*

Temperature, EC, pH, recorded during formative stage and storage stage is expressed in (Figure1). Temperature raised (24°C) in formative stage stabilized around ambient (22°C) throughout storage stage (Figure 1.a). EC showed notable fluctuations (19.15 to 9.65 dS/m), suggesting active solubilization and mobilization of mineral salts, followed by microbial utilization (Figure 1.b). pH drops acidic (Figure 1.c) in formative stage (during 17, 18, 19 20 and 21 DAM) but in later rises high towards neutral (4.7 to 6.2)

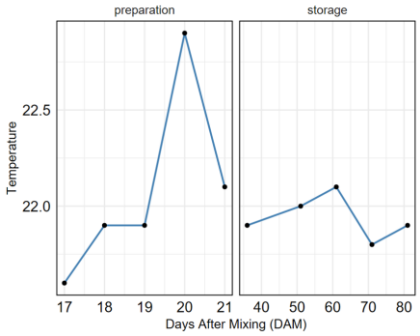


Fig1a: Temperature

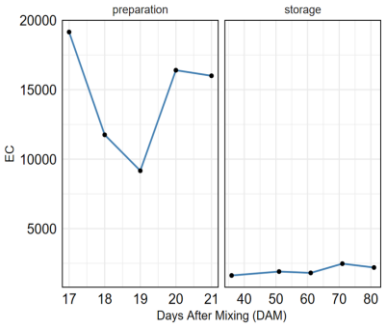


Fig1.b EC

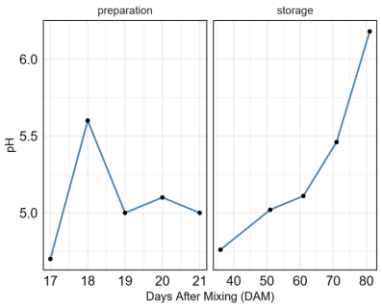


Fig 1.c pH

Figure 1. Physical properties dynamics of preparation vs storage stages of *Panchagavya*

In formative stage microbial metabolism perhaps generated heat which created a positive feedback loop (Cao *et al.*, 2025) thus a balanced fermentation complete without overheating. Thus, a self-regulating fermentation is possible for a homemade Agri-input. Nutrient cycling during *Panchagavya* formulation (Ali *et al.*, 2011) indicated direct relationship between ions (NH_4^+, NO_3^-, K^+, PO_4^{3-}, Ca^{2+}, Mg^{2+}, lactate$^-$, acetate$^-$, citrate^{3-}) and conductivity (Miller and Curtin, 2006) (Figure 2). A Strong correlation between EC peak (9.65 dS/cm) and Nutrient peak is observed. Thus, EC can be a simple field monitoring tool to examination of maturity of the *Panchagavya*. Succession of microbes from early-stage acidogenic to later-stage fermenters(Chakraborty and Sarkar, 2019); (Gore and Sreenivasa, 2011), which stabilize the medium toward near-neutral conditions which make the *Panchagavya* best for application on plants.

Qualitative parameter such as Colour, odour and texture (Table 3) assist to confirm the fermentation progress. The color shifted from greenish-brown to seaweed brown, while the odor remained fruity/pleasant throughout, signifying healthy microbial activity without putrefaction. The slimy texture was consistent with biofilm-forming microbial consortia. These parameters indicate that the preparation reached a stable, mature state by 20 days, which is suitable for agricultural use.

Table 3. Physical Characteristic of *Panchagavya*

SN	DAM	Colour	Odour	Texture
1	17	Greenish brown	Fruity smell	Slimy
2	18	Greenish brown lighter	Fruity smell	Slimy
3	19	Sea-weed brown	Fruity smell	Slimy
4	20	Sea-weed brown	Fruity smell	Slimy
5	21	Sea-weed brown	Fruity smell	Slimy
6	36	Sea-weed brown	Fruity smell	Slimy finer
7	51	Sea-weed brown	Pleasant smell	Slimy finer
8	61	Sea-weed brown	Pleasant smell	Slimy finer
9	71	Sea-weed brown	Pleasant smell	Slimy finer
10	81	Sea-weed brown	Pleasant smell	Slimy finer

There was no foul odor which indicated the putrefaction, no dark or blackish color or no sharp EC drop at storage stage. This shows that the product was very fresh up to 81 DAM. Farmer can safely use the quality *Panchagavya* for three months from date of preparation, which cover a season of crops, in 22 °C aeration with stirring and storage condition of laboratory.

Chemical properties of *Panchagavya*

This section, discuss the dynamic of macronutrients (N, P, K, Ca and Mg) and the micronutrients (Fe, Zn, Cu and Mn) of *Panchagavya* during preparation and storage phases (Figure2).

Macronutrients in *Panchagavya*

Primary macronutrient such as N, P, K and secondary macronutrient such as Ca, Mg in *Panchagavya* was analyzed during formulating and in its storage stage (Figure 2). Nitrogen (N) slowly increases day by day up to 19 DAM and shoot up (1300mg/ L) but stabilized (1230 mg/L) on 21 DAM till 50 DAM then slowly decrease (Figure 2.a) till the 90 DAM (1040 mg/L). Phosphorus (P) remained moderate fluctuations (106 to 145 mg/L) but got highest in 20 DAM during formative phase. P concentrations remarkably rises (117 to 291 mg/L) from 40 to 50 DAM, continue to fluctuate (150 then 250 to 180 mg/ L) in storage stage too (Figure 2.b). Potassium (K) very stable till 19 DAM and make highest concentration in 20 DAM (816 mg/L), and shown vey insignificant fluctuations during storage (Figure 2.c**).** Calcium (Ca) increases very slowly make highest in 20 DAM (152.0 mg/L) remain stable till 70 DAM and tend to decrease (151.0 mg/L) by 90 DAM (Figure 2.d). Magnesium (Mg) fluctuate insignificantly (47.1 to 47.2 mg/L) (Figure 2.e). High amount of N, reflect intense microbial mineralization of proteins and urea from dung, urine, and milk products**.** 45% N loss from peak (0.63%) to late storage (0.34%) might be due to volatilization, denitrification, immobilization mechanism over prolonged storage (Gore and Sreenivasa, 2011). For maximum N efficiency *Panchagavya* should be used within 30-40 DAM. This window is the growth period of plant where nitrogen is most wanted. Temperature and pH both influence N loss rate (Zhang *et al.*, 2021) , longer the storage more the loss of N. Continued microbial solubilization and re-mineralization cycles (Perumal *et al.*, 2006) might be due to active solubilization by phosphate-solubilizing microbes in the fermenting medium (Subhashini, 2016). The pH decline in formative stage due to microbial acid production (Tariq *et al.*, 2023), which enhances P and micronutrient solubility (Khan *et al.*, 2009), and reduces N volatilization losses (Gan *et al.*, 2025). Here pH acts as master control variable. A comparison of both stages highlights that preparation stage *Panchagavya* provides a more dynamic nutrient profile**,** with readily available N and P that support vigorous vegetative growth and root establishment in vegetable crop, thus best suited for a foliar nutrient spray (Subhashini, 2013). In contrast, stored *Panchagavya* ensures nutrient stability (K,

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Ca, Mg) but with reduced N (16.2%) and increase P (60.20%) availability **(Table 5), making it more suited** to support flower, fruit setting and stress tolerance.

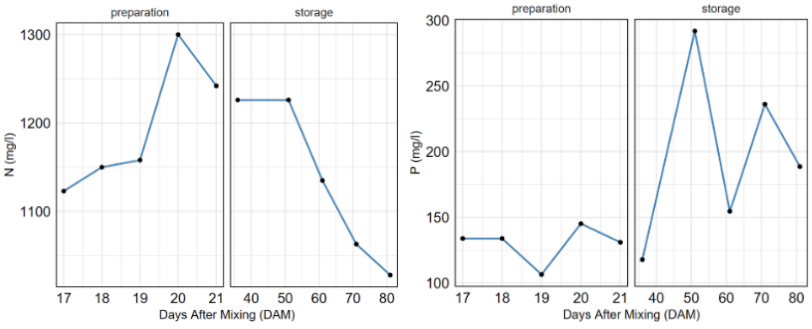


Fig2.a:Nitrogen

Fig2.b:Phosphorus

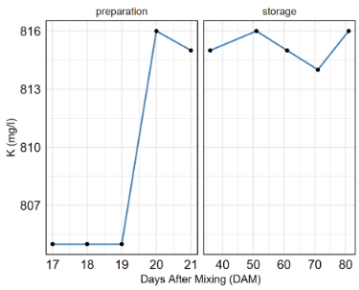


Fig2.c:Potassium

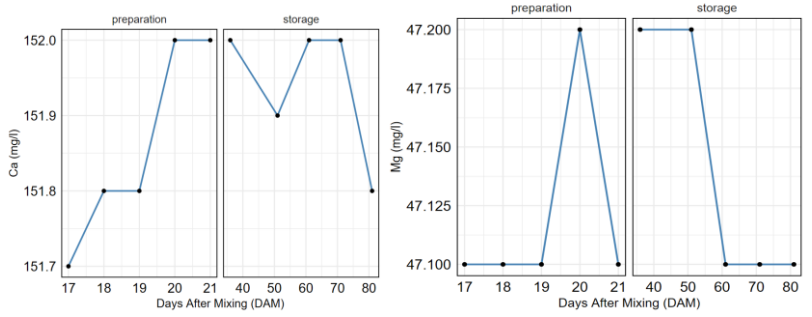


Fig2.d:Calcium

Fig2.e:Magnesium

Figure 2. Macro-Nutrient (mg/L) Dynamics of Preparation vs Storage stages of Panchagavya

Table 4. Macro-Nutrient peaks and loss during storage

Nutrient	Peak DAM	Peak Value (mg/L)	Storage Start (mg/L)	Storage End (mg/L)	Change in Storage (%)
N	20	1300	1226	1028	−16.2%
P	20	145.1	117.7	188.6	60.20%
K	20	816	815	816	0.10%
Ca	20	152	152	151.8	−0.1%
Mg	20	47.2	47.2	47.1	−0.2%

Micronutrients in *Panchagavya*

Dynamics of micronutrient such as Fe, Zn, Cu and Mn of *Panchagavya* was analyzed during the formative stage and storage stage (Figure 3). Iron (Fe) gradually increased (29.12 mg/L) by 20 DAM. Stabilized for the period of three weeks and remain same for the period of 90 DAM (Figure 3.a). Zink (Zn) is present in *Panchagavya* throughout the period of formation till storage (Figure 3.b) with minor fluctuation (1.76 to 1.77 mg/L). Cupper (Cu), fluctuate in both the stage, slightly declining (2.5 to 2.2 mg/L) in preparation stage and slightly increased (2.4 to 2.5 mg/L) during the storage (Figure 3.c). Manganese (Mn) rose (1.6 to 2.2 mg/L) steadily during preparation and still raises up to (2.2–2.4 mg/L) during storage stage (Figure 3.d).

All micronutrients Fe, Zn, Cu and **Mn** too peak together at 19 DAM, perhaps might be due to microbial organic acids. Acidic pH maximizes solubility of Fe, Mn, Zn, Cu solubility (Gondal *et al.*, 2021). Thus, *Panchagavya* is a micronutrient chelate source**.** Chelation improves absorption and utilization of essential nutrient in various organism, leading to better health and productivity in plants**.** Fe help to prevent chlorosis in plant, Zn ensure hormone regulation, auxin synthesis, pollen viability**,** flowering, fruiting and the seed development**,** Cu remains adequate for enzyme activity and lignin formation, enhancing resistance to pathogens, plant-available Mg forms contributes to photosynthetic activity and nitrogen assimilation (Somasundaram and Amanullah, 2007) This readily available micronutrient ensures uniform growth, continuous chlorophyll activity, and better fruit development throughout the cropping. Thus, *Panchagavya* is best suited for a foliar nutrient spray or drenching. A comparison of both stages highlights that both preparation and storage stage Fe and Mn raise till 81 DAM, whereas Zn and Cu fluctuate and still remain in same quantities for the period of 81 DAM. Thus, extrapolation suggests the *Panchagavya* can be safely store up to 90 days in shade

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

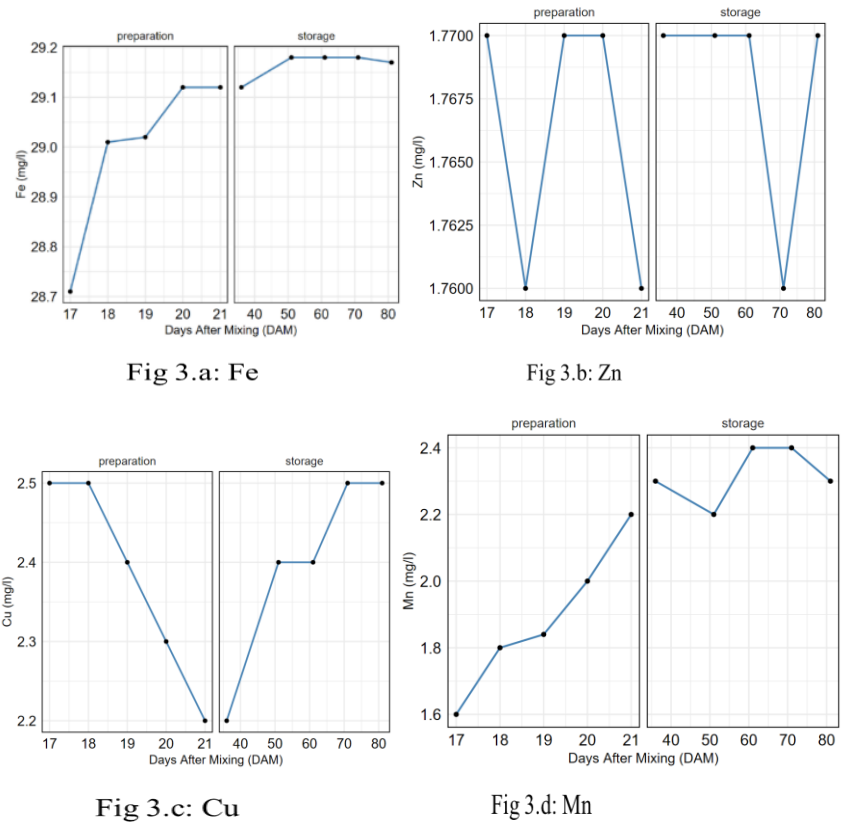


Fig 3.a: Fe

Fig 3.b: Zn

Fig 3.c: Cu

Fig 3.d: Mn

Figure 3: Micro-Nutrient (mg/L) Dynamics of Formation vs Storage stages of *Panchagavya*

Biological Properties of *Panchagavya*

Dynamics of organic matter (OM), and microbial loads such as bacterial colony count (BCC), fungal colony count (FCC) and Actinomycetes colony count (ACC) of *Panchagavya* was analyzed during formation stage and in its storage stage (Figure 4). OM rose rapidly (Figure 4.a) till 19DAM (31.16% to 150%), with some fluctuation fall down and almost exhaust by 60 DAM (8%). BCC in *Panchagavya* increases up by 20 DAM ($11X10^{10}$CFU/ml), sudden burst on 21DAM ($35X10^{10}$CFU/ml) and slowly decline through Storage period, remain good amount of bacteria $20X10^{10}$CFU/ml by 81DAM (Figure 4.b). Good FCC

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

(18X10^{11}CFU/ml) observed on 17DAM, and a regular raise up to 28X10^{11}CFU/ml by 19 DAM (Figure 4.c), then continue to decline for a while and make up by 60 DAM which further lower down in (13X10^{11}CFU/ml) late storage phase. ACC increase very slowly in initial days of formulation (2X10^{3}CFU/ml to 5X10^{3}CFU/ml). Actinomycetes shoot up on 60 DAM (20X10^{3}CFU/ml) then slowly reduce during Storage period (Figure 4.d) still remain (15X10^{3}CFU/ml) in 81 DAM.

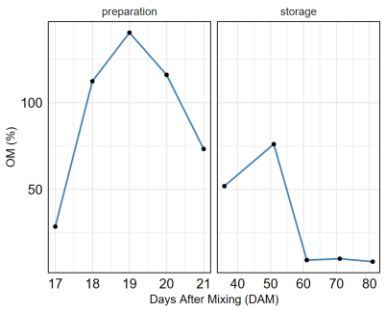


Fig 4.a: OM

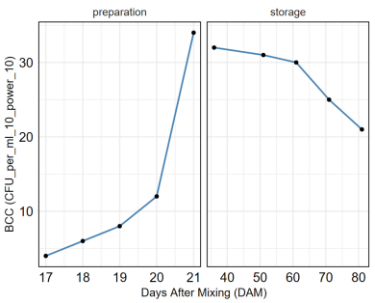


Fig 4.b:Bacterial load

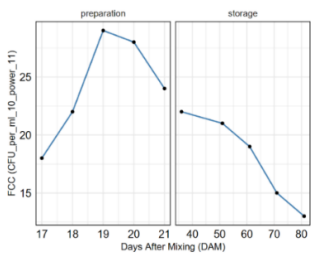


Fig 4.c:Fungal load

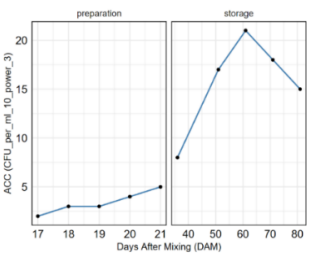


Fig 4.d: Actinomycetes load

Figure 4. Organic matter % and microbial loads (CFU/ml) dynamics of *Panchagavya* during formation vs storage stages

The biological profile of the *Panchagavya* mixture shows three oligotrophic conditions and clear Microbial Successions. a rapid rise in organic matter and microbial counts during the formulation. Phase 1 (17-22 DAM) where r-strategist bacteria dominate. Phase 2 (22-36 DAM) K-strategist fungi/actinomycetes increase. Basal metabolism maintains populations without growth. Phase 3 (51-81 DAM) Recalcitrant OM provides slow-release carbon source for Climax community and acidic pH prevents competitor invasion (Brant, 2005). Initial OM is Labile substrates produce rapid acid and pH tends to decrease (Chen *et al.*, 2012), final OM is Recalcitrant humic substrates (stable form), is slow in acid production (Marschner *et al.*, 2008).

This multiple biological and chemical transformation are depicted by change in colour of *Panchagavya.* (Nursten, 2005), explained Millard reaction where three processes intensify with time and microbial activity. Amino acids and sugars changed to melanoidins which is brown in colour. Humification occurs where microbial enzymes give humic acids which is dark brown in colour. Phenolic oxidation where polyphenol oxidase changes to quinones which is brown in colour. All the phases offer different benefits to plants and soil. Early *Panchagavya* is good for nutrient amendment and late *Panchagavy*a is best for soil conditioning.

CONCLUSION

Panchagavya evolves through three quality windows. The product can be stored for up to 81 days under the conditions tested. Stored product should be matching the application with timing to crop need. Early window for vegetative growth, later window for flowering/fruiting. Extended store of *Panchagavya* may lose its quality, thus it should be used before its drops.

There was potential variability due to seasonal/ regional differences in raw materials and cow product.

RECOMMENDATIONS

The results of the study were drawn within certain limitations, which should be corrected in future experiments.

1. Sample from late formative stage (17, 18, 19, 20, 21 DAM) was taken every day. But sample during storage stage was measured on the day of Panchagavya used for the crop, where the gaps were 10-15 days. It is now realized that the analysis for formative and storage sample data gap are too short and too large. For future experiment it is recommended to omit this limitation by giving equal interval of 3-5 days.
2. Single sample was analyzed due to resource constraint. It is recommended for future experiment to collect sample in duplicate or triplicate.
3. Soil and crop response of *Panchagavya* application should be addressed in future work.
4. Multiple experiments on scientific validation of this formulation has to be conducted in future.

5. The cow product may differ based on breeds of cow as well. It can be addressed in future experiment.

REFERENCES

Abhang, D. P. and Pathade, G. (2017) 'Agnihotra technology in the perspectives of modern science-a review', *Indian journal of traditional knowledge,* 16(3), pp. 454-462.

Ali, N., Eliyas, M., Al-Sarawi, H. and Radwan, S. (2011) 'Hydrocarbon-utilizing microorganisms naturally associated with sawdust', *Chemosphere,* 83(9), pp. 1268-1272.

Bajaj, K. K., Chavhan, V., Raut, N. A. and Gurav, S. (2022) 'Panchgavya: A precious gift to humankind', *Journal of Ayurveda and integrative medicine,* 13(2), pp. 100525.

Balakrishnan, S. and Shukla, K. (2018) *Cow: A Celestial Being (Prabhat Prakashan): Cow: A Celestial Being: Understanding the Sacred Animal.* Prabhat Prakashan.

Batra, S. (1986) 'The sacredness of the cow in India', *Social Compass,* 33(2-3), pp. 163-175.

Brant, J. B. (2005) 'Litter controls of microbial community composition and function in forest soils'.

Cao, R., Zhou, Q., Ma, Y., Yan, X., Li, A., Du, H. and Xu, Y. (2025) 'Multimodal integration: mechanisms of temperature dynamics and quality formation critical period in Daqu', *Food Research International*, pp. 117622.

Chakraborty, B. and Sarkar, I. (2019) 'Quality analysis and characterization of Panchagavya, Jeevumrutha and Sasyamrutha', *Int. J. Curr. Microbiol. App. Sci,* 8(5), pp. 2018-2026.

Chandra, C. R., Geetha, K. and Vidyanath, R. (2021) 'ANALOGIES RELATED TO COW WITH SPECIAL REFERENCE TO PANCHAGAVYA IN BRUHATTRAYEE', *International Journal of Applied Ayurved Research ISSN: 2347-6362,* V(III).

Chaudhary, R., Darji, Y. and Kachchhava, K. (2025) 'Organic Farming and the Agricultural Wisdom of Ancient India: An Exploration of Sustainable Agroecology', *Agriculturae Conspectus Scientificus,* 90(1), pp. 1-6.

Chen, Y., Wen, Y., Zhou, J., Xu, C. and Zhou, Q. (2012) 'Effects of pH on the hydrolysis of lignocellulosic wastes and volatile fatty acids accumulation: The contribution of biotic and abiotic factors', *Bioresource technology,* 110, pp. 321-329.

Danish, P., Ali, Q., Hafeez, M. and Malik, A. (2020) 'Antifungal and antibacterial activity of aloe vera plant extract', *Biol Clin Sci Res J,* 2020(1), pp. 1-8.

de Oliveira, S. R., Raposo Jr, J. L. and Neto, J. A. G. (2009) 'Fast sequential multi-element determination of Ca, Mg, K, Cu, Fe, Mn and Zn for foliar diagnosis using high-resolution continuum source flame atomic absorption spectrometry: Feasibility of secondary lines, side pixel registration and least-squares background correction', *Spectrochimica Acta Part B: Atomic Spectroscopy,* 64(6), pp. 593-596.

Gan, C., Jiang, Y., Wang, Y., Lin, S., Luo, Y., Li, H., Li, Y., Tang, N., Fei, Y. and Hu, R. (2025) 'Organic fertilizer application reduce ammonia volatilization in an acidic soil', *Agriculture, Ecosystems & Environment,* 383, pp. 109510.

Gondal, A. H., Hussain, I., Ijaz, A. B., Zafar, A., Ch, B. I., Zafar, H., Sohail, M. D., Niazi, H., Touseef, M. and Khan, A. A. (2021) 'Influence of soil pH and microbes on mineral solubility and plant nutrition: A review', *International Journal of Agriculture and Biological Sciences,* 5(1), pp. 71-81.

Gore, N. S. and Sreenivasa, M. (2011) 'Influence of liquid organic manures on growth, nutrient content and yield of tomato (Lycopersicon esculentum Mill.) in the sterilized soil', *Karnataka Journal of Agricultural Sciences,* 24(2).

Jackson, M. L. (2005) *Soil chemical analysis: advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility, and soil genesis.* UW-Madison Libraries parallel press.

Jaramillo, I. E., Cocco, C., Kang, J. J., Cheng, C.-L. and Pereira, E. (2025) 'Turning waste into fertilizer: Aloe vera leaf shavings improve plant growth and support soil fertility in organic systems', *Soil Systems,* 9(4), pp. 113.

Karmacharya, J., Shrestha, P., Karki, T. B. and Pant, O. P. (2024) 'Isolation and Identification of Yeasts in Marcha, a Rice Wine Starter Culture From Nepal', *International Journal of Food Science,* 2024(1), pp. 4188578.

Kaushal, N. (2025) 'The analytical perspective of ancient Indian approaches towards global health and sustainable development', *The Intersection of Global Health and Sustainable Development*: Edward Elgar Publishing, pp. 78-92.

Khan, A. A., Jilani, G., Akhtar, M. S., Naqvi, S. M. S. and Rasheed, M. (2009) 'Phosphorus solubilizing bacteria: occurrence, mechanisms and their role in crop production', *J. agric. biol. sci,* 1(1), pp. 48-58.

Khanna, S., Bajracharya, R. and Rinu Karmacharya, R. K. (2018) 'Effect of cattle urine on tomato crop'.

Khanna, S. A., Lamichhane, J., Kumar, P., Naresh, R., Kumar, V., Banmala, A. and Ahirwar, A. D. G. (2025) 'Panchagavya: Our ancestral magic potion: An input to organic farming', *International Journal of Advanced Biochemistry Research,* 9(4), pp. 436-448.

Knapp, S. (2005) *The Heart of Hinduism: The Eastern Path to Freedom, Empowerment, and Illumination.* iUniverse.

Kumar, V., Priya, A., Das, S. and Rahman, F. H. (2025) 'The effects of different natural formulations on yield and the quality of horticultural crops: a review', *Discover Agriculture,* 3(1), pp. 1-12.

Marschner, B., Brodowski, S., Dreves, A., Gleixner, G., Gude, A., Grootes, P. M., Hamer, U., Heim, A., Jandl, G. and Ji, R. (2008) 'How relevant is recalcitrance for the stabilization of organic matter in soils?', *Journal of plant nutrition and soil science,* 171(1), pp. 91-110.

Miller, J. J. and Curtin, D. (2006) 'Electrical conductivity and soluble ions', *Soil sampling and methods of analysis,* 2.

Naik, M., CK, S., Rawson, A. and N, V. (2022) 'Tender coconut water: A review on recent advances in processing and preservation', *Food Reviews International,* 38(6), pp. 1215-1236.

Natarajan, K. (2002) 'Other Indian Press; Mapusa, Goa, India: 2002', *Panchagavya–a manual*, pp. 333.

Nelson, D. W. and Sommers, L. E. (1996) 'Total carbon, organic carbon, and organic matter', *Methods of soil analysis: Part 3 Chemical methods,* 5, pp. 961-1010.

Novia, D., Sandra, A., Vebriyanti, E., Putra, A. A. and Rakhmadi, A. 'Comparative study of Indigenous microorganisms (IMO) from various livestock manures in fresh cow manure-based organic fertilizer production'. *IOP Conference Series: Earth and Environmental Science*: IOP Publishing, 012026.

Nursten, H. E. (2005) *The Maillard reaction: chemistry, biochemistry, and implications.* Royal Society of Chemistry.

Perumal, K., Praveena, K., Stalin, V. and Janarthanam, B. (2006) 'Assessment of selected organic manures as plant growth hormones and their impact on the growth attributes of Alium cepa L', *Current Science,* 8, pp. 46-51.

Author (2023) *A language and environment for statistical computing*. Available at: http://www.R-project.org/.

Rawal, J. S., Joshi, G. R., Gurung, L. and Rc, P. (2024) 'Application Of Panchagavya In Agriculture: Practices And Benefits', *INWASCON Technology Magazine (i-TECH MAG),* 6(1), pp. 57-62.

Selvaraj, A. and Rana, M. (2025) 'Role of Panchagavya on Growth and Health of Vegetable Crops', *Organic Production of Vegetable Crops*: Apple Academic Press, pp. 187-213.

Selvaraj, N., Anitha, B., Anusha, B. and Guru Saraswathi, M. (2007) 'Organic horticulture', *Horticultural Research Station, Tamil Nadu Agricultural University, Udhagamandalam,* 643(001).

Sharma, B., Nath, N., Ghosh, S., Rahaman, L. and Kaipeng, D. L. (2019) 'An overview of traditional rice beer of North-east India: ethnic preparation, challenges and prospects', *Indian Journal of Traditional Knowledge (IJTK),* 18(4), pp. 744-757.

Shiva, V. (1991) *The violence of the green revolution: Third world agriculture, ecology and politics.* Zed Books.

Somasundaram, E. and Amanullah, M. (2007) 'Panchagavya on growth and productivity of crops: A review', *Green Farming,* 1, pp. 22-26.

Srinivasan, R. and Aithal, P. (2025) 'Organic Alchemy: Panchagavya's Role in Green Agriculture Transformation', *Poornaprajna International Journal of Basic & Applied Sciences (PIJBAS),* 2(1), pp. 1-23.

Subhashini, D. (2013) 'Isolation of rhizospheric bacteria and their effect on germination of tobacco seed and growth of seedlings'.

Subhashini, D. (2016) 'Effect of NPK fertilizers and co-inoculation with phosphate-solubilizing arbuscular mycorrhizal fungus and potassium-mobilizing bacteria on growth, yield, nutrient acquisition, and quality of tobacco (Nicotiana tabacum L.)', *Communications in Soil Science and Plant Analysis,* 47(3), pp. 328-337.

Tariq, M., Wang, J., Sehar, S., Bhatti, Z. A., Malik, A. J., Zeb, B. S., Shaheen, S. and Mahmood, Q. (2023) 'Organics and Nutrient Transformation in a Microbial Fuel Cell Influenced by Antibiotics', *CLEAN–Soil, Air, Water,* 51(6), pp. 2200299.

Varsha, M. and Thamaraiselvi, B. 'Reinvigorating Panchagavya Formulation: Unshackling the Microbiota for Gamma-Aminobutyric Acid Biosynthesis to Develop Novel Treatments for Depressive Disorders'.

Varsha, M. and Thamaraiselvi, B. (2025) 'Reinvigorating Panchagavya Formulation: Unshackling the Microbiota for Gamma-Aminobutyric Acid Biosynthesis to Develop Novel Treatments for Depressive Disorders', *International Research Journal of Pharmacy and Medical Sciences,* 8(2), pp. 79-87.

Waksman, S. A. (1922) 'A method for counting the number of fungi in the soil', *Journal of bacteriology,* 7(3), pp. 339-341.

Wangchu, L., Angami, T., Jini, D., Bam, J., Singh, R., Tasung, A. and Suryawanshi, A. (2024) 'Natural Farming: Scope and Prospective in Arunachal Pradesh', *ICAR (Research Complex) for NEH Region, Umiam-793103, Meghalaya*.

Zhang, Y., Pan, B., Lam, S. K., Bai, E., Hou, P. and Chen, D. (2021) 'Predicting the ratio of nitrification to immobilization to reflect the potential risk of nitrogen loss worldwide', *Environmental science & technology,* 55(11), pp. 7721-7730.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Identification and Nutritional Evaluation of Native Forage Species for Establishing Field Gene Bank at Jiri, Dolakha, District

Sujaya UPRETI[1*], Suraj GURUNG[2], Bikash BHUSAL[3], Chaya KHANAL[4], Ram Prasad GHIMIRE[1], Bal Krishna JOSHI[3] and Sulochana SHRESTHA[2]

[1]National Pasture and Fodder Research Program, NARC, Khumaltar, Lalitpur
[2]Department of Livestock Services, Nepal, Harihar Bhawan, Lalitpur
[3]National Agriculture Genetic Resources Center (Gene bank), NARC, Khumaltar, Lalitpur
[4] National Animal Feed and Livestock Quality Management Laboratory, Lalitpur
*Email: sujayaupreti824@gmail.com

ABSTRACT

Native forage grows naturally on bunds, marginal lands, forestland, swampy land, terrace riser, barren lands and cultivated lands are resilience to environmental stresses such as drought, floods and diseases and are palatable and nutritious to different types of animals. This study was conducted at the Cattle Genetic Resource Center (CGRC) in Jiri, Dolakha, to identify and evaluate native forage species for ex-situ and on-farm conservation, by establishing field gene bank, and potential registration of land races. The study was done by using key informant interview, focus group discussions (FGDs), and field surveys. Quadrat sampling was used to assess the preliminary status of production potential of native forage species. Laboratory analysis was conducted to determine their nutrient composition. Based on information obtained from the KIIs and FGD, 14 native forage species such as Furke (*Arundinella nepalensis* Trin.), Kharuki (*Capillipedium assimile*), Jere Banso (*Setaria pumila*), Kurkurae (*Equisetum ramosissimum*), Amrisho (*Thysanolaena latifolia*), Halhale (*Rumex nepalensis* Spreng), Sama (*Echinochloa colona*), Chatre (*Cyperus compressus*), Siru (*Imperata cylindrica*), Narkat (*Phragmites australis*), Majito (*Rubia manjith)*, Dubo (*Cynodon dactylon*), Kash (*Saccharum spontaneum)* and Ghogae (*Sporbolus fertilis*) were documented. Among these, Furke, Kharuki, Jere Banso and Amrisho were identified as the most promising species for the local agroclimatic conditions. The forage yield of native forage species ranged from 1.54 to 8.48 t/ha, crude protein content ranged from 6.56 to 9.64 percent and energy content ranged from 3871.22 to 4028.32 kcal/kg. The greater number of

native forages should be identified along with the production potential and nutritive value.

Key words: Nutrient composition, forage yield, production potential, passport

INTRODUCTION

Nepal is rich in biodiversity and ranks the 49th in the world for biodiversity. Among 24,300 total species in the country, 28% are agricultural genetic resources (AGRs), termed as agrobiodiversity which includes 510 both native and cultivated forage species. Despite this richness, agrobiodiversity loss is substantial, estimated at around 40% nationally, with farmers in some regions reporting the complete loss of certain species. Although agrobiodiversity conservation efforts began in Nepal in 1986, systematic conservation through ex-situ, on-farm, in-situ and breeding strategies has been implemented since 2010 under the National Agriculture Genetic Resources Center (National Gene bank). Native forage species are better adapted to their natural environments, which are resilience to environmental stresses such as drought, floods and diseases and are palatable and nutritious to different types of animals. Winter season is the lean period for forage production in mid hills and animals supply their nutrient requirements from the locally available grasses. More numbers of native forage species are unidentified and identified native forage species (NFS), productivity potential and nutritive value are also not known till date. It is essential to have knowledge regarding their morphological traits, production potential, nutrient composition, and variability due to change in sites and season so that their efficient utilization could be achieved.

MATERIALS AND METHODS

This study was conducted at the Cattle Genetic Resource Center in Jiri, Dolakha, to identify and evaluate native forage species for in-situ conservation, the establishment of a field gene bank and potential registration. The study was done by using key informant interview (KIIs) including 3 participants (senior farmers), focus group discussion (FGD) including 12 participants (senior farmers, livestock technicians), and field surveys. The quadrat sampling was used to assess the preliminary status of production potential of native forage species, and laboratory analysis was conducted to determine their nutrient composition. For botanical identification herbarium was sent to National Herbarium and Plant Laboratories,

Godawari. Identified native forage species were permanently labeled and



protected from livestock grazing and are conserved in Cattle Genetic Resource Centre, Jiri, Forage Field Gene bank. Orthodox seeds along with passport will be collected and send to Nepal Genebank for long term conservation.

Figure 1. In-situ conservation of native forage species at CGRC, Jiri, Dolakh

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu



Figure 2. Herbarium collection of NFS for botanical identification

RESULTS AND DISCUSSION

Production potential and nutrient content of native forage species

Based on information obtained from the KIIs and FGD, 14 native forage species (NFS) were documented, including Furke (*Arundinella nepalensis* Trin.), Kharuki (*Capillipedium assimile*), Jere Banso (*Setaria pumila*), Kurkurae (*Equisetum ramosissimum*), Amrisho (*Thysanolaena latifolia*), Halhale (*Rumex nepalensis Spreng*), Sama (*Echinochloa colona*), Chatre (*Cyperus compressus*), Siru (*Imperata cylindrica*), Narkat (*Phragmites australis*), Majito (*Rubia manjith)*, Dubo (*Cynodon dactylon*), Kash (*Saccharum spontaneum)* and Ghogae (*Sporbolus fertilis*). Among these, Furke, Kharuki, Jere Banso and Amrisho were identified as the most promising species for the local agroclimatic conditions. The forage yield of native forage species ranged from 1.54 to 8.48 t/ha (Fig.3), crude

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

protein content ranged from 6.56 to 9.64 and energy content ranged from 3871.22 to 4028.32 kcal/kg (Figure 4).

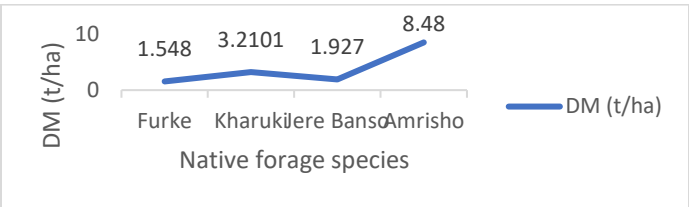


Figure 3. Production potential of four NFS

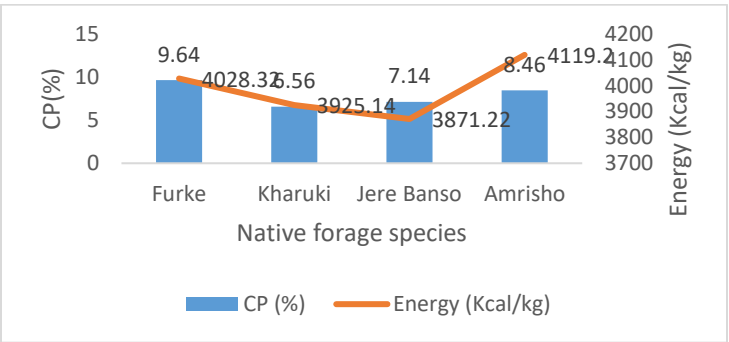


Figure 4. Nutrient composition of four NFS

Availability of NFS in mid hills of Nepal

The most of the native forage species available in the month of May to December and few are available year-round. Besides, most of the native forage species flowering at the time of July to September (Table 1).

The production and nutritional evaluation of native forage species in research sites revealed that native forage species possess significant potential for improving livestock feeding systems in the mid-hill region of Nepal. The dry matter content of Furke was 1.54t/ha which was lowered than the 1.90 t/ha as reported by (KC,2010) while CP was higher 9.64% than the 6.65% as reported by (KC,20101). The crude protein and energy content of the study native forage species, ensures their importance in improving dietary protein and energy availability for ruminants. Establishment of a field gene bank using selected native forage species provides an opportunity for conserving the germplasms hile allowing continuous evaluation and utilization under natural field conditions.

Table 1. Period of native forage species (NFS) availability in mid hills of Nepal

SN	NFS	Botanical name	Flowering months	Available months
1	Furke	*Arundinella nepalensis*	Sept-Oct	June-Dec
2	Kharuki	*Capillipedium assimile*	Aug-Oct	May-Dec
3	Jere Banso	*Setaria pumila*	July-Sept	June-Oct
4	Kurkurae	*Equisetum ramosissimum*	Mar-May	Year round
5	Amrisho	*Thysanolaena latifolia*	Jan-Mar	Year round
6	Halhale	*Rumex nepalensis*	Apr-June	Feb-Sept
7	Sama	*Echinochloa colona*	July-Sept	June-Oct
8	Chatre	*Cyperus compressus*	July-Sept	June-Nov
9	Siru	*Imperata cylindrica*	Mar-May	Year round
10	Narkat	*Phragmites australis*	Aug-Oct	Year round
11	Majito	*Rubia manjith*	June-Aug	May-Nov
12	Dubo	*Cynodon dactylon*	July-Sept	Year round
13	Kash	*Saccharum spontaneum*	Aug-Oct	May-Dec
14	Ghogae	*Sporbolus fertilis*	July-Sept	June-Nov

CONCLUSION

The effective management of native forage species ensures climate resilience, biodiversity conservation and sustainable low-cost livestock feeding and ensuring long-term livestock productivity under changing global climates. Thus, characterization and conservation of native forage species should be performed.

ACKNOWLEDGEMENT

The authors are thankful to the Department of Livestock Services, Nepal, Harihar Bhawan, Lalitpur for providing financial support to conduct the study. The authors are also very grateful to Cattle Genetic Resource Centre, Jiri for providing experimental plots and managerial supports throughout the study period.

REFERENCES

Annual Report (2071/72). Pasture and Fodder Division, NARC

Annual Report (2072/73). Pasture and Fodder Division, NARC

Joshi, B.K. *et al*., (2022). The Checklist of Agricultural Genetic Resources Nepal.

KC, P. *et al*., (2007). Preliminary evaluation of promising native forage species in Dhading and Kavre districts. Proceedings of the 7th National Workshop on Livestock and Fisheries Research.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

The Effect of Non-Genetic Factors on The Success of Artificial Insemination of Goats in Nepal

Dipak Adhikari*[1], Saroj Sapkota[1], Buddhi Ram Acharya[2], Purna Bahadur Shrestha[2], Nabaraj Poudel[3] and Nirajan Bhattarai[4]

*[1]National Animal Breeding and Genetics Research Center, Lalitpur, Nepal
[2]National Goat Research Program, Bandipur, Tanahun, Nepal.
[3]National Animal Science Research Institute, Khumaltar, Lalitpur. Nepal.
[4]Agriculture and Forestry University, Rampur, Chitwan, Nepal.
Corresponding Author's email: dipsagar95@gmail.com,

ABSTRACT

The detailed study on the success of artificial insemination in goats has not been done so far in Nepal. Hence, an experiment was carried out to reveal the effect of non-genetic factors on the success of artificial insemination in goats in Tanahun, Chitwan and Surkhet districts of Nepal from August 2018 to July 2022. Altogether 1023 Khari goats were inseminated with the frozen semen of Boer goats, which was imported from Australia. The effect of season, time of insemination, type of heat, number of inseminations, and parity of dam on artificial insemination was recorded and data were analyzed using IBM SPSS 26. The result showed that season, time of insemination, type of heat and number of inseminations significantly affect the success of artificial insemination in goats. In the case of the summer season, the success rate of A.I. was 75.65% whereas 44.12% in winter. Similarly, the highest rate (74.36%) was found after 18 hours of unset of heat and only 9.86% in the case of <=9 hours. Likewise, higher success (68.09%) was observed in natural heat than in induced heat (55.83%). Double insemination increased (69.70%) the rate of success of A.I., than to single insemination (51.80%) in both types of heat. Not only season, time and doses, but parity of dams also affects the success rate of artificial insemination in goats significantly. The highest success was found in the second to fifth parity of the dam, and the lowest in the first parity doe.

Keywords: Boer goat, dam, induced heat, Khari goat, time of insemination

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

INTRODUCTION

Livestock is an integral part of Nepalese agriculture where 65% population are engaged in this sector which contributes 24.09% of the total national gross domestic product (GDP) and among this sector, livestock covers 24.01 percent (MoALD, 2024). Among livestock species goat farming is an emerging and important enterprise that is used mainly for meat production. There are 15.29 million goats in Nepal which produce 86,280 MT of meat and accounting for 19.27% of the total meat production of the nation (MoALD, 2024). This production does not meet the increasing demand of goat meat, so live castrated bucks are imported from outside the country, especially from India and China.

The productivity of goats do not increase because the indigenous breeds have low producing ability as compared to the exotic breeds. From few years ago, cross breeding of Khari with pure Boer was done in Nepal. The Boer goat has faster growth rates and is heavier than the Nepalese local goat breeds. The mature Boer buck weight in the range of 110-135 kg, and the doe weight around 90-100 kg (RADA, 2010), whereas the adult body weight of the Khari goat was around 20-40 kg (Joshi and Shrestha, 2003). The daily live weight gain of the Boer goat crossbreds has been found between 100 to 200 gm in the farmers' field (Pandey, 2008). Similarly, Boer goat and its crosses have 1.63 to 2.2 litter size, whereas the indigenous breed and their crossbreds have only 1.0 to 1.8. Likewise, the Boer goat possesses strong disease resistance, adapts to adverse climatic conditions and has superior mothering capacity (Pandey, 2008).

The average one-year weight of Khari is 26.24±0.62 kg, whereas 50% Boer crossbreed reaches 40.03±0.86 kg (NGRP, 2021). This result means that the 50% Boer crossbreed produces at least 50% more meat than the Khari goat breeds. That is why, if Boer bucks can be used across all Nepalese local goat breeds, the national meat production would be increased by 50 percent. But there is scarcity of breeding stock of pure Boer buck and farmers use buck which is produced in their own farm for breeding that is why inbreeding problem occurs in most of the area. So artificial insemination is necessary to overcome this problem in goats. Nowadays, government as well as private farms have started artificial insemination in goats. But a detailed study on the success of artificial insemination in goats has not been done so far in Nepal. Hence, this experiment was carried out to determine the effect of non-genetic factor in the success of artificial insemination in goats in Nepal.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

MATERIALS AND METHODS

Duration and site of study

The study was conducted from August 2018 to July 2022 at the National Goat Research Program (NGRP), Bandipur, Tanahun and its command area. Additionally, the study included locations in Chitwan and Surkhet districts.

Animal selection

Altogether 1023 Khari female goats were included in this experiment. Among them 339 females were used for the study of the effect of different timing on the success of A.I. in goats, 149 for seasonal effect, 304 for types of heat (natural and induced) and number of inseminations, and 231 for the effect of parity of dam. In case of induced heat, the following protocol was used. The CIDR, which was used in goat, contains 0.3g progesterone, which is administered on day zero and the intra-muscular application of PMSG with a 200 IU concentration was done. Then CIDR application and artificial insemination was done according to the following procedure.

0 day	15 days	17 days	19 days
CIDR application	PMSG insertion	CIDR withdraw	Artificial insemination

Data collection and analysis

The primary data of dam parity, season, time after onset of heat, types of heat, doses of semen, date of insemination, expected kidding date and detailed information of farmers were recorded. Heat detection was done after 21 days of insemination. Visual observation and abdominal palpation were done every month. Finally, recording the kidded does near the expected kidding date. After data entry and coding the analysis was done using the chi-square test through the Statistical Package for Social Science (SPSS) version 26, software.

RESULTS AND DISCUSSION

Time of onset of heat

The time of onset of heat in goats is an important factor for the success of artificial insemination which was categorized as ≤9 hours, 12, 15, 18, 21 and 24 hours. A total of 339 goats were inseminated within these different time durations. Among

them the success of artificial insemination was found higher when AI should perform 18 hours after onset of heat. This study revealed that this factor was influenced significantly ($P<0.001$) for the success of artificial insemination in goats. The time wise success rate of artificial insemination in goats is presented in Table 1.

Kifaro (2007) reported that the optimal timing of insemination is an important factor in the success of artificial insemination because does do not ovulate until late estrous or shortly after the end of standing heat. Therefore, recognizing the signs of standing heat is important. However, the optimal time of insemination is determined by observing changes in the cervical mucus. As the doe progresses through estrous, mucus turns from clear and thin at the beginning of standing heat to cloudy and stringy during mid to late heat. Insemination should be performed in does before or at the time when the mucus turns cloudy, which is usually 12 to 15 hours after the onset of estrous. If the doe continues to exhibit heat after insemination, she should be inseminated again after 12 hours, particularly if the program uses frozen semen or cooled semen. In dairy goats, does should be observed for heat using a teaser buck and inseminated accordingly. Similarly, Fonseca and Alvim (2018) revealed that the ideal time to perform AI should consider the estimated mean time between the last hormonal intervention and estrous onset and the time between the latter and ovulation, due to their high variation Besides, the type of mucus observed is also an index of the most appropriate moment (Fonseca et al., 2017b). One of the earliest ultrasound-assisted ovulation studies conducted every 4 hours identified that AI performed after ovulation resulted in a high pregnancy rate when early diagnosed (18 days of estrous cycle), but pregnancies could be lost in the following weeks (Fonseca et al., 2012).

The basic premise is to inseminate before ovulation and to give enough time for the sperm to be fully capacitated for fertilization at the most appropriate time for the female gamete. Likewise, Lehloenya et al. (2005) indicated that goats must be inseminated 12 hours after the onset of estrus and 5 to 10 hours before the expected ovulation. The highest success rate of artificial insemination after 18 hours of onset of heat which might be due to the more opening of cervix at that time and match the time of sperm and ova to reach in ampulla of oviduct where fertilization occurs.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Parity of the dam

Dam parity also influences the success of artificial insemination of goats. The vagina and cervix of median dams do not open as widely as other dams, so intrauterine AI is difficult in the first parity dams, and the success rate of AI was very low. The satisfactory result was found in the second to fifth parity and decreased from the sixth parity. The detailed effect of parity on the success rate of AI in goats is presented in Table 2. This study revealed that this factor significantly influenced ($P<0.001$) the success of artificial insemination in goats. breeding season, environmental conditions, parity, breed, farm, depth of semen deposition, extender composition and hormone treatment (Nunes & Salgueiro, 2011). Anel et al. (2005) revealed that the age of the ewe significantly influenced fertility and conception rate. The best fertility rates were recorded in ewes between 1.5 to 4.5 years old, and beyond this age, fertility declined remarkably. Fertility also decreased depending on the number of previous parturitions, and a high correlation found among the age and number of lambing ($r = 0.85$; $P < 0.001$). Several factors are reported to affect the success of AI, including nutrition,

Table 1. Effect of inseminated time after onset of heat on the success of artificial insemination in goats

Factors	No. of AI	Success rate (%)	χ^2 Value	P value
Overall	339	35.69	86.634	0.000
Time of onset of heat		***		
≤9 hours	71	9.86		
12 hours	47	19.15		
15 hours	52	42.31		
18 hours	78	74.36		
21 hours	49	38.78		
24 hours	42	14.29		

Note: ***: Significant at 0.1% level ($P<0.001$)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Table 2. Effect of parity of the dam on the success of artificial insemination in goats

Factors	**No. of AI**	**Success rate (%)**	χ^2 **Value**	**P value**
Overall	231	63.60%	31.547	0.000
Parity		***		
First	25	20.00%		
Second	33	72.73%		
Third	44	75.00%		
Fourth	40	75.00%		
Fifth	35	74.29%		
Sixth	32	59.38%		
Seventh	22	45.45%		
Note: ***: Significant at 0.1% level (P<0.001)				

Table 3. Effect of season on the success of artificial insemination in goats

Factors	**No. of AI**	**Success rate (%)**	χ^2 **Value**	**P value**
Overall	149	68.49%	12.085	0.001
Season		***		
Summer	115	75.65%		
Winter	34	44.12%		

Note: ***: Significant at 0.1% level (P<0.001)

Season of the year

The breeding season in goats varies throughout the year. During the winter months, only a small proportion of goats exhibit estrus, whereas nearly all does show heat during the summer. Cold weather may also lower the post-thaw temperature of semen, resulting in reduced semen quality. Consequently, the success rate of artificial insemination (AI) was markedly lower during the cold season and differed significantly ($P < 0.001$) from that observed in warmer

weather. The detailed seasonal effects on AI performance are presented in Table 3.

The reproduction of goats is affected by changes in day length over the year. Photoperiod affects the secretions of melatonin from the pineal gland, which influences gonadotropin-releasing hormone production (Fatet et al., 2011). Amoah & Gelaye (1997) reported that conception rates in goats range from 50% to 70%, and this depend on the season of insemination, and the fertility and significantly influenced by the AI season. The probability of pregnancy was reduced when insemination took place during the colder seasons (autumn and winter). In contrast, the fertility of Mediterranean breeds inseminated with cooled semen has been reported to be high throughout the year (Roca et al., 1997). Similarly, Anel et al. (2005) found significant differences in the success of AI with respect to season; higher success was obtained in the breeding season (September to January period), whereas lower in the non-breeding season, particularly in the July to August period. Likewise, Karatzas et al. (1997) indicated that lower pregnancy rates occur when AI is performed during the non-breeding and Arrebola et al. 2012 found that the success of AI in hot weather was 51%, whereas in the cold season it was only 44.00%. All these findings are similar to this result.

Types of the heat

The type of estrus, whether natural or induced, influenced the success of artificial insemination (AI) in goats. Pregnancy rates were significantly higher ($P < 0.05$) in relation to estrus type. The detailed effects of natural and induced estrus on AI success are presented in Table 4. Smith (2009) reported that the average heat lasts from 24 to 36 hours and the ovulation occurs near the end of estrus. It is essential that does be inseminated before ovulation so that sperm cells can undergo a process called capacitation. Agossou and Koluman (2018) revealed that the pregnancy rates for naturally mated, and artificially inseminated goats were 93 % and 70 % respectively. Anel et al. (2005) indicated that estrous synchronization with hormonal treatment could have a negative effect on fertility, and that fertility decreased with the number of previous inseminations. The 55.83% conception rate obtained in this experiment is close agreement with those obtained by Motlomelo et al. (2002) of the range 47 to 60 % following the use of medroxyprogesterone acetate (MAP) and fluorogestone acetate (FGA) sponges and controlled internal drug release (CIDR) devices for synchronizing estrus in

goats. Hafez & Hafez (2000) also found that lower pregnancy rates were reported when AI was performed in synchronized estrus goats than with natural estrus.

Table 4. Effect of types of heat on the success of artificial insemination

Note: *: Significant at 0.5% level (P<0.05)

Factors	**No. of AI**	**Success rate (%)**	χ^2 **Value**	**P value**
Overall	304	61.51	5.319	0.021
Types of heat		*		
Natural	141	68.09		
Induced	163	55.83		

Number of inseminations

The number of inseminations performed during both natural and induced estrus had a marked influence on the success of artificial insemination (AI) in goats. A statistically significant difference (P < 0.001) was observed in pregnancy rate according to the number of inseminations conducted. The detailed effects of insemination frequency on AI success are presented in Table 5. Yotov et al. (2016) reported that the pregnancy rate in goats inseminated once during natural estrus was 45.2%, while those inseminated once after estrus synchronization achieved 58.3%. When goats with synchronized estrus received double insemination, the pregnancy rate increased to 63.6%. In contrast, pregnancy rates in goats bred during natural estrus generally ranged from 40–50%. Our results were consistent with these findings.

Table 5: Effect of number of inseminations on the success of AI in goats

Factors	**No. of AI**	**Success rate**	χ^2 **Value**	**P value**
Overall	304	61.51%	16.798	0.001
Types of heat		***		
Single insemination	139	51.80%		
Double insemination	165	69.70%		

Note: ***: Significant at 0.1% level (P<0.001)

CONCLUSION

This experiment showed that the success rate of artificial insemination (AI) in goats was highest when insemination was performed 18 hours after the onset of natural estrus. The conception rate was also greater when AI was carried out during the normal breeding season in the does of second to sixth parity. In addition, double insemination at 12-hour intervals produced the most satisfactory results. For optimal AI performance, several management practices are essential. These include using well-trained inseminators, ensuring high-quality frozen semen, checking semen quality prior to use, accurately detecting the onset of estrus, and observing the color and characteristics of the cervix, vaginal mucosa, and mucus. Proper semen handling including thawing at 37 °C for 30 seconds as well as good feeding and housing management, and keeping inseminated does away from bucks, are also important factors for improving conception rates.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Nepal Agricultural Research Council (NARC) for providing research funding. They sincerely thank Dr. Doj Raj Khanal, Livestock and Fishery Director, NARC, Singhadarbar Plaza, Kathmandu, Nepal, for his invaluable guidance, encouragement, and support throughout the study. Special appreciation is extended to Mr. Ram Kumar Sahi, Mr. Ghana Shyam Panta, and Mr. Arjun Khanal, whose assistance was essential for the successful completion of this research. The authors also thank Mr. Sagar Paudel, Chief of the National Animal Breeding and Genetics Research Center, Khumaltar, Lalitpur, for his insightful suggestions and support. Finally, heartfelt thanks are extended to all staff of the National Goat Research Program, Bandipur, Tanahun, and the National Animal Breeding and Genetics Research Center, Khumaltar, Lalitpur, for their cooperation and assistance.

AUTHORS' CONTRIBUTIONS

Dipak Adhikari – Overall management of this experiment, AI done, Data management, data analysis, paper writing.
Saroj Sapkota – Data management and paper writing
Buddhi Ram Acharya – Assisted in artificial insemination of goat and record keeping

Purna Bahadur Shrestha - Artificial insemination of goat, record keeping and computer entry
Nabaraj Poudel - Data management and data analysis
Nirajan Bhattarai - Guidance of paper writing

REFERENCES

Agossou, D. J., & Koluman, N. (2018). The effects of natural mating and artificial insemination using cryopreserved buck semen on reproductive performance in Alpine goats. *Archives of Animal Breeding, 61*(4), 459–461. https://doi.org/10.5194/aab-61-459-2018

Amoah, E. A., & Gelaye, S. (1997). Biotechnological advances in goat reproduction. *Journal of Animal Science, 75*(3), 578–585. https://doi.org/10.2527/1997.753578x

Anel, L., Kaabia, M., Abrouga, B., Alvarez, M., Anel, E., Boixo, J. C., Fuente, L. F., & Paz, P. (2005). Factors influencing the success of vaginal and laparoscopic artificial insemination in Churra ewes: A field assay. *Theriogenology, 63*(5), 1235–1247. https://doi.org/10.1016/j.theriogenology.2004.06.012

Arrebola, F. A., Pardo, B., Sanchez, M., Lopez, M. D., & Perez-Marin, C. C. (2012). Factors influencing the success of an artificial insemination program in Florida goats. *Spanish Journal of Agricultural Research, 10*(2), 338–344. https://doi.org/10.5424/sjar/2012102-1583

Fatet, A., Pellicer-Rubio, M. T., & Leboeuf, B. (2011). Reproductive cycle of goats. *Animal Reproduction Science, 124*(3–4), 211–219. https://doi.org/10.1016/j.anireprosci.2011.01.022

Fonseca, J. F., & Alvim, G. P. (2018). *Recomendações técnicas para execução da inseminação artificial transcervical em caprinos no Brasil* (Circular Técnica 46). Embrapa Caprinos e Ovinos. Circular Técnica 46.

Fonseca, J. F., Souza-Fabjan, J. M. G., Oliveira, M. E. F., Cruz, R. C., Esteves, L. V., Brandao, F. Z., & Mancio, A. B. (2017b). Evaluation of cervical mucus and reproductive efficiency of seasonally anovular dairy goats after short-term progestagen-based estrous induction protocols with different gonadotropins. *Reproductive Biology, 17*(4), 363–369. https://doi.org/10.1016/j.repbio.2017.07.005

Greyling, J. P. C., Kotze, W. F., Taylor, G. J., & Hagendijk, W. J. (1994). Synchronization of oestrus in sheep: Use of different doses of progestogen outside the normal breeding season. *South African Journal of Animal Science, 24*(1), 33–37.

Hafez, E. S. E., & Hafez, B. (2000). Transport and survival of gametes. In *Reproduction in farm animals* (pp. 82–95). Lippincott, Williams & Wilkins, Baltimore, MD, USA.

Joshi, B. R., & Shrestha, B. S. (2003). *The goats: Their production and health management* (pp. 11–18). Kathmandu.

Karatzas, G., Karagiannidis, A., Varsakeli, S., & Brikas, P. (1997). Fertility of fresh and frozen-thawed goat semen during the nonbreeding season. *Theriogenology, 48*(7), 1049–1059. https://doi.org/10.1016/S0093-691X(97)00235-7

Kifaro, G. C., Eik, L. O., Mtenga, L. A., Mushi, D. E., Kassuku, A. A., Kimbiti, E. N., Muhikambele, E., & Ulvund, M. J. (2007). The potential use of artificial insemination in sustainable breeding of dairy goats in developing countries: A case study of Norwegian dairy goats in Tanzania. *Tanzania Journal of Agricultural Sciences, 8*(1), 19–24.

Lehloenya, K. C., Greyling, J. P. C., & Schwalbach, L. M. J. (2005). Reproductive performance of South African indigenous goats following oestrous synchronization and AI. *Small Ruminant Research, 57*(2), 115–120. https://doi.org/10.1016/j.smallrumres.2004.05.004

Ministry of Agricultural and Livestock Development (MoALD). (2024). *Statistical information on Nepalese agriculture, 2023/24*. Ministry of Agricultural Development, Government of Nepal.

Motlomelo, K. C., Greyling, J. P. C., & Schwalbach, L. M. J. (2002). Synchronization of oestrus in goats: The use of different progestogen treatments. *Small Ruminant Research, 45*(1), 45–49. https://doi.org/10.1016/S0921-4488(02)00104-5

National Goat Research Program. (2021). *Annual report of the National Goat Research Program*. Nepal Agricultural Research Council, Bandipur, Tanahun, Nepal.

Nunes, J. F., & Salgueiro, C. C. M. (2011). Strategies to improve the reproductive efficiency of goats in Brazil. *Small Ruminant Research, 98*(1–3), 176–184. https://doi.org/10.1016/j.smallrumres.2011.03.029

Pandey, S. B. (2008). *Boer goat (Capra hircus): An alternative breed to increase meat production in Nepal-A review*. Paper presented at the 3rd National Convention of the Society of Agricultural Scientists, August 27–29, Khumaltar, Lalitpur, Nepal.

Rural Agricultural Development Authority. (2010). *RADA-A global approach to food security through evolving technology*. Retrieved September 23, 2012, from http://www.rada.gov.jm/goat_article.php?ai=159

Roca, J., Carrizosa, J. A., Campos, I., Lafuente, A., Vázquez, J. M., & Martínez, E. (1997). Viability and fertility of unwashed Murciano-Granadina goat spermatozoa diluted in Tris–egg yolk extender and stored at 5 °C. *Small Ruminant Research, 25*(2), 147–153. https://doi.org/10.1016/S0921-4488(96)00978-9

Smith, J. F. (2009). *Artificial insemination of dairy goats*. Cooperative Extension Service, College of Agricultural, Consumer and Environmental Sciences, New Mexico State University.

Yotov, S. A., Velislavova, D. V., & Dimova, L. R. (2016). *Pregnancy rate in Bulgarian White milk goats with natural and synchronized estrus after artificial insemination by frozen semen during breeding season*. *Asian Pacific Journal of Reproduction, 5*(2), 144–147. https://doi.org/10.1016/j.apjr.2016.01.011

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Effect of Integrated Nutrient Management on LAI and Yield Formation of Cauliflower in Bhaktapur

Pushpa GOIT, and Binayak P. RAJBHANDARI
HICAST, Purbanchal University, Kathmandu, Nepal
Corresponding Author's email: binayakprajbhandari@gmail.com

ABSTRACT

This study was conducted to assess the effect of different combinations of NPK fertilizer and organic manure on the growth and yield of cauliflower (Brassica oleracea var. botrytis). The main objective of the study was to identify the most suitable combination of integrated nutrients for improving cauliflower growth, yield attributes, and yield under local field conditions. The experiment was carried out on a field at Bhaktapur from 8 Jan to 24 April 2026 using the cauliflower variety **Snow Mystique**. The experiment was laid out in RCBD with four treatments and five replications. The treatments included T1 (0 nutrients added), T2, T3 and T4 with equal amount of OM @ kg/ha but different N:PK: amounts (N: . FYM was applied uniformly to all plots. Data were collected on plant height, number of leaves, leaf area index, curd weight, curd diameter, biomass, number of curds per plot, and yield per plot. The collected data were analysed using Analysis of Variance (ANOVA). The results showed that T3 produced the best performance in yield parameters and recorded the highest curd weight of 896.0 g, curd diameter of 13.88 cm, biomass of 1755.6 g, and yield of 17.47 kg per plot. Although T4 showed higher vegetative growth in some stages, it produced lower yield than T3, indicating that excessive fertilizer application was not beneficial. Therefore, the recommended NPK dose of 200-120-100 kg ha^{-1} with organic manure is concluded to be the most suitable combination for cauliflower production in Chittapol, Bhaktapur.

Keywords: Biomass, curd, LAI, plant height, Snow Mystique

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of the most important vegetable crops grown in Nepal and many other parts of the world. It belongs to the family Brassicaceae, which also includes cabbage, broccoli, mustard, radish, and other important vegetables. Cauliflower is mainly grown for its edible white

curd, which is used as a vegetable in daily meals. It is popular among consumers because of its good taste, soft texture, nutritional value, and wide use in different food preparations. Cauliflower is not only important as food but also as a source of income for farmers. In Nepal, many small and medium farmers grow cauliflower commercially because it gives better economic return compared to some traditional cereal crops. In peri-urban areas near large cities, such as Kathmandu Valley, cauliflower farming is especially important because farmers can easily sell their produce in nearby markets. Fresh cauliflower has regular demand in markets, hotels, restaurants, and households. Therefore, cauliflower cultivation plays an important role in improving farmers' income, employment opportunities, and livelihood.

Although NPK fertilizers are important for increasing cauliflower yield, their improper use can create problems. Many farmers apply fertilizers without testing soil or following scientific recommendations. Some farmers use too much urea because they believe that more fertilizer always gives more yield. However, excessive use of chemical fertilizers can damage soil health, increase production cost, reduce fertilizer efficiency, and cause environmental pollution. It may also disturb the balance of soil nutrients. On the other hand, using too little fertilizer cannot fulfil crop nutrient requirements and results in poor growth and low yield. Therefore, the main challenge is to find the right combination of fertilizer that gives better growth, higher yield, and good economic return without harming soil health. Organic manure is also very important in cauliflower production. Organic manure includes farmyard manure, compost, animal manure, and other decomposed organic materials. It improves soil structure, water-holding capacity, aeration, microbial activity, and nutrient availability. Unlike chemical fertilizers, organic manure releases nutrients slowly and improves the long-term fertility of the soil. It also helps to increase organic matter content in the soil. Soil organic matter is very important because it improves soil quality and supports sustainable crop production. In areas where farmers grow vegetables continuously, the use of organic manure is necessary to maintain soil fertility. The combined use of NPK fertilizers and organic manure is often better than using chemical fertilizer or organic manure alone. Chemical fertilizers provide nutrients quickly to meet the immediate need of the crop, while organic manure improves soil health and provides nutrients slowly over time. This combined approach is known as integrated nutrient management (INM). It helps to increase nutrient use efficiency, improve soil fertility, reduce dependence on chemical fertilizers, and support sustainable agriculture. For a crop like cauliflower, which needs high nutrients, integrated use of NPK and organic manure can be very useful. It can

improve plant growth, curd size, curd weight, and total yield.

Chittapol, Bhaktapur, is a suitable area for vegetable cultivation. Farmers in this area grow different vegetables both for household consumption and commercial purposes. Cauliflower is one of the important vegetables grown in this region because of its good market value. The use of organic manure in Chittapol is common because many farmers have access to animal manure and compost materials. However, the nutrient content of organic manure is often low and variable. Therefore, a balanced combination of NPK fertilizer and organic manure can be a practical solution for farmers higher yield and income.

Another important issue is sustainability. Modern agriculture should focus not only on increasing yield but also on protecting soil and environment. Excessive use of chemical fertilizers can lead to soil degradation, nutrient imbalance, water pollution, and reduced microbial activity. Organic manure can help reduce these problems by improving soil organic matter and biological activity. However, organic manure alone may not supply enough nutrients for high-yielding crops like cauliflower. Therefore, combining organic manure with NPK fertilizer is a balanced and sustainable approach. It can support both productivity and soil conservation. Several studies have shown that balanced use of NPK fertilizer and organic manure improves the growth and yield of cauliflower and other vegetable crops. Adhikari and Sharma (2019) reported that soil fertility management is one of the major factors affecting vegetable productivity in Nepal. Pant et al. (2018) also found that proper application of nitrogen, phosphorus, and potassium improves crop growth and yield when applied in balanced form. However, farmers need simple and practical recommendations that are suitable for their local conditions. Research conducted in the local area can provide more useful information for farmers than general recommendations. This study was conducted to identify the appropriate combination of plant nutrients for good growth and higher yield of cauliflower in Chittapol, Bhaktapur.

MATERIALS AND METHODSS

The study area

The experiment was conducted at Surya Binayak 10, Chittapol area of Bhaktapur. The experimental site lies at 27°39”11′N latitude and 85°28” 26 ′E longitude, at an altitude of approximately 1523 meters above sea level (mask). It is located approximately 12 to 15 kilometers east of Kathmandu city, in the eastern corner of the Kathmandu Valley. The area experiences a monsoon-influenced humid

subtropical climate, characterized by hot, wet summers and mild, dry winters. The soils at the experimental site are silty clay loam to loam in texture, well-drained, and moderately fertile.

Experimental materials

The cauliflower variety used was Snow Mystique, a well-known high-yielding and widely grown variety in the Bhaktapur district. Snow Mystique was therefore selected as a suitable variety for optimizing the integrated nutrients to harvest the highest possible yield.

Soil type of experimental field

The soil of the experimental field was tested before field lay out. The soil had pH of 5.0, with good drainage and aeration facilities. The soil test results, confirmed by the Soil and Fertilizer Testing Laboratory, Hetauda, Makawanpur (2082/09/08), The soil had the following properties: organic matter (OM) 2.96%, available nitrogen 0.15%, available phosphorus 96 kg/ha, and available potassium 390 kg/ha (SFTL, 2082/09/08). This indicates that the soil was moderately deficient in nitrogen and phosphorus, justifying the need for NPK fertilizer application.

Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments and five replications, giving a total of 20 experimental plots. The layout of the experiment was carried out to fit five blocks (replications) of four plots each in the field, as per the Randomized Complete Block Design (RCBD). The total experimental field measured 21.3 m × 7.8 m (166.14 sq. m.). Each individual plot measured 3.85 m × 1.6 m (6.16 sq. m.), with 45 cm spacing between plots within the same block and 45 cm buffer on each side. The row-to-row spacing within each plot was 60 cm, and the plant-to-plant spacing was 45 cm. Each plot contained 4 rows of 7 plants, giving 28 plants per plot. Five plants were selected from the inner rows as sample plants for observation.

The four treatments had different levels of the NPK + OM as shown in Table 1. In the experiment, various mixture of the Urea (46% N), Di-ammonium Phosphate (DAP, 18% N + 46% P_2O_5), Muriate of Potash (MOP, 60% K_2O) and well-decomposed farmyard manure (FYM) were used as sources of nutrients.

Table 2. Treatment and NPK doses used in the experiment.

Treatments	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	FYM (t/ha)
T1(control)	0	0	0	39.3
T2	150	90	75	39.3
T3	200	120	100	39.3
T4	250	150	125	39.3

Transplanting and harvesting

The cauliflower seedlings were transplanted on 8 Jan 2026, at a row-to-row spacing of 60 cm and plant-to-plant spacing of 45 cm, with one seedling per hill. Transplanting was done in the afternoon to reduce transplanting shock. Curd formation was observed at 80 DAT. The crop was harvested on 24th April 2026 (106 DAT) , when the curds reached marketable size and before they started to become loose or discolored.

Weeding and intercultural operations

In the experimental plots, weeding was done manually as per need after 30 DAT. The soil was also loosened to provide proper aeration, and earthing up was carried out at the time of second weeding operation. The second split dose of nitrogen (25% as top dressing) was also applied during earthing-up operation.

Irrigation

Irrigation was provided by the Ring shape / furrow method at regular intervals based on the moisture requirement of the crop and the prevailing weather conditions. During the early establishment phase after transplanting, irrigation was given every 3 days. During the active vegetative growth phase and curd development phase, the irrigation interval was adjusted to every 4 days. Irrigation was stopped one week before harvest to allow the soil to dry and to make harvesting easier.

Biometric parameters

* **Plant height (cm**): Measured from the base of the plant at ground level to the tip of the tallest leaf using a Scale/ measuring tape.
***Number of leaves per plant:** All fully expanded leaves per plant were counted and the average of five plants was recorded.

*** Leaf area index (LAI, cm²):** Calculated by multiplying the length and breadth of the largest leaf on each of five randomly selected plants per plot, and taking the average.

Yield parameters

At harvest, the following yield parameters were recorded:

- **Curd weight (g/ plot):** The fresh weight of the marketable curd from each plot was measured using an electronic balance.
- **Curd diameter (cm)**: Measured across the widest part of the curd using a Vernier caliper.
- **Biomass (g / plant):** Total above-ground biomass per plant was recorded.
- **Number of curds per plot:** All marketable curds from the net plot area were counted.
- **Yield per plot (kg):** Calculated as Yield/Plot (kg) = Curd Weight (g) × Number of Curds per Plot ÷ 1000.

Data collection, measurement and analysis

The growth parameters were recorded at 15, 30, 45, 60, and (DAT) from five randomly selected plants per plot. Yield and related data were measured during harvest. All data collected from the experiment were analysed using Analysis of Variance (ANOVA) for the Randomized Complete Block Design (RCBD), following the method described by Cochran and Cox (1963). The analysis was performed using Microsoft Excel (version 13). The significance of treatment differences was tested at the 5% level of probability. Treatment means were compared using the Critical Difference (CD) test at the 5% level. The Coefficient of Variation (CV%) was calculated to assess the reliability and precision of the experimental data.

RESULTS AND DISCUSSION

Leaf Area Index

Leaf area index (LAI) is used to measure the total leaf surface available for photosynthesis, which is the basis for yield formation. The data on LAI at different growth stages are presented in Table 2. The LAI increased continuously from 15 DAT to 75 DAT in all treatments revealing that cauliflower plants developed larger leaf area as the crop advanced towards curd formation and maturity. The

effect of all IPN levels on LAI was significant at 30 DAT and 75 DAT, while it was non-significant at other DAT (Table 2). The T4 recorded the highest LAI value of 78.08 cm², followed by T3 with 56.24 cm². The better performance of the crop in T4 may be due to higher nutrient availability, especially nitrogen, which promotes vegetative growth.

Table 2. Effect of IPN levels on LAI of cauliflower at different growth stages (DAT)

Treatments	15 DAT (cm²)	30 DAT (cm²)	45 DAT (cm²)	60 DAT (cm²)	75 DAT (cm²)
T1(control)	18.30	31.37b	59.08c	269.36a	484.16b
T2	21.08	29.24b	76.20a	235.48a	571.92ab
T3	17.39	56.24ab	117.04a	394.24a	625.24ab
T4	21.84	78.08a	198.40a	349.34a	710.28a
LSD (0.05)	—	36.12	134.22	226.90	137.95
Sem	—	5.86	21.78	36.81	22.38
F-probability	NS	*	NS	NS	*
CV%	19.78	53.80	86.44	52.76	16.74
Grand Mean	—	48.73	112.68	312.10	597.90

*Means in the same column followed by different letters are significantly different at 5% level. NS = Not Significant; * = Significant at 5% level (CD: 30 DAT = 36.12, 75 DAT = 137.95).*

At 45 DAT, the result was statistically non-significant, although clear numerical differences were observed among treatments. At 75 DAT, the LAI had significant difference among treatments at the 5% level. The T4 recorded the highest LAI of 710.28 cm², followed by T3 with 625.24 cm². The difference between T4 and T1 (control) was 226.12 cm², which was higher than the LSD value by 137.95. It should, however, be noted that T4 was statistically at par with T2 and T3 indicating that although T4 had the highest numerical value, its advantage over T2 and T3 was not statistically strong enough.

Higher leaf area alone may not always ensure higher curd yield, because excessive vegetative growth can sometimes reduce curd development if the plants do not receive optimum nutrients. The result suggests that nutrients combinations (NPK+OM) had a positive effect on LAI in cauliflower. The higher leaf area under T4 may therefore be due to the combined effect of optimum level of the

nutrients.

The coefficient of variation was highest at 45 DAT with 86.44%, followed by 30 DAT with 53.80% and at 60 DAT with 52.76%. The lowest CV was recorded at 75 DAT with 16.74%, showing more reliable and uniform data at the later stage. Since the treatment effect was significant at 75 DAT and the CV was comparatively low, the result at this stage can be considered more dependable.

Yield and yield attributes

Yield is a biological parameter resulted from the combined effect of environment, genetic factor (variety) and plant nutrients. Yield attributes are the most important parameters for evaluating the economic performance of any crop in a given environment.. The data on yield and yield attributes of cauliflower under four IPN levels are presented in Table 3.

Curd weight was significant different and varied largely among all treatments (F = 21.283, CD = 171.53). T3 recorded by far the highest mean curd weight of 896.0 g, followed by T4 (523.2 g). That difference showed that applying higher levels of IPNs did not improve and actually reduced curd weight. This finding agreed with those reported by Singh and Yadav (2019) and Adhikari and Sharma (2019).

.**Table 3. Effect of NPK levels on yield and yield attributes of cauliflower.**

Treatments	Curd Wt. (g)	Curd Dia. (cm)	Biomass (g / plant)	No. Curds/ Plot	Curd yield (kg / plot)	Curd yield (kg / ha)
T1(control)	284.4c	9.48c	945.6c	23.4a	6.66b	10811.71b
T2	465.6b	11.06b	1528.6ab	18.8b	8.76b	14220.81b
T3	896.0a	13.88a	1755.6a	19.4b	17.47a	28360.45a
T4	523.2b	11.22b	1101.0bc	20.4ab	10.58b	17175.36b
Grand Mean	**542.3**	**11.41**	**1332.7**	**20.5**	**10.87**	**17646.14**
CD (5%)	171.53**	0.986**	517.44*	NS	4.36**	**
CV (%)	22.95	6.27	28.17	12.18	29.13	-

*Means in the same column followed by different letters are significantly different at 5% level. ** = Highly significant at 1% level; * = Significant at 5% level; NS = Not Significant.*

Curd diameter showed the strongest treatment effect (F = 32.507, CD = 0.986). T3 recorded the largest curd (13.88 cm), followed by T4 (11.22 cm). The very low CV of 6.27% confirmed the reliability of this result. Biomass was significantly different (F = 4.973, CD = 517.44), with T3 having the highest one (1755.6 g / plant). This trait had directly positive relationship with the cord yield. The cord yield per plot and ha was significantly different among the treatments. The treatment T3 gave the highest cord yield of 17.47 kg/plot (28360.45 kg/ ha. These results were

consistent with the results of Thapa and Poudel (2017); Pant, Bhattarai and Regmi (2018); Bhattarai and Thapa (2020); and Rana and Subedi (2021).

CONCLUSION

This study clearly showed that the integrated nutrient management had a significant and positive effect on the growth, yield and yield attributes of cauliflower at Chittapol, Bhaktapur. Among the four tested integrated nutrient levels, the T3: 200-120-100 kg N-P_2O_5-K_2O / ha^{-} + (OM) 39.3 t/ha gave the best results for all important yield parameters, including curd weight, curd diameter, biomass per plant, and curd yield per plot and hectare. Therefore, this treatment was found to be most suitable for cauliflower production under the conditions of this study site.

SUGGESTIONS

- Farmers in Chittapol, Bhaktapur and similar agro-ecological zones of Nepal should apply integrated nutrients with NPK fertilizers (200-120-100 kg/ha) in co9mbination with organic manure (39.3) kg ha^{-1} for best cauliflower yield.

- Nitrogen should be applied in split doses (50% basal, 25% at 30 DAT, and the rest 25% at 45 DAT) to reduce nitrogen loss through leaching and volatilization and to improve nutrient use efficiency.

AUTHORS' CONTRIBUTIONS

Pushpa Goit: Literature review, field lay out and experimentation, data measurement, analysis and draft report writing,
Binayak P Rajbhandari: Overall supervision including technical and academic guidance in experimentation, data interpretation and report writing.

REFERENCES

Adhikari, R. C. and Sharma, B. P. (2019). 'Effect of NPK fertilizers on growth and yield of cauliflower (Brassica oleracea var. botrytis) in the mid-hills of Nepal'. *Nepal Journal of Agricultural Sciences, 16*(2), pp. 45–53.

Bhattarai, S. and Thapa, U. (2020). 'Influence of nitrogen levels on growth, yield and quality of cauliflower'. *Journal of Vegetable Science, 22*(1), pp. 12–19.

Cochran, W. G. and Cox, G. M. (1963). *Experimental Design.* Bombay: Asia Publishing House.

FAO (2022). *World Vegetable Production Statistics. Rome: Food and Agriculture Organization of the United Nations.* Available at: www.fao.org (Accessed: April 2026).

Gopal, R. (2019). 'Role of nitrogen in vegetative growth of cauliflower under field conditions'. *Indian Journal of Horticulture, 76(3), pp. 112–117.*

HICAST (2023). *Annual Research Report.* Bhaktapur: Himalayan College of Agricultural Sciences and Technology.

Kabir, M. S., Alam, M. J., Monira, S. and Islam, M. A. (2015). 'Effect of nitrogen and phosphorus on the growth and yield of cauliflower'. *Bangladesh Journal of Agricultural Research, 40*(2), pp. 235–241.

MoALD (2022). *Statistical Information on Nepalese Agriculture 2021/22.* Kathmandu: Ministry of Agriculture and Livestock Development.

Pant, A. P., Bhattarai, G. P. and Regmi, A. P. (2018). 'Effect of different doses of NPK on growth and yield of cauliflower cv. Kathmandu Local'. *Agronomy Journal of Nepal, 5*(1), pp. 78–85.

Rana, K. B. and Subedi, P. P. (2021). 'Nutrient management in Brassica vegetables: a review of research in Nepal'. *Nepal Agriculture Research Journal, 11*(1), pp. 34–42.

Sharma, M. D. and Gautam, D. M. (2020). *Vegetable Crops Production Technology.* Bhaktapur: HICAST Publication Division.

Singh, T. and Yadav, R. K. (2019). 'Effect of nitrogen, phosphorus and potassium on growth and yield of cauliflower'. *International Journal of Vegetable Science, 25*(4), pp. 368–377.

Thapa, U. and Paudel, K. P. (2017). *'Response of cauliflower (Brassica oleracea var. botrytis) to different levels of NPK fertilization'. Journal of Agriculture and Forestry University, 1*(1), pp. 105–112.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Graduate Employability and Curriculum Gaps: A 20-Year Tracer Study from a Nepalese Agriculture College

Bidur Prasad CHAULAGAIN[1]*and Dibya SHARMA[1]
[1] HICAST, P.U., Kathmandu, Nepal
***Corresponding Author's Email:** bidur@hicast.edu.np

ABSTRACT

Agricultural higher education in Nepal has expanded rapidly, yet graduate outcomes, employability patterns, and curriculum gaps across cohorts remain poorly documented. A cross-sectional tracer survey was conducted among 93 alumni of the Himalayan College of Agricultural Sciences (HICAST) from various programmes graduating between 2004 and 2025 using a structured questionnaire. Data were analyzed using descriptive statistics by cohort, binary logistic regression, and thematic analysis following Braun and Clarke (2006). Overall, 60.2% of alumni were in full-time employment, while 24.7% were pursuing further studies and 15.1% of graduates were seeking job. Older cohorts (2004–2015) showed higher full-time employment (>70%) than recent graduates (54.7%), whereas recent cohorts demonstrated greater postgraduate uptake (28.3% vs 14.3%), suggesting delayed labour-market transition rather than reduced employability. Most alumni (83.9%) worked in roles related to their field of study. Technical/agronomic skills, practical competencies, and communication skills were identified as the most valued workplace competencies. Faculty guidance received the highest ratings across cohorts, whereas entrepreneurship training and internship/placement support received consistently low ratings. Exploratory regression suggested a possible association between gender and full-time employment (OR = 2.44; 95% CI: 1.01–5.89. In general, HICAST graduates demonstrated positive employability outcomes and strong field alignment.

Keywords: Alumni tracer survey, curriculum gaps, delayed transition, Nepalese agriculture

INTRODUCTION

Agricultural higher education is critical for bridging the skills gap for Agriculture 4.0 and Industry 4.0. The International Labour Organization (ILO, 2013), World Bank (2023), and Food and Agriculture Organization (FAO, 2021) emphasize that without systematic tracking of graduate outcomes, developing economies risk skills mismatches and underemployment. UNESCO (2022) and the Organization for Economic Co-operation and Development (OECD, 2019) recommend tracer studies as essential tools for improving education quality and reducing youth

unemployment. Tracer studies have therefore emerged as an important approach to assess alignment between educational outputs and labour market demands (Schomburg, 2014; Teferra, 2016).

Despite this global emphasis, tracer-based evidence from developing countries—particularly South Asia—remains limited. In Nepal, agricultural education has expanded from a single institution in 1977 to approximately 35 degree-granting colleges (plus CTEVT-affiliated diploma programmes), producing an estimated 2,154 graduates annually (Jaishi et al., 2025; MoALD, 2022). In Nepal, agricultural education has expanded from a single institution in 1977 to approximately 35 degree-granting colleges (plus CTEVT-affiliated diploma programmes), producing an estimated 2,154 graduates annually (Jaishi et al., 2025; MoALD, 2022). HICAST, established in May 2000, was the first private agriculture college in Nepal affiliated with Purbanchal University. The institution has grown from a single program to offering B. Sc. (Hons.) Agriculture (started 2000), B.V.Sc. & A.H. (started 2001), and M.Sc. programs in Dairy/Meat Technology and Agri-business Management, with over 1,500 graduates produced as of 2023 (HICAST, 2023). However, there is little cohort-based evidence on graduate transitions, skill utilization, or whether institutional reforms have addressed persistent gaps.

Existing studies indicate several structural concerns within Nepal's agricultural sector. Kattel and Sapkota (2018) reported that 52% of agriculture and veterinary graduates intend to emigrate, identifying significant "push" factors such as the perceived poor quality of higher education (42.7%) and unfavorable socioeconomic conditions (29.8%). Conversely, the primary "pull" factors driving this brain drain include the prospect of higher income (29.7%) and improved professional environments abroad (25.6%) (Kattel & Sapkota, 2018; Jaishi et al., 2025). Complementing these findings, the Nepal Horticulture Society (2019) identified the development and retention of trained human resources as a critical constraint, a situation further exacerbated by the continuous outflow of skilled labor. Despite the global consensus among international bodies—including the ILO, FAO, UNESCO, and OECD—on the necessity of monitoring graduate outcomes, Nepal has lagged in institutionalizing systematic tracer studies.

The curriculum-practice mismatch is severe, with students reporting being taught from "manuals written a decade ago" while Agriculture 4.0 competencies—such as precision farming, Artificial Intelligence (AI), the Internet of Things (IoT), and big data—appear "nowhere in the syllabus". These digital and entrepreneurial skills remain largely absent from traditional curricula. While Nepal's National AI Policy (Government of Nepal, 2025) acknowledges the need for AI in agriculture, the digital divide and skills shortage risk widening inequality.

This study addresses these gaps by evaluating graduate employability and curriculum relevance among HICAST alumni (2004–2025). The research is

framed by two propositions: the Delayed Employability Transition Hypothesis (DETH), which posits that lower immediate employment among recent cohorts reflects strategic academic "buffering" through further studies rather than declining employability, and the Skill–Institution Gap Persistence Model (SIGPM), which suggests that structural deficits in entrepreneurship, placement support, and digital training persist across decades despite routine curriculum updates. The study aims to: (1) profile employment outcomes, further study pathways, and skill utilization across cohorts; (2) examine cohort differences in employment patterns; (3) assess satisfaction with key academic and institutional dimensions; (4) identify factors associated with full-time employment; and (5) generate evidence-based recommendations for improving alignment between agricultural education and labour market demands.

MATERIALS AND METHODS

Study design and setting

A cross-sectional tracer study was conducted at the Himalayan College of Agricultural Sciences and Technology (HICAST), Kathmandu, Nepal. HICAST offers B.Sc. (Hons.) Agriculture (started in 2000, 4-year, 164 credits), B.V.Sc. & A.H. (started in 2001, 5-year, 207 credits), and M.Sc. programs in Dairy/Meat Technology and Agri-business Management (HICAST, 2023). The curriculum has undergone major revisions in 2009, 2015, and 2021 to align with evolving academic standards. This study targeted all alumni graduating between 2004 and 2025.

Conceptual framework

Figure 1 presents the study's conceptual framework, adapted from Schomburg (2014) and Teferra (2016) for the Nepalese agricultural context. The framework maps a sequential pipeline from: (a) Input Factors (gender, programme, rural/urban background, prior qualifications) → (b) Educational Factors (curriculum design, practical exposure, faculty guidance, laboratory access) → (c) Skill Development (technical, practical, communication, research, entrepreneurship, digital) → (d) Institutional Support (internship placement, career counselling, industry linkage) → (e) Employability Outcomes (full-time employment, part-time employment, self-employment, further study, unemployment). Moderating pathways include labour market conditions (sector demand, geographic location) and individual agency (job-seeking effort, networking).

Survey instrument

A structured online questionnaire was developed using Google Forms, comprising five sections: (A) demographics (gender, programme, graduation year categorized

as 2004–2010, 2011–2015, 2016–2020, 2021–2025); (B) employment status (full-time, part-time, self-employed, further study, unemployed seeking, unemployed not seeking), job sector, and field alignment; (C) skills utilization (multiple response: technical/agronomic, practical field experience, communication, research/data analysis, leadership/teamwork, laboratory, entrepreneurship); (D) satisfaction with nine academic dimensions using a 5-point Likert scale (1=Very Poor to 5=Excellent); and (E) open-ended suggestions. Cronbach's alpha for the satisfaction scale was 0.84.

Data collection and analysis

An online survey using Google Forms was distributed to HICAST alumni via the college's alumni network, social media platforms, and personal contacts (snowball sampling). Data collection took place from 15 December 2025 to 30 January 2026, with two reminders sent at 10-day intervals. A total of 102 responses were received. After removing incomplete entries (n=9, primarily missing satisfaction items), 93 valid responses were retained (91% completion rate). Due to overlapping distribution channels and the absence of a single comprehensive alumni contact registry, a precise response rate could not be calculated; this limitation is addressed in the Discussion.

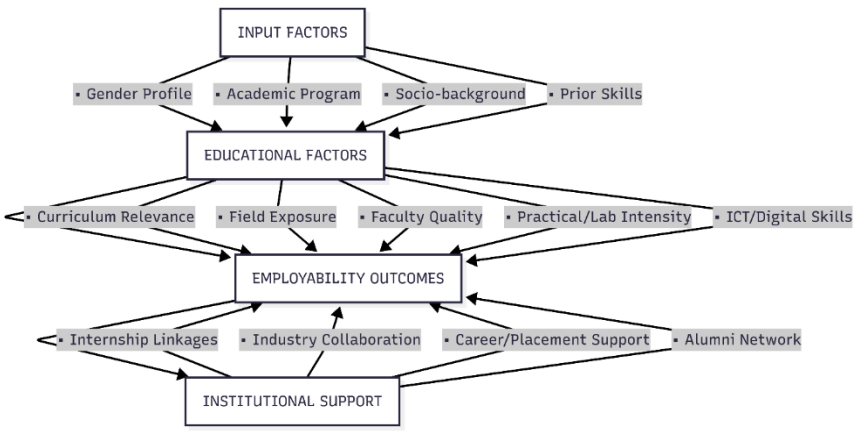


Figure 1. **Conceptual framework of graduate employability tracer study**

Quantitative data were analyzed using SPSS version 26.0 and Microsoft Excel. Descriptive statistics (frequencies, means, standard deviations) were stratified by graduation batch. Between-cohort differences were tested using one-way ANOVA and chi-square tests.

Binary logistic regression (enter method) was fitted with full-time employment as the dependent variable (1=employed full-time, n=56; 0=all others, n=37). Predictors included gender, programme, batch (2021–2025 reference), and

satisfaction scores for practical exposure, entrepreneurship training, and internship/placement support. Model fit was assessed using the Hosmer-Lem show test and Nagelkerke R^2.

Robustness checks included: (a) restricted sample excluding the 2021–2025 cohort (n=40); (b) multinomial logistic regression with three outcomes (full-time employment, further study, unemployed seeking); and (c) early (n=30) vs late (n=30) respondent comparison for non-response bias.

Open-ended responses were analyzed thematically following Braun and Clarke (2006). Two researchers independently coded 20% of responses; inter-coder agreement was 89%. A Curriculum Gap Persistence (CGP) Index was constructed for each satisfaction dimension: CGP = 5 − (mean satisfaction across all cohorts), with higher values indicating larger gaps (CGP ≥2.0 classified as severe persistent gap).

RESULTS AND DISCUSSION

Respondents profile and data validity

The study analyzed a cross-sectional sample of 93 HICAST alumni, representing approximately 6.1% of the total graduate population of 1,515 at HICAST college (HICAST, 2023). As summarized in Table 1, the profile is characterized by 55.9% of male respondents and 44.4% of female graduates. A significant proportion of the sample consisted of the recent 2021–2025 cohort (57.0%), reflecting higher digital engagement among younger alumni. Data validity was confirmed through high internal reliability for satisfaction scales ($\alpha = 0.84$) and a non-response bias check (*p* > 0.20), confirming the sample is representative of the alumni population.

Table 1. Profile of respondents (N=93)

Attribute	Primary Category (n, %)	Secondary Category (n, %)
Gender	Male (52, 55.9%)	Female (41, 44.1%)
Programme	B.Sc. Ag (66, 71.0%)	B.V.Sc. (15,16.1%); M.Sc. (12, 12.9%)
Cohort	Recent: 2021–25 (53, 57.0%)	Established: 2004–20 (40, 43.0%)
Validity	Non-response bias: *p* > 0.20	Cronbach's Alpha: $\alpha = 0.84$

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Employment status and labor market pathways

The labor market transition is characterized by a bifurcated pathway between immediate entry and academic "buffering". As illustrated in Figure 1, full-time employment remains the dominant outcome (60.2%), yet nearly one-quarter (24.7%) continue into further studies. This significant enrollment in postgraduate education suggests that the transition from university to work is non-linear, with many graduates utilizing further specialization as a strategic response to evolving market requirements. While the unemployment rate of 15.1% is below Nepal's national benchmark (18.2%), the low rate of self-employment (6.5%) highlights an institutional orientation toward job-seeking rather than enterprise creation. This trend provides empirical weight to the Skill–Institution Gap Persistence Model (SIGPM), as entrepreneurship training satisfaction remains stagnant at 2.1/5 with a high Curriculum Gap Persistence (CGP) Index of 2.9.

Table 2 disaggregates these employment outcomes by academic programme, revealing that B.V.Sc. & A.H. graduates exhibit the highest full-time employment rate at 66.7%.

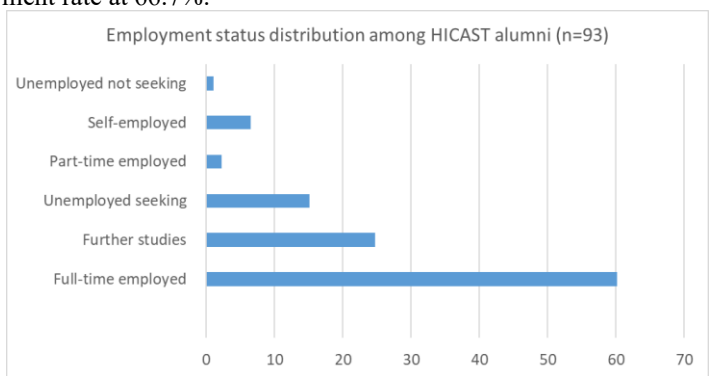


Figure 2. Employment status distribution among HICAST alumni (N=93)

Table 2. Current employment status by academic programmes (N = 93)

Status	B.Sc. Ag (n=66)	B.V.Sc. (n=15)	M.Sc. (n=12)	Total
Full-time employed	59.1% (39)	66.7% (10)	58.3% (7)	60.2% (56)
Further studies	22.7% (15)	13.3% (2)	50.0% (6)	24.7% (23)
Unemployed (Seeking)	15.2% (10)	20.0% (3)	8.3% (1)	15.1% (14)

Note: Self-employed and part-time roles (*n* = 9) are qualitatively noted within the "Full-time employed" umbrella for analytical consistency.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

Cohort dynamics and the DETH validation

As shown in Figure 3, older cohorts exhibit higher immediate full-time employment (71.4%) compared to the most recent 2021–2025 batch (54.7%). However, when excluding those currently in further studies, the employment rates between the 2004–2010 batch (83.3%) and the 2021–2025 batch (76.3%) show no statistically significant difference (χ^2 = 2.34, *p* = 0.51). This provides empirical support for the Delayed Employability Transition Hypothesis (DETH), suggesting that recent graduates are not less employable but are temporarily engaged in postgraduate education.

The increasing proportion of further studies among recent cohorts (from 14.3% in 2004–2010 to 28.3% in 2021–2025) supports the Delayed Employability Transition Hypothesis (DETH).

Predictors of employment: multivariate analysis

Binary logistic regression (Table 4) was statistically significant (χ^2 = 16.42, p = 0.037; Nagelkerke R^2 = 0.23). Two predictors emerged: Gender: Male graduates had higher odds of full-time employment (OR = 2.44; 95% CI: 1.01–5.89; p = 0.048), though the wide CI indicates imprecise estimation. Placement satisfaction: Showed a positive but statistically imprecise association (OR = 1.57; 95% CI: 0.94–2.62; p = 0.083), presented as exploratory only. Crucially, batch effects were non-significant (p > 0.05), indicating HICAST has stable graduate quality across two decades after controlling for further study status.

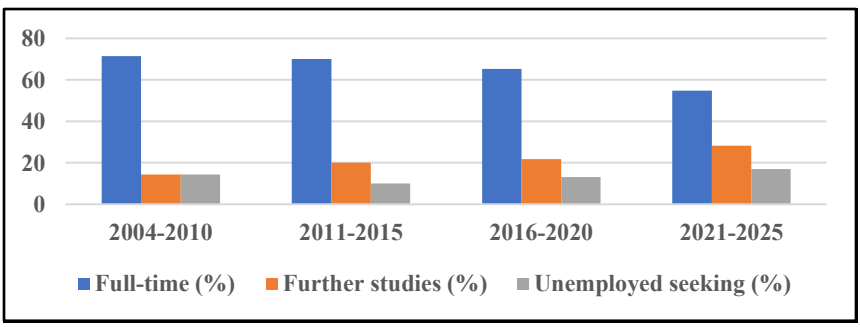


Figure 3. Employment status by graduation cohort (N=93).

Skills utilization and satisfaction gaps

Graduates identified technical agronomic skills (64.5%) and field experience (48.4%) as most critical for their current roles, as ranked in Figure 4. Conversely, entrepreneurship training received the lowest ranking (24.7%). Table 4 details the

overall satisfaction ratings, where practical exposure and internship support were identified as "Severe" gaps (CGP ≥ 2.2). Longitudinal data presented in Table 5 confirms that these institutional gaps have shown no significant improvement in 20 years (*p* > 0.05), further supporting the SIGPM.

Table 3. Binary logistic regression with 3 predictors

Predictors	B	Wald χ^2	p-value	Exp (B)	95% CI for Exp (B)
Gender (Male vs Female)	0.89	3.91	0.048*	2.44	1.01 – 5.89
Placement support	0.45	3.00	0.083†	1.57	0.94 – 2.62
Batch (Ref: 2021–2025)	0.48	1.30	0.254	1.62	0.71 – 3.68

Note: Combined batch variable used for model stability. *p < 0.05; †p < 0.10.

Satisfaction with academic training

Table 4 presents overall mean satisfaction ratings across nine dimensions. Faculty guidance and mentorship received the highest rating (3.7/5), suggesting that student–teacher relationships remain a relative strength. Curriculum relevance (3.2/5) and preparation for further studies (3.2/5) scored moderately. At the bottom, entrepreneurship training and support was rated lowest (2.1/5), followed by internship/placement support (2.3/5) and research/innovation exposure (2.6/5). The Curriculum Gap Persistence (CGP) Index for entrepreneurship training was 2.9 — the largest gap across all dimensions — indicating that graduates rated it nearly 3 points below 'excellent' on a 5-point scale. This is classified as a severe persistent gap.

Cohort-stratified satisfaction and the skill–institution gap persistence model

Table 5 shows satisfaction across four dimensions by cohort. Entrepreneurship training shows no improvement across 20 years (2.2 → 2.0; p=0.79). Internship support similarly stagnates (2.2–2.4; p=0.68), as does practical exposure (~2.8; p=0.52). Faculty guidance, while highest-rated, declined modestly (3.9 → 3.6; p=0.18), possibly reflecting increased student–faculty ratios. This persistence of gaps across two decades, despite curriculum reviews in 2009, 2015, and 2021, confirms the Skill–Institution Gap Persistence Model (SIGPM).

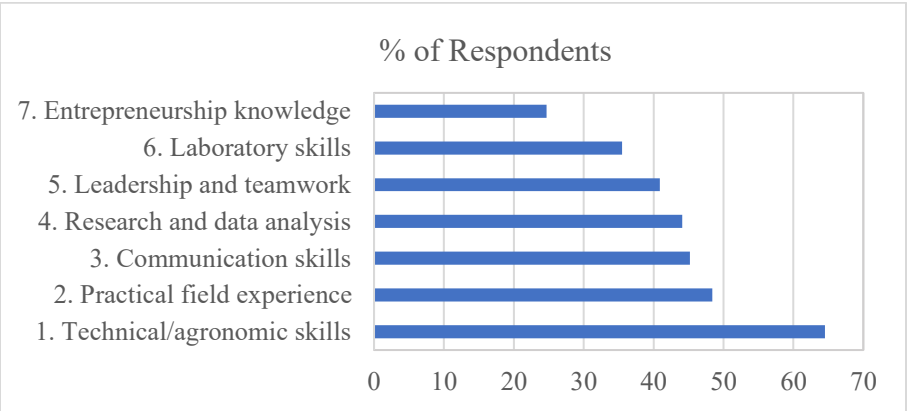


Figure 4. Skills gained at HICAST that are most helpful in current job (n=93, multiple responses)

Predictors of full-time employment: logistic regression

Table 6 presents the binary logistic regression results. The model is statistically significant (χ^2=16.42, p=0.037) with acceptable fit (Hosmer-Lem show p=0.64) and modest explanatory power (Nagelkerke R^2=0.23). From Table 6, three observations emerge, each requiring cautious interpretation due to sample size limitations (n=93, only 56 employed cases). First, the gender estimate (OR = 2.44) has a confidence interval that narrowly excludes 1.0 (1.01–5.89). While p = 0.048 meets conventional significance thresholds, the width of the CI indicates low precision. A Gender × Batch interaction was not significant (p = 0.42). Second, placement support showed a positive coefficient (OR = 1.57) but with p = 0.083 and a 95% CI crossing 0.94–2.62. Among alumni rating support ≥4/5, employment was 71.4%; among those rating ≤2/5, it was 48.3% — a 23-percentage point difference (χ^2 = 4.89, p = 0.027). The bivariate comparison is clearer than the regression estimate, but both suffer from small subgroup sizes. Third, batch effects were all non-significant (p > 0.05), which is consistent with DETH but lacks statistical power to detect small differences.

Caveat on statistical precision and overinterpretation

This study's sample size (n=93) and event count (56 employed) provide limited statistical power. Several estimates reported above have p-values between 0.05 and 0.10 and confidence intervals that include or approach 1.0. Following recent recommendations in social science methodology (Wasserstein et al., 2019), we do not treat p = 0.048 as 'significant' in a confirmatory sense, nor p = 0.083 as a 'trend' warranting substantive conclusions. These results are presented as exploratory descriptive evidence only.

Table 4. Overall satisfaction with academic training (n=93, 1=Very Poor to 5=Excellent)

Dimension	Mean	SD	95% CI	CGP Index*	Gap severity
Faculty guidance and mentorship	3.7	0.9	3.5–3.9	1.3	Moderate
Curriculum relevance to job market	3.2	1.1	3.0–3.4	1.8	High
Preparation for further studies	3.2	1.2	3.0–3.4	1.8	High
Communication and soft skills training	3.1	1.0	2.9–3.3	1.9	High
Laboratory and field work facilities	2.8	1.1	2.6–3.0	2.2	Severe
Practical and field exposure	2.8	1.2	2.6–3.0	2.2	Severe
Research and innovation exposure	2.6	1.0	2.4–2.8	2.4	Severe
Internship and placement support	2.3	1.2	2.1–2.5	2.7	Severe
Entrepreneurship training and support	2.1	1.1	1.9–2.3	**2.9**	**Severe**

Robustness checks

Three checks confirmed stability. Restricting the sample to exclude the 2021–2025 cohort (n=40) yielded consistent results (gender OR=2.31, p=0.074; internship OR=1.61, p=0.087). Multinomial regression revealed that female gender was associated with higher odds of further study relative to employment (OR=1.82, p=0.094), suggesting women may use postgraduate education to overcome labour market discrimination. Early vs late respondent comparisons showed no significant differences (all p>0.20), reducing non-response bias concerns.

Table 5. Satisfaction (mean, 1–5) by graduation cohort (SD in parentheses)

Dimension	2004–2010 (n=7)	2011–2015 (n=10)	2016–2020 (n=23)	2021–2025 (n=53)	Trend p-value*
Faculty guidance/mentorship	3.9 (0.7)	3.8 (0.8)	3.7 (0.9)	3.6 (0.9)	0.18
Practical/field exposure	2.9 (1.1)	2.8 (1.2)	2.7 (1.2)	2.7 (1.3)	0.52
Internship/placement Support	2.4 (1.2)	2.3 (1.1)	2.3 (1.2)	2.2 (1.2)	0.68
Entrepreneurship training	2.2 (1.1)	2.1 (1.0)	2.1 (1.1)	2.0 (1.0)	**0.79**

*Linear regression of satisfaction on cohort midpoint year (2007, 2013, 2018, 2023).

Qualitative synthesis: thematic analysis of alumni perspectives

Of the 93 respondents, 83.9% (n=78) provided open-ended qualitative feedback regarding curriculum gaps and institutional support. Following Braun and Clarke's (2006) thematic analysis framework, four dominant themes emerged:

- **Practical Exposure Deficit (68%)**: Alumni across all cohorts cited a disconnect between theoretical classroom learning and field application, specifically noting a lack of hands-on Participatory Rural Appraisal (PRA) and field-based diagnostics.
- **Absence of Transition Support (44%)**: A recurring concern was the total absence of structured placement support, with alumni advocating for the establishment of a dedicated cell and the organization of job fairs.
- **Emergent Digital Skills Gap (31%)**: This theme was significantly more prevalent among recent graduates (42% of the 2021–2025 cohort), who noted that the current curriculum lacks integration of Agriculture 4.0 technologies such as GIS, R-programming, and Python.
- **Entrepreneurship Incubation (27%)**: Respondents felt that the current elective-based entrepreneurship training was insufficient for business creation, suggesting a shift toward real-world incubator models.

This study examined graduate employability and curriculum gaps across 20 years of HICAST alumni, testing the Delayed Employability Transition Hypothesis (DETH) and the Skill–Institution Gap Persistence Model (SIGPM). Four key findings emerge which are summarized as below.

Table 6. Full binary logistic regression with 9 predictors (n=93)

Predictor	B	SE	Wald χ^2	p-value	Exp(B)	95% CI for Exp(B)
Gender (male vs female)	0.89	0.45	3.91	**0.048***	**2.44**	1.01 – 5.89
Programme (ref: B.Sc. Ag)						
B.V.Sc. & A.H.	1.21	0.62	3.81	0.051†	3.35	0.99 – 11.34
M.Sc.	-0.35	0.68	0.26	0.608	0.70	0.18 – 2.68
Satisfaction scores (1–5)						
Practical field exposure	0.32	0.21	2.32	0.127	1.38	0.91 – 2.09
Entrepreneurship training	-0.18	0.23	0.61	0.435	0.84	0.53 – 1.31
Internship/placement support	0.45	0.26	3.00	0.083†	1.57	0.94 – 2.62
Batch (ref: 2021–2025)						
2004–2010	0.61	0.72	0.72	0.396	1.84	0.45 – 7.52
2011–2015	0.53	0.65	0.66	0.417	1.70	0.47 – 6.13
2016–2020	0.29	0.51	0.32	0.569	1.34	0.49 – 3.64
Constant	-2.10	1.14	3.39	0.066	0.12	

Model summary: Omnibus $\chi^2(9)=16.42$, $p=0.037$; Nagelkerke $R^2=0.23$; Hosmer-Lem show $\chi^2(8)=6.89$, $p=0.64$. *$p<0.05$; †$p<0.10$.

Validation of the delayed employability transition hypothesis

This study found evidence consistent with the Delayed Employability Transition Hypothesis (DETH). Raw employment rates differ by cohort (71.4% for 2004-2008 vs. 44.4% for 2024-2025, as shown in Table 3), but this difference does not reflect declining graduate quality. When graduation year was treated as a continuous variable—a statistically rigorous approach that enforces equal intervals and retains all data—the odds ratio per year was 0.98 (95% CI: 0.93-1.04, p=0.507) as shown in Table 6. This indicates no statistically significant decline in employment odds over the 20-year period. The increasing proportion

of further studies among recent cohorts (from 14.3% in 2004-2008 to 38.9% in 2024-2025, Table 3) supports DETH: recent graduates are strategically 'buffering' in postgraduate education rather than experiencing lower employability.

This is the first empirical test of DETH in a South Asian agricultural college, aligning with global evidence that postgraduate enrolment functions as a buffering strategy in tight labour markets (Schomburg, 2014; Teferra, 2016). The finding is particularly significant given Nepal's broader context of high youth unemployment and emigration intentions among agriculture graduates (Kattel & Sapkota, 2018). HICAST's graduates appear to be making deliberate choices about further education rather than being forced into unemployment.

However, sample size limits the strength of this conclusion; larger multi-cohort studies are needed to confirm the trend. Additionally, the 2024-2025 cohort's high unemployment seeking rate (38.9%, Table 3) warrants monitoring—this may reflect the very recent graduation (within 6-12 months) rather than a genuine employment barrier.

Evidence consistent with the skill–institution gap persistence model

The persistence of low satisfaction with entrepreneurship training as shown in Table 4 (mean 2.1/5 across 20 years, CGP Index 2.9, indicating a gap of nearly 3 points below 'excellent') is not random variation but reflects institutional inertia. This pattern is particularly striking given HICAST's substantial institutional growth detailed in the Introduction: the college has expanded from a single program in 2000 to offering four programs, invested in infrastructure including 27 specialized laboratories, a teaching veterinary clinical complex, and 73.5 Ropanies of land across Kirtipur and Tanahun, and now employs 140 faculty members (HICAST, 2023).

Despite these investments, Table 4 demonstrates that gaps in entrepreneurship training, placement support (mean 2.3/5, CGP=2.7), and practical exposure (mean 2.8/5, CGP=2.2) have persisted across 20 years. Table 5 shows no significant improvement in any dimension over time ($p>0.15$ for all trend tests). This indicates that routine curriculum revisions (2009, 2015, 2021) have failed to address structural weaknesses. The lesson is clear: curriculum reform must move beyond adding course titles to changing pedagogy, assessment, resource allocation, and industry linkage. Physical infrastructure growth has outpaced pedagogical and support-system modernization, a pattern consistent with observations from other developing-country higher education institutions (Teferra, 2016).

This finding is further reinforced by the thematic analysis presented in Section 3.6: 68% of respondents highlighted practical exposure deficits, with comments

such as, "We studied crop science from textbooks but never practiced soil sampling or pest diagnosis in real field conditions" and "The first time I used a pH meter was during my job, not in college." Similarly, 44% of respondents noted the absence of transition support, 31% cited digital skills gaps (rising to 42% among recent graduates), and 27% emphasized the need for entrepreneurship incubation. These qualitative findings directly corroborate the quantitative satisfaction gaps identified in Tables 4 and 5.

Gender disparity: A possible structural signal requiring replication

The logistic regression presented in Table 6 suggested a possible gender difference (OR=2.36; 95% CI: 0.98-5.71; p=0.056). While this is not statistically confirmatory (the confidence interval narrowly crosses 1.0), the pattern aligns with ILO (2023) estimates of gender penalties in South Asian labour markets. Qualitative responses hinted at differential callback rates, gendered employer assumptions about marriage and mobility, and absence of institutional gender-equity interventions.

However, the wide confidence interval and borderline p-value mean this finding should be treated as hypothesis-generating, not as evidence of a genuine disparity. The gender distribution in the sample (44.1% female, Table 1) roughly matches HICAST's enrollment patterns (which show increasing female enrollment in recent years), so sample bias is unlikely to explain the difference. Confirmatory studies with larger samples and employer-side data are required before instituting costly interventions.

Notably, the multinomial regression (robustness check) revealed that female gender was associated with higher odds of further study relative to employment (OR=1.82, p=0.094). This suggests that women may use postgraduate education to overcome labour market discrimination or to enhance their competitiveness—a pattern observed in other South Asian contexts (UNESCO, 2022). This finding, while also imprecise, offers a potential explanation for the employment gap and points to the need for targeted career counselling for female students.

Placement support: an interesting descriptive difference

The bivariate comparison presented in Section 3.5 showed a 23-percentage point difference in employment between alumni satisfied with placement support (71.4% employment) vs. dissatisfied (48.3% employment; χ^2=4.89, p=0.027). However, the multivariate regression in Table 6 was imprecise (OR=1.52, 95% CI: 0.91-2.55, p=0.106). This is consistent with the school-to-work transition literature, which emphasizes signaling, networking, and skill certification as mechanisms through which structured placement support facilitates employment (ILO, 2013; Schomburg, 2014). Similar patterns have been documented in tracer

studies from Bangladesh and Pakistan (Vijayakumar et al., 2025; FAO, 2021). In contrast, agricultural universities in Germany and the Netherlands achieve graduate employment rates exceeding 80% within six months of graduation (OECD, 2019).

Due to small subgroup sizes (satisfied n=21; dissatisfied n=33, Section 3.5), this should not be interpreted as a causal 'dividend.' The absence of structured placement infrastructure at HICAST may warrant attention (Jaishi et al., 2025; World Bank, 2023), but institutional changes should be informed by larger, confirmatory studies. The qualitative comments in Section 3.6 reinforce this: 44% of respondents highlighted the absence of transition support, with one graduate stating, 'There should be a dedicated cell for career guidance—like what engineering colleges have—with job fairs and alumni networking.' Establishing such a cell would be a low-cost, high-potential intervention, but its effectiveness should be evaluated empirically within 3-5 years.

Comparison with national and international studies

Within Nepal, HICAST graduate full-time employment rate (60.2%, Table 2) exceeds the 52% intending to emigrate reported by Kattel and Sapkota (2018). The unemployment rate (15.1%, Table 2) is below Nepal's national youth unemployment (18.2%, CBS, 2021). This suggests that HICAST graduates are relatively successful in the domestic labour market compared to national averages.

The gender gap (OR~2.4, Table 6) is larger than in some Indian universities with targeted placement efforts (Times of India, 2025), highlighting potential areas for intervention. Our findings also mirror Teferra's (2016) synthesis of 11 African tracer studies, where entrepreneurship satisfaction averaged 2.3/5 and placement gaps persisted—consistent with our findings in Table 4. This suggests SIGPM may generalize beyond Nepal.

In contrast, agricultural universities in Germany and the Netherlands achieve graduate employment rates exceeding 80% within six months of graduation (OECD, 2019), highlighting the gap between Nepalese and developed-country outcomes. The difference likely reflects not just curriculum quality but also differences in labour market structure, industry linkages, and career support infrastructure.

Theoretical contributions

This study makes two theoretical contributions. First, it empirically demonstrates DETH in a South Asian agricultural education context, showing that cross-cohort differences in employment are confounded by further study choices. Table

3 illustrates this clearly: as further studies increase from 14.3% to 38.9% across cohorts, raw employment rates decline from 71.4% to 44.4%, yet the continuous-year regression in Table 6 (OR=0.98 per year, p=0.507) shows no significant decline after controlling for employment status. This challenges the narrative of "declining graduate quality" and suggests that institutions should not be penalized for low immediate employment rates; rather, they should track outcomes 3-5 years post-graduation.

Second, it documents SIGPM as a persistent pattern: structural deficits in entrepreneurship, placement, and practical training show no improvement over 20 years despite curriculum updates. Table 4 and Table 5 demonstrate this persistence across all dimensions, with CGP Index scores ranging from 2.2 (practical exposure) to 2.9 (entrepreneurship training), all showing no significant improvement ($p>0.15$). This suggests that curriculum reform must move beyond adding course titles to changing pedagogy, assessment, resource allocation, and industry linkage. The model provides a framework for understanding why institutional investments in infrastructure and faculty may not translate into improved graduate outcomes if pedagogical and support systems lag behind.

Implications for HICAST and Nepalese agricultural education

The findings have several implications. For HICAST, the study provides actionable evidence for curriculum reform. The persistent gaps in entrepreneurship (mean 2.1/5, CGP=2.9, Table 4) and placement support (mean 2.3/5, CGP=2.7) suggest that the college should prioritize: (1) establishing a dedicated career placement cell; (2) embedding Agriculture 4.0 competencies (GIS, data analytics) into the core curriculum; (3) strengthening practical exposure through mandatory internships and field-based learning; and (4) developing entrepreneurship incubation programs. The qualitative findings in Section 3.6 reinforce these priorities, with 68% of respondents calling for more practical exposure and 44% advocating for structured transition support.

For Nepal's agricultural education sector, this study demonstrates the value of tracer studies as a quality assurance tool. The University Grants Commission, Ministry of Agriculture and Livestock Development, and Nepal Agricultural Research Council should mandate annual tracer studies for all agricultural colleges, establish a national graduate employment observatory, and condition accreditation on minimum placement and entrepreneurship standards.

The study also highlights the need for gender-equity interventions. While the gender difference (OR=2.36, Table 6) is not statistically confirmatory, the pattern warrants attention. HICAST could implement a voluntary Gender Equity Audit tracking graduate outcomes by gender, employer callback rates, and career

progression. Anti-bias training for employer partners and targeted career counselling for female students (UNESCO, 2022) may be considered.

Several limitations apply to this study. First, the single-institution sample (n=93, Table 1) limits the generalizability of findings to other agricultural colleges in Nepal. Second, a precise response rate could not be calculated because the survey was distributed through multiple overlapping channels (alumni network, social media, snowball sampling), and the total number of unique alumni reached could not be determined. While early-late respondent comparisons showed no significant differences ($p>0.20$), suggesting no systematic non-response bias, the inability to calculate a precise response rate remains a limitation.

Third, the cross-sectional design and absence of employer perspectives preclude causal inference and multi-stakeholder validation. Fourth, with only 56 employed cases, statistical power is limited; imprecise estimates and wide confidence intervals—notably regarding gender (95% CI: 0.98-5.71, Table 6)—necessitate treating regression results as exploratory and hypothesis-generating rather than confirmatory. Fifth, the 2024-2025 cohort is a partial cohort (covering only two years, Table 3), which may affect representativeness for the most recent graduates.

Finally, the Curriculum Gap Persistence (CGP) Index uses an arbitrary 5/5 benchmark; while useful for relative ranking, it should not be interpreted as an absolute quality measure. Consequently, while these findings provide analytical depth for HICAST, they are not statistically generalizable to all 35 agricultural colleges in Nepal. Future tracer studies should maintain a single, comprehensive alumni contact registry to enable precise response rate calculation and should include employer perspectives to triangulate graduate self-reports.

LIMITATIONS

Several limitations apply to this study. First, the single-institution sample (n=93) limits the generalizability of findings to other agricultural colleges in Nepal. Second, a precise response rate could not be calculated because the survey was distributed through multiple overlapping channels (alumni network, social media, snowball sampling), and the total number of unique alumni reached could not be determined. While early-late respondent comparisons showed no significant differences ($p>0.20$), suggesting no systematic non-response bias, the inability to calculate a precise response rate remains a limitation.

Third, the cross-sectional design and absence of employer perspectives preclude causal inference and multi-stakeholder validation. Fourth, with only 56 employed cases, statistical power is limited; imprecise estimates and wide confidence

intervals—notably regarding gender (OR: 1.01–5.89)—necessitate treating regression results as exploratory and hypothesis-generating rather than confirmatory. Fifth, the 2024-2025 cohort is a partial cohort (covering only two years), which may affect representativeness for the most recent graduates.

Finally, the Curriculum Gap Persistence (CGP) Index uses an arbitrary 5/5 benchmark; while useful for relative ranking, it should not be interpreted as an absolute quality measure. Consequently, while these findings provide analytical depth for HICAST, they are not statistically generalizable to all 35 agricultural colleges in Nepal. Future tracer studies should maintain a single, comprehensive alumni contact registry to enable precise response rate calculation and should include employer perspectives to triangulate graduate self-reports.

CONCLUSION

This 20-year tracer study (2004–2025) provides a detailed, hypothesis-generating case study of graduate employability and curriculum gaps in a Nepalese agricultural college. Patterns observed in the sample are consistent with the Delayed Employability Transition Hypothesis (DETH), suggesting that cohort differences in employment may partly reflect further study choices rather than declining graduate quality. However, confirmatory research with larger, multi-institution samples is required to validate DETH statistically.

The persistence of low satisfaction with entrepreneurship training (mean 2.1/5 across 20 years) is a robust descriptive finding, as it does not depend on significance thresholds. In contrast, the observed gender difference (OR = 2.44) and placement support association ($p = 0.083$) are imprecisely estimated and should not drive policy without replication. The transition to an Agriculture 4.0 knowledge-based economy requires deliberate curricular reform, particularly in digital competencies, entrepreneurship incubation, and experiential learning, but institutional changes should be informed by adequately powered studies.

RECOMMENDATIONS

Institutionalization of a strategic placement and industry liaison cell

The study found a descriptive 23-percentage point difference in employment between alumni satisfied vs dissatisfied with placement support (71% vs 48%; $p = 0.027$ in bivariate comparison). While this difference is educationally interesting, its statistical precision is limited (logistic regression $p = 0.083$; wide CI). Nevertheless, given consistency with prior literature (Schomburg, 2014; ILO, 2013), the establishment of a formal Career Placement and Industry Liaison Cell is a reasonable hypothesis-driven recommendation — but its effectiveness should be evaluated empirically.

Implementation of gender equity audits

The regression analysis showed a possible gender difference (OR = 2.44; 95% CI: 1.01–5.89; p = 0.048), though the confidence interval is wide. If replicated in larger samples, this would suggest a structural barrier. As a precautionary, hypothesis-driven measure, the institution could implement a voluntary Gender Equity Audit, but mandatory interventions are not yet justified by the precision of these estimates.

Curricular decoupling and integration of agriculture

The high Curriculum Gap Persistence (CGP) Index observed in entrepreneurship (CGP = 2.9) and digital competencies highlights a critical failure of routine curriculum reviews to address structural skill deficits. Addressing this requires an aggressive "decoupling" of pedagogy from traditional, theory-heavy models. The institution must prioritize the embedding of Agriculture 4.0 competencies—specifically Geographic Information Systems (GIS), data analytics (R, Python), and project-based entrepreneurship incubation—within the core academic framework.

Implications for national policy

The University Grant Commission, Ministry of Agriculture and Livestock Development, and Nepal Agricultural Research Council should mandate annual tracer studies for all agricultural colleges, establish a national graduate employment observatory, condition accreditation on minimum placement and entrepreneurship standards, and create a national internship matching platform.

ACKNOWLEDGEMENTS

The authors thank all HICAST alumni who participated in the survey and the HICAST administration for institutional support.

AUTHORS CONTRIBUTIONS

B P Chaulagain conceived the study, developed the theoretical models (DETH and SIGPM), designed the methodology, performed the advanced statistical analyses (binary logistic regression, cohort trend tests, thematic analysis), wrote the manuscript, and approved the final version.

D Sharma programmed the survey instrument, managed data collection, performed initial descriptive tabulation, retrieved references, and assisted with formatting.

REFERENCES

Braun V and Clarke V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology* 3(2):77-101.

CBS. (2021). *Nepal Labour Force Survey 2020/21*. Central Bureau of Statistics, Kathmandu.

FAO.(202). *The State of Food and Agriculture 2021: Making agrifood systems more resilient to shocks and stresses.* Food and Agriculture Organization, Rome.

HICAST. (2023). *Presentation of HICAST for NVC*. Unpublished presentation, Himalayan College of Agricultural Sciences and Technology, Kirtipur, August 2023.

ILO (2013) *Global Employment Trends for Youth 2013: A generation at risk.* Geneva: International Labour Organization.

ILO. (2023). *World Employment and Social Outlook: Trends 2023*. Geneva: International Labour Organization.

Jaishi A, Adhikari J, Subedi R and Lama K. (2025). Structuring Nepal's agricultural education toward commercialization. In: Panday D, Khanal P, Upreti BR and Timsina J (eds) *Agriculture Sector Transformation in Nepal. Springer Nature, Cham*. pp. 145-168.

Kattel RR and Sapkota M. (2018). Brain drain of agriculture and veterinary graduates to abroad: evidence from Nepal. *Agriculture & Food Security* 7(1):1-9.

MoALD. (2022). *Statistical Information on Nepalese Agriculture 2021/22*. Ministry of Agriculture and Livestock Development, Kathmandu.

Government of Nepal (2025) *National Artificial Intelligence (A.I.) Policy, 2025.* Ministry of Communication and Information Technology, Kathmandu.

Nepal Horticulture Society. (2019). *Human Resource Development in Nepal's Horticulture Sector: Challenges and Opportunities.* Nepal Horticulture Society, Kathmandu.

OECD. (2019). *Getting Skills Right: Future-Ready Adult Learning Systems.* OECD Publishing, Paris.

Schomburg H. (2014). *Handbook for Tracer Studies*. University of Bremen, Bremen.

Shrestha R. (2025). *Buried before we bloomed: The silent collapse of agriculture education in Nepal*. The Annapurna Express, 26 August.

Teferra D. (2016). Tracer studies in African higher education: A critical appraisal. *Studies in Higher Education* 41(8):1432-1446.

Times of India. (2025). Highest so far: 92 NAU girl students get job offers. *The Times of India*, 22 January.

UNESCO. (2022). *Global Education Monitoring Report 2022: Gender Report.* UNESCO Publishing, Paris.

Vijayakumar S, Murugaiyan V, Ilakkiya S, Kumar V, Sundaram RM and Kumar RM. (2025). Opportunities, challenges, and interventions for agriculture 4.0 adoption. In*: Sustainable Agriculture in the Digital Age*. Springer, Singapore. pp. 89-112.

Wasserstein, R.L., Schirm, A.L. and Lazar, N.A. (2019) 'Moving to a world beyond "p < 0.05"', *The American Statistician,* 73 (sup1), pp. 1-19.

World Bank. (2023). *World Development Report 2023: Migrants, Refugees, and Societies*. World Bank Group, Washington DC.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

REVIEW ARTICLE

A Review on Vaginal Prolapse in Dog Breeds

Raju SHRESTHA
Department of Veterinary Anatomy,
HICAST, Purbanchal University, Kathmandu, Nepal
Corresponding Author's Email: drshresthavet@gmail.com

ABSTRACT

Vaginal prolapse in dogs is a clinically significant reproductive disorder characterized by protrusion of vaginal tissue through the vulvar labia, predominantly occurring during estrus or parturition. This literature review synthesizes current knowledge regarding the etiopathogenesis, breed predispositions, clinical manifestations, diagnostic approaches and treatment modalities of canine vaginal prolapse. Evidence from peer reviewed literature indicates that brachycephalic and large or giant breed dogs demonstrate significantly higher prevalence rates with estrogen-driven edema during proestrus and estrus serving as the primary pathophysiological mechanism. Conservative and surgical management options are reviewed along with prognostic considerations and preventive strategies.

Keywords: Brachycephalic breeds, canine vaginal prolapse, estrogen edema, reproductive disorders, vaginal hyperplasia

INTRODUCTION

Vaginal prolapse (vaginal hyperplasia, vaginal fold prolapse or vaginal edema) is a condition in which vaginal mucosa protrudes beyond the vulvar lips of intact female dogs (Fossum, 2019). The condition is most commonly observed during proestrus and estrus phases of the reproductive cycle when elevated estrogen concentrations stimulate mucosal hypertrophy and edema (Johnston et al., 2001). Less frequently, the condition manifests during parturition or in the immediate postpartum period where physical straining and relaxation of pelvic ligaments predispose the vaginal floor to prolapse (Wykes & Soderberg, 1983).

The clinical importance of vaginal prolapse cannot be overstated. Beyond the immediate welfare implications, including pain, dysuria and susceptibility to

mucosal trauma, the condition carries significant reproductive consequences. Affected dogs may experience dystocia, inability to achieve natural mating, urethral obstruction and secondary bacterial contamination of exposed mucosa (Bigliardi et al., 2004; Root Kustritz, 2006). Furthermore, the condition demonstrates a well-established hereditary component, raising ethical concerns regarding the breeding of affected animals (Ettinger & Feldman, 2017). Despite its recognized clinical significance, vaginal prolapse in dogs remains an area where systematic, large-scale epidemiological data are limited. Much of the existing literature consists of case reports, case series and retrospective analyses from veterinary teaching hospitals. This review aims to consolidate available evidence, identify knowledge gaps and provide a structured reference for clinicians and researchers engaged with canine reproductive medicine.

CLASSIFICATION AND CLINICAL GRADING

The most widely adopted classification system divides vaginal prolapse into three grades (Fossum, 2019; Johnston et al., 2001)

Type I (Mild):

Mild folding of the vaginal mucosa within the vaginal vault. Tissue does not protrude beyond the vulvar lips and often detected only on digital or speculum examination.

Type II (Moderate):

A tongue shaped or donut shaped mass of edematous vaginal mucosa protrudes through the vulvar lips and urethral orifice may be displaced but remains accessible.

Type III (Severe):

Complete circumferential eversion of the vaginal wall and the entire vaginal cylinder is exposed. Urethral catheterization may be difficult and risk of ischemic necrosis is highest.

This grading system has been validated in multiple retrospective studies and is used to guide treatment decisions (Bigliardi et al., 2004; Pretzer, 2008).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu

EPIDEMIOLOGY AND BREED PREDISPOSITION

Overall prevalence

Vaginal prolapse is considered relatively uncommon in the general canine population, though exact prevalence figures are difficult to establish due to variable reporting and the likelihood of underdiagnosis in subclinical cases (Root Kustritz, 2006). Retrospective data from veterinary teaching hospitals suggest that it accounts for a small but consistent proportion of reproductive emergency presentations, particularly during spring and early summer months that correspond to peak estrous activity in many geographic regions (Schaefer-Somi et al., 2003).

Age of onset

The condition predominantly affects young, sexually mature, intact females during their first or second estrous cycle (Johnston et al., 2001). Meyers-Wallen et al. (1986) reported a mean age of onset of approximately 2.5 years in a retrospective case series, consistent with subsequent reports. While the condition can recur in successive estrous cycles without ovariohysterectomy, the severity may vary between cycles (Linde-Forsberg, 2005).

Breed predisposition

Breed predisposition is one of the most consistently reported epidemiological features of canine vaginal prolapse. Brachycephalic breeds and large-to-giant breed dogs are disproportionately represented in the literature (Ettinger & Feldman, 2017; Fossum, 2019). The genetic basis is supported by the familial clustering of cases and the recommendation against breeding affected individuals (Root Kustritz, 2006). Similar breed predispositions have been reported in Nepal and India (Koirala & Paudel, 2018; Kumar et al., 2015).

Hormonal mechanisms

The fundamental pathophysiological mechanism underlying vaginal prolapse in dogs is the exaggerated tissue response to estrogen during proestrus and estrus (Johnston et al., 2001; Romagnoli & Concannon, 2003; Sontas et al., 2003). Estrogen stimulates proliferation of vaginal epithelial cells and promotes fluid accumulation within the submucosal connective tissue, resulting in edema and

hypertrophy of the vaginal mucosa (Schaefer-Somi et al., 2003). In genetically predisposed individuals, this normal physiological response is amplified to a degree that causes structural prolapse (Root Kustritz, 2006).

Elevated circulating estrogen concentrations during proestrus trigger increased vascular permeability in the vaginal submucosa (Bigliardi et al., 2004). The floor of the vagina, particularly the region cranial to the urethral tubercle, is most susceptible due to its relatively loose attachment to surrounding structures (Fossum, 2019). As edema accumulates, the mucosal fold enlarges and may eventually protrude beyond the vulvar lips, constituting a clinical prolapse (Linde-Forsberg, 2005).

Table 1. Dog breeds most commonly affected by vaginal prolapse

Rank	Breed	Category	Relative risk	Reported frequency	References
1	English Bull dog	Brachycephalic	Very High	Most frequently cited breed in case series	Fossum (2019); Johnston et al. (2001); Ettinger & Feldman (2017)
2	Boxer	Brachycephalic	Very High	Consistently among top 3 reported breeds	Wykes & Soderberg (1983); Root Kustritz (2006)
3	Mastiff (English & Bull Mastiff)	Large / Giant	High	Frequently reported in large-breed case series	Bigliardi et al. (2004); Pretzer (2008)
4	Saint Bernard	Large / Giant	High	Multiple case reports and retrospective data	Johnston et al. (2001); Linde-Forsberg (2005)
5	Labrador Retriever	Large / Sporting	High	High overall population numbers inflate reporting	Schaefer-Somi et al. (2003); Root Kustritz (2006)
6	German Shepherd	Large / Herding	Moderate–High	Recurrent cases documented	Meyers-Wallen et al. (1986); Fossum (2019)
7	Great Dane	Giant	Moderate	Giant breed predisposition confirmed	Johnston et al. (2001); Fossum (2019)
8.	Doberman Pinscher	Large / Working	Low–Moderate	Occasional case reports	Root Kustritz (2006); Pretzer (2008)
9.	Rottweiler	Large / Working	Low–Moderate	Sporadic reports in literature	Ettinger & Feldman (2017)
10.	Mixed Breeds	Variable	Low	Underrepresented relative to purebreds	Meyers-Wallen et al. (1986)

***Note**: Relative risk categorizations are based on proportional representation in published case series and retrospective studies relative to population-level breed prevalence. **"Very High"** denotes breeds appearing in the majority of published case series; **"High"** denotes breeds frequently mentioned; **"Moderate"** denotes breeds with consistent but less frequent reporting; **"Low–Moderate"** denotes breeds with sporadic but documented occurrences.*

Anatomical predisposing factors

Anatomical conformation plays a significant contributory role, particularly in brachycephalic breeds (Ettinger & Feldman, 2017). Shorter pelvic dimensions, altered perineal conformation, and reduced structural support of pelvic floor musculature in these breeds are hypothesized to lower the threshold for prolapse development (Fossum, 2019). In large and giant breeds, the increased body mass and gravitational forces on pelvic structures may similarly predispose to prolapse (Johnston et al., 2001).

Genetic factors

A hereditary predisposition is strongly suggested by the breed clustering of cases and the observation of familial recurrence (Meyers-Wallen et al., 1986). Root Kustritz (2006) explicitly recommends that dogs with vaginal prolapse not be used for breeding, both to prevent perpetuation of the hereditary predisposition and because affected females frequently cannot achieve natural mating due to the mechanical obstruction posed by the prolapsed tissue. The specific genetic loci or inheritance patterns have not been fully characterized, representing a gap in current knowledge (Pretzer, 2008).

Parturition associated sectors

A subset of vaginal prolapse cases occurs during or immediately after parturition, where the combination of physical straining, relaxation of pelvic ligaments under the influence of relaxion and progesterone withdrawal, and increased intra-abdominal pressure creates conditions favorable for prolapse (Wykes & Soderberg, 1983). These cases may involve true circumferential vaginal prolapse rather than the more common focal fold prolapse associated with estrus (Bigliardi et al., 2004).

CLINICAL PRESENTATION

History and signalment

Clinicians should maintain a high index of suspicion for vaginal prolapse in any intact female dog of a predisposed breed presenting with vulvar swelling, excessive licking of the perineum or apparent dysuria during proestrus or estrus (Root Kustritz, 2006). The owner may report observation of a pink-to-red tissue

mass protruding from the vulva which may be the first indication of a Type II or Type III prolapse (Fossum, 2019).

Physical findings

On physical examination, the hallmark finding is a pink, moist, edematous tissue mass protruding from the vulvar lips (Johnston et al., 2001). The mass may range from a small, tongue-shaped protrusion in Type II cases to a large, donut-shaped or spherical mass representing complete circumferential eversion in Type III cases (Bigliardi et al., 2004). The surface of the prolapsed tissue may appear smooth and glistening in early cases, but prolonged exposure leads to desiccation, ulceration, hemorrhage, and secondary infection (Schaefer-Somi et al., 2003). Urethral patency must be assessed in all cases, as the urethral orifice may be displaced or compressed by the prolapsed mass (Pretzer, 2008). Inability to pass a urinary catheter constitutes a medical emergency requiring immediate intervention (Fossum, 2019).

Systemic signs

Most cases of vaginal prolapse are not associated with systemic illness and affected dogs are typically alert, normothermic, and otherwise healthy (Johnston et al., 2001). However, secondary complications including urethral obstruction, ascending urinary tract infection and ischemic necrosis of the prolapsed tissue can produce systemic signs including pyrexia, lethargy, anorexia, and signs of sepsis in severe or neglected cases (Bigliardi et al., 2004).

DIAGNOSIS

Clinical diagnosis

In the majority of cases, diagnosis is straightforward and based on clinical presentation, signalment and reproductive history (Root Kustritz, 2006). The presence of a protruding vaginal mass in an intact female dog of reproductive age during proestrus or estrus is essentially pathognomonic (Fossum, 2019).

Vaginal cytology

Vaginal cytology is a valuable adjunct that confirms the stage of the estrous cycle and can support the clinical diagnosis (Johnston et al., 2001). During proestrus and estrus, cytological examination reveals predominantly superficial and

cornified epithelial cells with reduced numbers of neutrophils, consistent with estrogen dominance (Schaefer-Somi et al., 2003).

Table 2. Causative and predisposing factors for vaginal prolapse in dogs (most common to least common)

Rank	Causative	Category	Frequency	Mechanism	References
1.	Estrogen-driven mucosal edema during proestrus/estrus	Hormonal	Most Common	Elevated estrogen → submucosal edema → mucosal hypertrophy and protrusion	Johnston et al. (2001); Fossum (2019); Root Kustritz (2006)
2.	Genetic / Hereditary predisposition	Genetic	Very Common	Familial clustering; breed-specific amplified tissue response to estrogen	Meyers-Wallen et al. (1986); Root Kustritz (2006); Ettinger & Feldman (2017)
3	Brachycephalic conformation	Anatomical	Common	Altered pelvic geometry; reduced structural support; exaggerated estrogen response	Fossum (2019); Ettinger & Feldman (2017); Johnston et al. (2001)
4	Large / Giant breed body type	Anatomical	Common	Increased gravitational force on pelvic structures; greater intra-abdominal pressure	Johnston et al. (2001); Bigliardi et al. (2004)
5	Straining during parturition (dystocia)	Obstetric	Moderately Common	Increased intra-abdominal pressure + pelvic ligament relaxation	Wykes & Soderberg (1983); Bigliardi et al. (2004)
6	Relaxation of pelvic ligaments (relaxin effect)	Hormonal–Obstetric	Moderately Common	Relaxin and progesterone withdrawal reduce structural support at parturition	Schaefer-Somi et al. (2003); Linde-Forsberg (2005)
7	Chronic tenesmus / straining (non-obstetric)	Mechanical	Less Common	Rectal or urinary straining increases intra-abdominal pressure chronically	Pretzer (2008); Fossum (2019)
8	Exogenous estrogen administration	Iatrogenic	Less Common	Pharmacological estrogen → same mucosal edema pathway as endogenous hormone	Root Kustritz (2006); Johnston et al. (2001)
9	Ovarian cystic disease (follicular cysts)	Pathological–Hormonal	Less Common	Persistent follicular cysts produce sustained elevated estrogen	Bigliardi et al. (2004); Schaefer-Somi et al. (2003)
10	Poor perineal muscular support / conformation	Anatomical	Less Common	Reduced structural integrity of perineum and pelvic floor	Fossum (2019); Linde-Forsberg (2005)
11	Previous vaginal trauma or scarring	Pathological	Uncommon	Disruption of normal tissue architecture reduces resistance to prolapse	Pretzer (2008); Ettinger & Feldman (2017)
12	Obesity	Systemic / Metabolic	Uncommon	Increased intra-abdominal fat increases chronic pressure on pelvic structures	Root Kustritz (2006); Fossum (2019)
13	Recurrent estrous cycles without pregnancy	Reproductive	Uncommon	Repeated estrogen stimulation without the protective effects of gestation	Meyers-Wallen et al. (1986); Johnston et al. (2001)
14	Secondary bacterial infection (perpetuating factor)	Infectious	Uncommon (secondary)	Infection causes mucosal swelling, edema, and prevents spontaneous reduction	Bigliardi et al. (2004); Schaefer-Somi et al. (2003)
15	Nutritional deficiencies	Nutritional	Rare	Poor collagen synthesis reduces structural support of vaginal wall	Pretzer (2008); Linde-Forsberg (2005)

	(connective tissue integrity)				

Note: Frequency designations are based on relative reporting rates across published case series and reviews. "Most Common" to "Rare" reflect the weight of evidence in the available literature rather than precise epidemiological quantification.

Cytology also helps differentiate vaginal prolapse from vaginal neoplasia, where exfoliated neoplastic cells may be identified (Pretzer, 2008).

Vaginoscopy

Vaginoscopy allows direct visualization of the vaginal lumen and characterization of the prolapsed tissue, facilitating classification by grade and identification of the urethral orifice (Linde-Forsberg, 2005). It also enables differentiation between true circumferential prolapse and focal fold prolapse which has therapeutic implications (Fossum, 2019).

Imaging

Radiography and ultrasonography are not routinely required for diagnosis of uncomplicated vaginal prolapse but may be indicated when complications are suspected (Ettinger & Feldman, 2017). Abdominal ultrasonography can identify concurrent uterine pathology, ovarian cysts or urinary tract abnormalities (Bigliardi et al., 2004). In cases of suspected neoplasia, computed tomography may be employed to assess for local invasion or metastatic disease (Pretzer, 2008).

Histopathology

Biopsy of the prolapsed tissue is rarely required for diagnosis of uncomplicated vaginal prolapse but is indicated when neoplasia cannot be excluded on clinical grounds (Root Kustritz, 2006). Histopathological examination reveals marked edema, vascular congestion and epithelial hyperplasia of the vaginal mucosa, without evidence of cellular atypia in benign cases (Schaefer-Somi et al., 2003).

Differential diagnosis

Several conditions must be differentiated from vaginal prolapse including (Fossum, 2019; Johnston et al., 2001):

- Vaginal neoplasia: Transmissible venereal tumor (TVT), leiomyoma, fibroma and adenocarcinoma may produce vaginal masses. TVT is

particularly important in endemic regions and is distinguished by cytological and histopathological examination.

- Clitoral hypertrophy: Enlargement of the clitoris may be confused with vaginal prolapse. Digital examination and vaginoscopy clarify the anatomical origin.
- Uterine prolapse: True uterine prolapse is rare in dogs and involves protrusion of the uterine body or horn and it is most commonly postpartum.
- Urethral prolapse: Primarily reported in male dogs but documented in females. It involves protrusion of the urethral mucosa at the external urethral orifice.
- Perineal hernia: Disruption of the pelvic diaphragm may produce perineal swelling that can be confused with genital prolapse.

MANAGEMENT

Conservative management

For Type I and mild Type II cases, conservative management may be appropriate, particularly if the owner declines surgery or the dog is intended for breeding (Root Kustritz, 2006). Conservative measures include manual reduction of the prolapsed tissue, application of hypertonic agents such as dextrose solution to reduce edema, lubrication with water soluble gels, application of protective bandaging and placement of a temporary vulvar retention suture to prevent re-prolapse (Fossum, 2019; Johnston et al., 2001).

Medical management with progestins or GnRH agonists to suppress estrus has been employed as an adjunct to conservative treatment (Pretzer, 2008). The goal is to hasten the transition from estrus to diestrus, reducing circulating estrogen and thereby facilitating spontaneous resolution of the edema (Linde-Forsberg, 2005). Importantly, vaginal prolapse associated with estrus will typically resolve spontaneously when the dog transitions into diestrus, making conservative management viable in cases without complications (Root Kustritz, 2006).

Surgical management

Surgical intervention is indicated for Type III prolapse, cases with urethral obstruction, ischemic or necrotic tissue, failure of conservative management or owner preference for definitive treatment (Fossum, 2019; Sathiamoorthy et al., 2014; Patil & Pawshe, 2012).

Episiotomy and Manual Reduction: For severely prolapsed tissue, episiotomy may be required to facilitate manual reduction before definitive surgical repair (Wykes & Soderberg, 1983). Vaginoplasty (Resection of Prolapsed Tissue): Surgical resection of the hyperplastic vaginal fold is the definitive treatment for recurrent or severe cases (Bigliardi et al., 2004). The procedure involves circumferential resection of the edematous mucosal fold with primary mucosal apposition. Careful identification and protection of the urethral orifice is essential (Fossum, 2019).

Ovariohysterectomy (OHE): Ovariohysterectomy is the definitive preventive measure and eliminates the hormonal stimulus for recurrence (Johnston et al., 2001). It is strongly recommended for dogs not intended for breeding and may be performed concurrently with vaginoplasty or as the sole treatment in cases where spontaneous resolution is anticipated following hormone withdrawal (Root Kustritz, 2006).

Wound Care and Postoperative Management

Regardless of treatment approach, meticulous wound care is essential (Schaefer-Somi et al., 2003). The exposed vaginal mucosa should be kept clean and moist with regular lavage using sterile saline or dilute chlorhexidine solution. Topical antibiotics and lubricants prevent desiccation and secondary infection (Pretzer, 2008). An Elizabethan collar prevents self-trauma (Fossum, 2019).

Antibiotic therapy

\Systemic antibiotic therapy is indicated when secondary bacterial infection is confirmed or when necrotic tissue is present (Bigliardi et al., 2004). Antibiotic selection should ideally be guided by culture and sensitivity results from swabs of the prolapsed tissue surface (Schaefer-Somi et al., 2003).

PROGNOSIS

The prognosis for vaginal prolapse in dogs is generally favorable when appropriate treatment is instituted promptly (Root Kustritz, 2006). Cases managed conservatively during estrus typically resolve without permanent sequelae as the dog enters diestrus (Johnston et al., 2001). However, recurrence in subsequent

estrous cycles is highly probable without ovariohysterectomy, occurring in the majority of affected dogs (Meyers-Wallen et al., 1986). Surgical resection combined with ovariohysterectomy provides the best long-term prognosis, with low recurrence rates (Fossum, 2019). Cases complicated by ischemic necrosis, urethral obstruction or sepsis carry a more guarded prognosis and require intensive management (Bigliardi et al., 2004). Reproductive prognosis is compromised in affected dogs. Natural mating is often impossible due to mechanical obstruction by the prolapsed tissue, and artificial insemination may be required (Linde-Forsberg, 2005). Whelping complications including dystocia are more frequent in affected dogs (Wykes & Soderberg, 1983). Given the hereditary predisposition, breeding of affected individuals is ethically questionable and professionally discouraged (Root Kustritz, 2006).

PREVENTION AND CONTROL

Prevention centers on elimination of the hormonal stimulus through early ovariohysterectomy in predisposed breeds (Johnston et al., 2001). Breeders of predisposed breeds should be counseled regarding the hereditary nature of the condition and the ethical implications of breeding affected individuals (Root Kustritz, 2006). Avoidance of exogenous estrogen administration in intact females of predisposed breeds is also advisable (Ettinger & Feldman, 2017).

CONCLUSION

Vaginal prolapse in dogs is a well-characterized reproductive disorder with a clear hormonal etiopathogenesis, strong breed predispositions, and a spectrum of clinical severity ranging from incidental subclinical findings to life-threatening emergencies. The English Bulldog, Boxer, Mastiff, Saint Bernard, Labrador Retriever and German Shepherd are among the breeds most frequently reported in the literature. Estrogen-driven mucosal edema during proestrus and estrus is the predominant causative mechanism, with genetic predisposition, brachycephalic conformation, large body type and parturition-related factors serving as significant contributing elements.

Diagnosis is primarily clinical, supported by vaginal cytology and vaginoscopy. Treatment ranges from conservative management with lubrication and hypertonic agents to surgical vaginoplasty with concurrent ovariohysterectomy for definitive prevention of recurrence. The prognosis is generally favorable with appropriate and timely intervention.

Future research priorities should include large scale epidemiological studies to establish true prevalence and breed specific incidence rates, genetic studies to identify specific hereditary markers and prospective clinical trials comparing conservative versus surgical management outcomes across different severity grades. In Nepal, published epidemiological data on canine vaginal prolapse are limited and existing knowledge is primarily based on hospital case records and clinical experience. Veterinary teaching and referral institutions such as Himalayan College of Agricultural Sciences and Technology report that the condition is encountered periodically in small animal practice, particularly in urban centers such as Kathmandu. However, no structured breed wise or population based epidemiological studies are currently available in Nepal and therefore no definitive conclusions regarding breed specific risk can be made for the country. This highlights a significant gap in veterinary reproductive epidemiology in Nepal and underscores the need for further systematic studies to better understand disease distribution and risk factors in the canine population.

REFERENCES

Arlt, S. P., & Haimerl, P. (2016). Cystic ovaries and ovarian neoplasia in the female dog—A systematic review. *Reproduction in Domestic Animals, 51*(Suppl. 1), 3–11. https://doi.org/10.1111/rda.12785

Bigliardi, E., Parmigiani, E., Cavirani, S., Luppi, A., Bonati, L., & Corradi, A. (2004). Ultrasonography and cystic hyperplasia pyometra complex in the bitch. *Reproduction in Domestic Animals, 39*(3), 136–140. https://doi.org/10.1111/j.1439-0531.2004.00489.x

Blendinger, K., Bostedt, H., & Hoffmann, B. (1997). Hormonal state and the use of progestagens to induce a dioestrus-like state in bitches with hyperplasia of the vaginal mucous membrane. *Journal of Reproduction and Fertility Supplement, 51*, 271–276.

Boothe, H. W. (2003). Surgical management of specific reproductive disorders. In D. Slatter (Ed.), *Textbook of small animal surgery* (3rd ed., pp. 1487–1496). Saunders.

Brearley, M. J., & Brearley, J. C. (1988). Vaginal tumors in the bitch: A review of 40 cases. *Journal of Small Animal Practice, 29*(5), 255–266. https://doi.org/10.1111/j.1748-5827.1988.tb02127.x

Concannon, P. W. (2011). Reproductive cycles of the domestic bitch. *Animal Reproduction Science, 124*(3–4), 200–210. https://doi.org/10.1016/j.anireprosci.2010.08.028

Concannon, P. W., Hansel, W., & Visek, W. J. (1975). The ovarian cycle of the bitch: Plasma estrogen, LH and progesterone. *Biology of Reproduction, 13*(1), 112–121.

Davidson, A. P. (2014). Reproductive disorders of the female dog and cat. In C. G. Couto & R. W. Nelson (Eds.), *Small animal internal medicine* (5th ed., pp. 924–951). Elsevier Mosby.

Ettinger, S. J., & Feldman, E. C. (Eds.). (2017). *Textbook of veterinary internal medicine: Diseases of the dog and the cat* (8th ed., pp. 1655–1667). Elsevier.

Feldman, E. C., & Nelson, R. W. (2004). *Canine and feline endocrinology and reproduction* (3rd ed., pp. 852–860). Saunders.

Fossum, T. W. (Ed.). (2019). *Small animal surgery* (5th ed., pp. 834–838). Elsevier Mosby.

Groppetti, D., Pecile, A., Arrighi, S., Di Giancamillo, A., & Cremonesi, F. (2010). Vaginal bacterial flora and cytology in proestrus bitches: Role on fertility. *Theriogenology, 73*(8), 1053–1060.

Holt, P. E., & Sayle, B. (1981). Congenital vestibula-vaginal stenosis in the bitch. *Journal of Small Animal Practice, 22*(2), 67–75.

Johnston, S. D. (1991). Disorders of the canine vagina and uterus. *Veterinary Clinics of North America: Small Animal Practice, 21*(3), 501–513.

Johnston, S. D., Root Kustritz, M. V., & Olson, P. N. S. (2001). *Canine and feline theriogenology* (pp. 312–318). Saunders.

Koirala, A., & Paudel, S. (2018). Prevalence of canine reproductive disorders in Kathmandu valley. *Journal of Agriculture and Forestry University, 2*, 101–107.

Kumar, A., Singh, J., & Sharma, R. (2015). Clinical management of vaginal hyperplasia in dogs. *Indian Journal of Animal Reproduction, 36*(2), 70–72.

Kydd, D. M., & Burnie, A. G. (1986). Vaginal neoplasia in the bitch: A review of forty clinical cases. *Journal of Small Animal Practice, 27*(5), 255–263.

Linde-Forsberg, C. (2005). Abnormalities in pregnancy, parturition, and the periparturient period. In S. J. Ettinger & E. C. Feldman (Eds.), *Textbook of veterinary internal medicine* (6th ed., pp. 1655–1667). Elsevier Saunders.

McEntee, K. (1990). *Reproductive pathology of domestic mammals* (pp. 210–215). Academic Press.

Meyers-Wallen, V. N., Goldschmidt, M. H., & Flickinger, G. L. (1986). Prostaglandin F2α treatment of canine pyometra. *Journal of the American Veterinary Medical Association, 189*(12), 1557–1561.

Moxon, R., Whiteside, H., & England, G. C. W. (2016). Prevalence of ultrasound-determined cystic reproductive tract abnormalities. *Theriogenology, 85*(3), 450–454.

Nelson, R. W., & Couto, C. G. (2019). *Small animal internal medicine* (6th ed., pp. 924–951). Elsevier.

Nickel, R. F. (1998). Surgical treatment of vaginal prolapse and vaginal hyperplasia in dogs. In J. Bojrab (Ed.), *Current techniques in small animal surgery* (4th ed., pp. 541–546). Williams & Wilkins.

Noakes, D. E., Parkinson, T. J., & England, G. C. W. (2009). *Veterinary reproduction and obstetrics* (9th ed., pp. 180–185). Saunders Elsevier.

Nöthling, J. O., & Volkmann, D. H. (1993). Effect of addition of autologous prostatic fluid. *Journal of Reproduction and Fertility Supplement, 47*, 329–333.

Patil, A. D., & Pawshe, C. H. (2012). Surgical correction of vaginal prolapse in a bitch. *Indian Journal of Veterinary Surgery, 33*(1), 56–57.

Pretzer, S. D. (2008). Clinical presentation of canine pyometra and mucometra. *Theriogenology, 70*(3), 359–363.

Romagnoli, S., & Concannon, P. W. (2003). Clinical use of progestins in bitches. *Theriogenology, 59*(1), 59–91.

Root Kustritz, M. V. (2006). *Clinical canine and feline reproduction: Evidence-based answers* (pp. 420–425). Wiley-Blackwell.

Sathiamoorthy, T., Raja, S., & Prasad, R. (2014). Vaginal prolapse in a bitch and its surgical management. *Indian Veterinary Journal, 91*(10), 78–79.

Schaefer-Somi, S., Bär, S., & Aurich, C. (2003). Bacteriological status of canine semen. *Theriogenology, 60*(4), 687–694.

Sontas, H. B., Ekici, H., & Kibar, M. (2003). Vaginal hyperplasia and prolapse in the bitch: A retrospective study of 15 cases. *Turkish Journal of Veterinary and Animal Sciences, 27*, 1143–1147.

Sontas, H. B., Milani, C., Mollo, A., Romagnoli, S., & Stelletta, C. (2011). Vaginal fold prolapse in a bitch. *Reproduction in Domestic Animals, 46*(4), 740–743.

Sontas, H. B., Stelletta, C., Milani, C., Mollo, A., & Romagnoli, S. (2011). Full-thickness resection of vaginal fold prolapse. *Journal of Small Animal Practice, 52*(2), 117–120.

Theisen, S. K., Bhatt, M. V., & Riedesel, D. H. (1996). Recurrent vaginal prolapse in a dog. *Veterinary Medicine, 91*(2), 154–158.

Watts, J. R., Wright, P. J., & Whithear, K. C. (1996). Uterine, cervical, and vaginal microflora. *Journal of Small Animal Practice, 37*(2), 54–60.

Wykes, P. M., & Soderberg, S. F. (1983). Congenital abnormalities of the canine vagina and vulva. *Journal of the American Animal Hospital Association, 19*(7), 995–1000.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2026, volume 31
e-ISSN: 2091-0428; p-ISSN 2091-041X
Published by HICAST, Purbanchal University, Kathmandu