NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES

July, 2025, volume 29

Himalayan College of Agricultural Sciences and Technology (HICAST)
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Published on: 20 July 2025

Access and download to online version is free of cost.

Price for hard copy	Nepal	NRs 500.00
(Including postage charge)	SAARC Countries	US $ 15.00
	Other countries	US $ 25.00

PUBLISHER

Directorate of Research and Extension (DoRE)
Himalayan College of Agricultural Sciences & Technology (HICAST)
Purbanchal University affiliate
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URL://www.nepjas.com/ URL://www.hicast.edu.np/ URL://www.nepjol.com/

Citation: Nepalese Journal of Agricultural Sciences, July, 2025, Volume 29
(e-ISSN: 2091-0428; p-ISSN: 2091-041X; esjindex ID = 6279)

Euro-Asian Scientific Journal Link: *http://esjindex.org/search.php?id=6279*

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RESEARCH ARTICLES

Effect of Amla Juice on Growth Performance, Carcass Characteristics, and Lipid Profile of Broiler

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(Article received on 2 March 2025; Accepted for 20 July 2025)

ABSTRACT

This study was carried out to evaluate the effect of Amla juice on growth performance, carcass characteristics, and lipid profile of broiler. This 35-day study at HSTU, Dinajpur, evaluated the effects of Amla juice in drinking water on broilers. 120 chicks were divided into five groups (0%, 0.75%, 1%, 1.25%, and 1.5% Amla). The 1% group (T2) showed significantly higher body weight, better feed conversion ratio, and improved carcass traits. Lipid profiles improved with lower cholesterol and LDL, and higher HDL and triglycerides. T2 also yielded the highest net profit. Amla juice at 1% enhances growth, health, and profitability, making it a natural growth promoter in broiler production.

Keywords: Chicks, economic benefit, immunity, live weight, slaughter weight

INTRODUCTION

The poultry industry in Bangladesh has emerged as one of the fastest-growing segments of the agriculture sector, with a flourishing impact to provide a sustainable and cheap protein source. The livestock and poultry sector contributed 1.47% to GDP with a growth rate of 3.47%, the current price GDP volume was 43212 crore taka, and the current price share of livestock and poultry was 13.46 in 2018-2019. The livestock and poultry sector provided direct opportunity to 20% population and indirect opportunity to 50% population of the country in 2018-2019. The total number of poultry and chicken population was 3563.18 and 2966.02 lakh, respectively, in 2019-2020. Meat production in 2019-2020 was 74.76 lakh metric tons, and egg production was 1736 crores. The national population of poultry has gradually increased from 2788.06 lakhs in 2010-2011 to 6563.18 lakhs in 2019-2020; except in 2005, the number of chickens consistently increased from 2346.86 lakhs in 2010-2011 to 2966.02 lakhs in 2019-2020 (BBS, 2020).

Broiler farming is very much desired and liked industry among urban and rural farmers because of the very fast economic return. In present days, Bangladeshi are attracted to broiler chicken production because of the fast return and high demand. The condition of broiler production in Bangladesh is improving day by day. The success of the poultry industry depends upon its fast growth and low mortality during the first two weeks of life, which can be managed by good hygienic and feeding conditions. The production of safer poultry products without the use of any chemical or microbial residues is the demand of the day. Feed additives are one of the important tools used for improving feed conversion ratio, growth rate, and disease resistance. The additives that hold great promise in the feeding of poultry comprise antibiotics, coccidiostat, antioxidants, enzymes, hormones, probiotics, buffers, organic acids, mold inhibitors, herbal products, synthetic micronutrients, etc. Use of antibiotics has negative effects on animal health and its production, such as residues in tissues, withdrawal period, and development of resistance in microorganisms (Botsoglou and Fletouris, 2001). The nutritionists and researchers attempted other alternatives to enhance the performance of broiler chicken. Herbs, spices, and various plant extracts have received increased attention as a possible antibiotic growth promoter replacement. In this view, the plants identified with properties of secondary metabolites became interesting due to their antimicrobial, antioxidant effects, and their stimulating effects on animal performance and digestive enzymes. At present, there are large numbers of Natural Growth Promoters available in the market, including herbs, probiotics, prebiotics, and symbiotics etc. (Sapkota et al., 2006).

In the last decade, herbal feed additives have attracted the attention of scientists as useful resource for improving productivity with no drug residue and no side effect. Besides, these herbs are natural component and do not have any side effects like residues in meat products. Amla (*Emblica oficinalis*) fruit powder is one of the herbs which have potential to boost broiler production. Amla is extensively cultivated all over Nepal. The fruits of the plants are used in Ayurveda as a potent rasayana (revitalizers, biological response modifiers), in which the Amla was added as an anti-stress agent. Phytochemical analysis of Amla fruit powder provided evidence of the presence of the medicinally important bioactive compounds, which can be exploited beneficially to improve productivity in broilers. Amla (*Emblica officinalis*) is one of the richest sources of ascorbic acid, minerals, amino acids, tannins, and phenolic compounds (Yokozawa et al., 2007). Rapid growth rate in commercial broilers accelerates the metabolic rate and makes them vulnerable to oxidative stress owing to increased free radical generation (Feng et al., 20012). Gallic acid and tannic acids are the phenolic acids present in E. officinalis that contribute to the antioxidant activity, in addition to ascorbic acid (Suresh et al., 2006). Therefore, the present study was conducted to evaluate the dietary addition of E. officinalis (Amla) juice in drinking water with the following objectives:

1) To determine the effects/potential of Amla juice on the growth performance and carcass characteristics of broiler;
2) To investigate the effects/potential of Amla juice on the lipid profile of broiler, and
3) To assess the cost and benefit.

MATERIALS AND METHODS

Experimental Site

The study was conducted at Hajee Mohammad Danesh Science and Technology University (HSTU) Poultry Shed, Dinajpur.

Experimental Birds

A total of one hundred twenty (120) active and healthy day-old broiler chicks (Cobb 500) were purchased from Kazi Farms Limited's local dealer, Sadar Dinajpur, Bangladesh. Immediately after the arrival of chicks, the chicks were weighed and brooded in a proper brooding, lighting, ventilation, and heating arrangement for 7 days.

Layout of the Experiment

The day-old chicks were reared at the brooder house to adjust to the environmental conditions for seven days. After seven days, chicks were randomly allocated into five treatment groups, each group having three replications.

Table 1. Layout showing the distribution of experimental broilers

Dietary Treatments		Number of broilers in each replication			Total
		R1	R2	R3	
Control (Only basal diet)	T0	8	8	8	24
Basal diet + 0.75% Amla juice	T1	8	8	8	24
Basal diet + 1% Amla juice	T2	8	8	8	24
Basal diet + 1.25% Amla juice	T3	8	8	8	24
Basal diet + 1.5% Amla juice	T4	8	8	8	24
Total no. of broilers		40	40	40	120

Preparation of the Amla Solution

The Amla solution of different compositions, i.e., 0.75%, 1%, 1.25% and 1.5% was made by the addition of 0.75 ml, 1ml, 1.25ml, and 1.5ml pure Amla juice in 100ml of drinking water, respectively. The chicks during the brooding period (seven days) were supplied only with clean, fresh drinking water and commercial diet. The Amla solution treatment was started from the 8th day to the treatment group: - T1 supplied 0.75% Amla solution, similarly, birds under treatment group T2, T3, and T4 fed 1%, 1.25% and 1.5% Amla solution, respectively, except the control group (T0).

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RESULTS AND DISCUSSION

This experiment was conducted to evaluate the efficacy of Amla juice on production performance, including weekly body weight, final live weight gain, feed intake, feed efficiency, carcass characteristics, mortality rate, and lipid profile for a period of 35 days at the University poultry shed, HSTU, Dinajpur, Bangladesh. A total of 120 chicks were randomly assigned to 5 dietary treatment groups. During the study period, all the birds were provided with standard husbandry conditions required for broiler production. The treatments were T_0 (control group), T_1 (0.75%), T_2 (1%), T_3 (1.25%), and T_4 (1.5%) of Amla juice administered through drinking water. During the experimental period, data on feed intake were noted daily, the body weight of birds was noted weekly, and at the end of the study the carcass characteristics and lipid profile data were noted for further evaluation. All results are expressed as mean ± standard error mean (SEM). Some values had undergone one-way ANOVA, and then Duncan's t-test was used to determine whether there were any differences. Results were presented in different tables and discussed under the following subheadings.

Effect of Amla Juice on Feed Intake (g) of Broiler

Data on weekly and total feed intake of experimental birds are presented in Table 2. It was observed that T_4 consumed more amount of feed (3317.95±40.93 g) followed by T_2 (3297.39±13.44 g), T_3 (3290.16±12.41 g), T_1 (3285.64±13.16 g) and T_0 (3285.32±14.21 g) which were statically non-significant (P>0.05). The results of the current study revealed that there was no significant (P>0.05) difference among the treatment groups in weekly and total feed intake throughout entire experimental period.

Table 2. Effect of amla juice on feed intake (g)

Feed intake (g)/bird (days)	Treatment Group					Level of significance
	T_0	T_1	T_2	T_3	T_4	
7th	155.67±0.88	154.00±2.08	156.00±1.53	155.67±2.33	157.67±1.76	NS
14th	360.11±3.64	363.09±3.91	356.55±3.90	360.11±2.78	365.16±2.47	NS
21st	642.34±2.65	640.56±3.51	638.74±3.57	640.66±3.29	634.69±3.48	NS
28th	935.32±2.89	929.81±2.71	941.45±1.10	933.88±1.43	932.06±2.68	NS
35th	1191.88±4.15	1198.18±0.95	1204.65±3.34	1199.84±2.58	1228.37±30.54	NS
Total feed intake	3285.32±14.21	3285.64±13.16	3297.39±13.44	3290.16±12.41	3317.95±40.93	NS

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).

Feed Intake

This study showed no significance difference (P>0.05) in weekly and total feed intake throughout entire experimental period (Table 2). Total feed intake was highest in T_4 (3317.95±40.93 g) followed by T_2 (3297.39±13.44 g), T_3 (3290.16±12.41 g), T_1 (3285.64±13.16 g) and T_0 (3285.32±14.21 g) which were statically non-significant (P>0.05). The results of the current study revealed that there was no significantly difference (P>0.05) in weekly and total feed intake throughout the entire experimental period among all groups. Supplementation of Amla showed no adverse effect on feed intake of broiler may because of herbal products having negligible side effects. This study seemed closely related with the findings of Patel *et al.* (2016) in which 0.4% and 0.8% Amla powder supplemented group had no effect on feed intake and so as reported by Islam *et al.* (2020), Sanjyal *et al.* (2011). The results obtained in the study differ with the results of Gaikward *et al.* (2016) in which 0.5% and 1% Amla supplemented group consumed less amount of feed compared to control group. Similar findings were reported by Dalal (2018), Naik (2020) and Kumari (2012), they reported that Amla supplemented group consumed lower amount of feed compared to control. It may be due to the difference in the form of amula used i.e. Powder and liquid.

Growth Performance of Broiler

Live Weight (g) of Broiler

The results of the present study showed that there was no significant (P>0.05) differences in live weight (Table 3) on 7th day (first week) among all five groups of the experiment (T_0, T_1, T_2, T_3 and T_4).

Table 3. Effect of amla juice on live weight (g) of broilers

Live weight (g)/ bird (days)	Treatment Group					Level of significance
	T_0	T_1	T_2	T_3	T_4	
Initial Body Weight	47.67±0.33	46.67±0.33	47.00±0.58	47.33±0.33	47.00±0.58	NS
7^{th}	201.67±1.45^a	207.00±1.00^b	202.67±1.20^a	199.00±1.15^a	200.33±0.88^a	*
14^{th}	515.00±1.53^a	517.00±4.58^a	541.00±4.51^b	516.00±7.09^a	508.67±4.10^a	*
21^{st}	1017.67±14.84^a	1007.33±7.69^a	1068.00±8.33^b	997.33±8.67^a	1011.33±8.88^a	*
28^{th}	1608.00±26.91^{ab}	1582.67±22.93^a	1725.67±19.40^c	1660.33±9.21^b	1589.00±11.06^a	*
35^{th}	2255.67±28.43^a	2334.67±36.09^{ab}	2574.67±10.73^c	2385.33±33.78^b	2363.67±35.03^b	**

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).

$^{a\ b\ c\ d\ e}$ means having different superscript in the same row differed significantly (P<0.05) *indicates 5% level of significance, and **indicates highly significant

The live weight was differed significantly (P<0.05) from 14^{th} to 28^{th} days and highest significant different (P<0.01) was recorded on 35^{th} days of the experiment among groups (T_0, T_1, T_2, T_3 and T_4) where, lowest body weight was observed in T_0 (2255.67±28.43 g) and T_2 group gained highest body weight (2574.67±33.78 g) followed by T_3 (2385.33±33.78), T_4 (2363.67±35.03) and T_1 (2334.67±36.09), respectively.

Live Weight Gain

The results of the present study showed that there was no significant (P>0.05) differences observed in live weight gain (Table 4) on 7th 14^{th} and 21^{st} days among all treatment group (T_0, T_1, T_2, T_3 and T_4). The significant (P<0.05) differences was observed in live weight gain on 28^{th} and 35^{th} days of experiment among all groups (T_0, T_1, T_2, T_3 and T_4) where, T_2 recorded significantly highest live weight gain (657.67±12.35 g) and (849.00±29.96 g) on 28^{th} and 35^{th} days of experiment respectively. Significant difference (P<0.05) in average live weight gain was also recorded at end of the study (35^{th} days) where, T_0 recorded significantly lowest live weight gain (2208±59.25 g) and T_2 recorded significantly highest live weight gain (2527.67±56.96 g) followed by T_3 (2338±83.3 g), T_1 (2321.32±80.66 g) and T_4 (2316.67±61.07g), respectively.

Table 4. Effect of amla juice on weight gain

Live weight gain (g)/ bird (days)	Treatment Group					Level of significance
	T_0	T_1	T_2	T_3	T_4	
7^{th}	154.00±1.73	160.33±0.88	155.67±0.67	151.67±1.20	153.33±1.45	NS
14^{th}	313.33±2.85	313.00±5.13	338.33±3.38	317.00±7.00	308.33±3.28	NS
21^{st}	502.67±13.59	492.33±11.98	527.00±10.60	481.33±15.45	502.67±12.68	NS
28^{th}	590.33±14.31^{a}	579.33±30.38^{a}	657.67±12.35^{b}	663.00±17.39^{b}	577.67±10.20^{a}	*
35^{th}	647.67±26.77^{a}	779.33±32.13^{bc}	849.00±29.96^{c}	725.00±42.34^{ab}	774.67±33.46^{bc}	*
Total weight gain	2208±59.25^{a}	2321.32±80.66^{b}	2527.67±56.96^{d}	2338±83.38^{bc}	2316.67±61.07^{b}	*

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).

$^{a\ b\ c}$ means having different superscript in the same row differed significantly (P<0.05); *indicates 5% level of significance.

The study shows no significance difference (P>0.05) in live weight gain on 7^{th}, 14^{th} and 21^{st} days among all treatment groups (Table 4). Significance difference (P<0.05) were recorded in live weight gain on 28^{th} and 35^{th} days among all five group. Significance difference (P<0.05) in average live weight gain was recorded on 35^{th} days where, T_0 registered significantly lowest average live weight gain (2208±59.25 g) and T_2 gained highest (2527.67±56.96 g) followed by T_3 (2338±83.38) T_1 (2321.32±80.66) and T_4 (2316.67±61.07).

The study showed that Amla supplementation had no significant effect on live weight gain from 7^{th} to 21^{st} days while, Amla supplementation showed significant effect on live weight gain on 28^{th} and 35th days. Also, Amla supplementation had significant effect on total average live weight gain at the end of experiment (35^{th} days). The results of the study reveals that significantly higher live weight was recorded in Amla treated groups compared to control where, 1% Amla supplement recorded highly significant highest live weight. This study seems closely related with the findings of Gaikward *et al.* (2016) who found highest live weight gain in 1% Amla treated group than 0.5% Amla supplement and control group. Naik *et al.* (2020), found highest live weight in 1% Amla supplement than 0.5% and 2% Amla powder supplement group. The obtained results is comparable with previous findings of Patel *et al.* (2016) who recorded significantly higher live weight gain in 0.8% and 0.4% Amla powder supplemented group; Patil *et al.* (2012) recorded significantly higher live weight gain in 1.5% and 2% Amla powder supplemented group; Tiwari *et al.* (2016), recorded highest body weight in 10% Amla powder supplement group. Aljumaily et al. (2019), recorded highest live weight in 0.1% Amla supplement.

Effect of amla juice on feed conversion ratio (FCR)
The results of the current study showed that there was no significance ($P>0.05$) difference in FCR (Table 5) on 7^{th}, 14^{th} and 21^{st} days among all treatment groups (T_0, T_1, T_2, T_3 and T_4) and significantly different ($P<0.05$) FCR was observed on 28^{th} and 35^{th} days of treatment. Amla supplemented group showed better FCR than control group where, T_2 recorded significantly improved FCR (1.30±0.24) than T_3 (1.41±0.15), T_1(1.42±0.16), T_4 (1.43±0.67), and T_0 (1.49±0.24), respectively.

Supplementation of Amla showed a significantly beneficial effect on FCR which may be because of enhancement of intestinal activities of trypsin, lipase, and amylase (Lee *et al.,* 2004) and improved gut morphological characteristics (Jamroz *et al.,* 2003). The beneficial influence of the phytogenic feed additives on improved performance and feed conversion ratio could be also explained due to the antioxidant activity of bioactive compounds such as carvacrol, thymol, cineol and pinene (Hazzit *et al.,* 2006) as well as from improved enzyme activity in the alimentary tract, stimulation of useful and inhibition of pathogenic microflora which eventually resulted in improved absorption and utilization of nutrients (Windisch *et al.,* 2008). This study seems closely related with the findings of Gaikward *et al.* (2016), in which 1% Amla supplement resulted lowest FCR and 0.5% Amla supplement resulted better FCR than control; Dalal *et al.* (2018), who recorded best FCR in 1% Amla supplemented group, Aljumaily *et al.* (2019) also recorded higher FCR in 1% Amla supplemented group; Kumar *et al.* (2013) recorded highest FCR in 1% Amla treated group. The results of this study is comparable with previous findings of Patel *et al.* (2012) who, recorded lower FCR in 1.5% and 2% Amla supplement group and Naik *et al.* 2020 recorded higher FCR in 0.5% Amla powder supplement.

Table 5. Effect of amla juice on feed conversion ratio (FCR)

FCR (days)	Treatment Group					Level of significance
	T_0	T_1	T_2	T_3	T_4	
7th	1.01±0.02	0.98±0.01	1.00±0.01	1.03±0.02	1.03±0.00	NS
14th	1.15±0.02	1.16±0.03	1.15±0.02	1.14±0.03	1.18±0.00	NS
21st	1.28±0.03	1.30±0.04	1.21±0.03	1.33±0.04	1.26±0.03	NS
28th	$1.59±0.04^{bc}$	$1.61±0.09^{c}$	$1.43±0.03^{ab}$	$1.41±0.04^{a}$	$1.62±0.03^{c}$	*
35th	$1.85±0.08^{b}$	$1.54±0.07^{a}$	$1.42±0.05^{a}$	$1.67±0.10^{ab}$	$1.59±0.07^{a}$	*
Final FCR	$1.49±0.24^{b}$	$1.42±0.16^{ab}$	$1.30±0.24^{a}$	$1.41±0.15^{ab}$	$1.43±0.67^{ab}$	*

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).
$^{a\ b\ c}$ means having different superscript in the same row differed significantly (P<0.05); *indicates 5% level of significance.

Effect of amla juice on carcass yield characteristics of broiler

Live weight, slaughter weight and carcass weight

Final live weight, slaughter weight and carcass weight and carcass characteristics data are presented in Table 6. From Table 5 it is observed that T_2 gained higher live weight (2574.67±10.73 g), slaughter weight (2492.80±37.64 g) and carcass weight (2574.67±10.73 g) compared to T_0 live weight (2574.67±10.73 g), slaughter weight (2492.80±37.64 g) and carcass weight (2574.67±10.73 g). T_3 (2385.33±33.78 g), T_4 (2363.67±35.03 g) and T_1 gained (2334.67±36.09g) live weight 0n 35th days of the experimental period; T_3 (2272.57±34.41 g), T_4 (2263.33±33.20g) and T_1 gained (2231.00±38.81 g) slaughter weight on 35th days of the experiment and T_3 (1643.33±45.04 g), T_4 (1637.20±33.43 g) and T_1 gained (1620.33±18.01 g) slaughter weight on 35th days of the experiment.

Weight of thigh, drumstick, breast, wings, abdominal fat, liver and heart

Data on weight of thigh, drumstick, breast, wings, abdominal fat, and liver and on heart 35th days are presented in table 6. Thigh weight was significantly (P<0.05) differed among all the treatment groups, T_2 recorded higher thigh weight (394.67±2.96 g) compared T_0 (350.67±7.69 g), T_1 (359.33±6.33 g), T_4 (360.47±7.99 g) and. T_3 (364.23±7.03g) on 35th days of the experiment respectively. Non-significant (P>0.05) differences were recorded in drumstick weight where, T_0 (242.33±0.88 g), T_1 (235.33±8.09 g), T_2 (240.00±3.06 g), T_3 (595.70±14.23 g) and

T_4 (235.80±3.37 g) respectively. Although high drumstick weight was non-significant but higher drumstick weight was observed in T_2 (240.00±3.06 g) and lower in T_0 (242.33±0.88g) groups. Breast weight was significantly ($P<0.05$) differed among the all treatments groups. In T_0 breast weight was (566.67±18.68 g), T_1 (602.33±17.61 g), T_2 (659.00±10.50 g), T_3 (595.70±14.23 g) and T_4 (607.27±17.69 g), where higher breast weight was observed in T_2 group. Wings weight was also differed significantly ($P>0.05$) T_0 recorded 118.00±5.86 g, T_1 gained (116.67±6.23) g, T_2 (144.67±2.19 g), T_3 (132.10±9.07 g) and T_4 (128.33±9.94g) respectively. Higher drumstick weight was recorded in T_2 (144.67±2.19 g) and lower in T_1 (116.67±6.23 g) during 35th days of experiment. No significant ($P>0.05$) differences were recorded in abdominal fat weight. Abdominal fat in T_0 was (48.83±1.74 g), T_1 (49.17±1.59 g), T_2 (46.67±3.53 g), T_3 (44.67±3.18 g) and T_4 (39.17±0.44 g) respectively. Increasing the inclusion level of Amla resulted decreasing in abdominal fat weight. Significant ($P<0.05$) differences were observed in liver weight. Liver weight was 49.33±1.86 g in T_0, T_1 (53.33±1.45 g), T_2 (58.00±0.58 g), T_3 (52.83±2.09 g) and T_4 (53.67±0.33 g) respectively, where, T_2 recorded higher and T_0 recorded liver weight among all treatment groups. Significant ($P<0.05$) differences were also shown in heart weight. Heart weight was (13.33±0.33 g) in T_0, T_1 (12.67±0.33 g), T_2 (14.17±0.17 g), T_3 (12.53±0.26 g) and T_4 (13.20±0.20 g) respectively, where, T_2 recorded (14.17±0.17 g) higher and T_3 recorded lower heart weight among all treatment groups.

Cost effectiveness on production

Data on cost benefit analysis of the present study are presented in table 7. It is observed that chick cost was non-significant ($P>0.05$) among the treatment groups. All treatment groups recorded similar chick cost that 57.00Tk/chick. Average feed consumption per bird was non-significant ($P>0.05$). Price of concentrate per kg was also non-significant ($P>0.05$), all treatment groups recorded similar feed price (56.8 TK/kg). Amla juice supplemented group was not significantly ($P>0.05$) differed. Total feed consumed cost was non-significant ($P>0.05$).

Amla juice cost was non-significant ($P>0.05$). Miscellaneous cost /bird registered non-significant ($P>0.05$). Total cost of production per bird was little bit similar with another groups. Sell price per kg live of broiler was similar 145 Tk/kg which is non-significant ($P>0.05$). Sell price per broiler of Amla supplemented group was significant ($P<0.05$), lowest sell price per broiler (TK 327.07±4.12) was recorded in T_0 whereas, highest sell price per broiler (TK 373.33±1.56) was recorded in T_2 followed by T_3 (TK 345.87±4.90), T_4 (TK 43.38±5.06) and T_4 (TK 338.53±5.23), respectively. Net profit/ broiler was significantly different ($P<0.05$) among treatment groups, lowest net profit (TK 35.53±5.07) was recorded in T_4 whereas, highest net profit (TK 74.77±1.57) was recorded in T_2 followed by T_1 (TK 60.42±21.50) T_3 (TK 43.38±5.06) and T_0 (TK 38.56±4.11), respectively.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES, July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Table 6. Carcass yield characteristics

Parameter	Treatment Group					Level of sign.
	T_0	T_1	T_2	T_3	T_4	
Live wt.	2225.00±9.07^a	2334.67±36.09^b	2574.67±10.73^c	2385.33±33.78^b	2363.67±35.03^b	**
Slaughter wt.	2110.33±7.54^a	2231.00±38.81^b	2492.80±37.64^c	2272.57±34.41^b	2263.33±33.20^b	**
Carcass wt.	1441.33±15.30^a	1620.00±18.01^b	1758.00±3.46^c	1643.33±45.04^b	1637.20±33.43^b	**
Thigh	350.67±7.69^a	359.33±6.33^a	394.67±2.96^b	364.23±7.03^a	360.47±7.99^a	*
Drum stick	242.33±0.88	235.33±8.09	240.00±3.06	234.67±4.41	235.80±3.37	NS
Breast	566.67±18.68^a	602.33±17.61^a	659.00±10.50^b	595.70±14.23^a	607.27±17.69^a	*
Wings	118.00±5.86^a	116.67±6.23^a	144.67±2.19^c	132.10±9.07^b	128.33±9.94^b	*
Abdominal fat	48.83±1.74	49.17±1.59	46.67±3.53	44.67±3.18	39.17±0.44	NS
Liver	49.33±1.86^a	53.33±1.45^{ab}	58.00±0.58^b	52.83±2.09^a	53.67±0.33^{ab}	*
Heart	13.33±0.33^{ab}	12.67±0.33^a	14.17±0.17^b	12.53±0.26^a	13.20±0.20^a	*

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).
$^{a\ b\ c}$ means having different superscript in the same row differed significantly (P<0.05); *indicates 5% level of significance.

Data on cost benefit analysis of the study are presented in table 7. The study showed no significant difference (P>0.05) in chick cost, feed cost, total feed cost, average feed consumed per bird, Amla cost, miscellaneous cost, total cost of production per broiler and sell price per kg live broiler among all treatment group. Significance difference (P<0.05) was recorded in average live weight of broiler where, T_0 registered the lowest average body weight (2.22±0.03 g) and T_2 registered the highest average body weight (2.57±0.01 g) followed by T_3 (2.39±0.03), T_4 (2.36±0.04 g) and T_1 (2.33±0.04 g) on 35th day. Significance difference (P<0.05) was recorded in sell price of per broiler among all group where, T_0 recorded lowest sell price per broiler (TK 327.07±4.12) and T_2 recorded highest sell price per broiler (TK 373.33±1.56) followed by T_3 (TK 345.87±4.90), T_4 (TK 342.73±5.08) and T_1 (TK 338.53±5.23).

Significant difference (P<0.05) was recorded in net profit per broiler among all group where, T_4 recorded lowest net profit per broiler (TK 35.53±5.07) and T_2 recorded highest net profit per broiler (TK 74.77±1.57) followed by T_1 (TK 60.42±21.50), T_3 (TK 60.42±21.50) and T_0 (TK 38.56±4.11). The study reveals that significantly higher selling price per broiler and net profit were achieved with

Amla juice supplementation. 1% Amla juice supplemented group achieved highest net profit and sold price of per broiler chicken whereas T_3 and T_4 recorded lowest net profit because of high dose of Amla cost. This study seems closely related with the findings of Gaikward *et al.* (2016), who gained highest economic profit in 1% Amla treated group. The result seems comparable with the findings of Patel *et al.* (2016), who gained highest profit in 0.4% Amla supplement followed by 0.8% Amla supplement. Patil *et al.* (2012) gained slightly lower profit in Amla treated group than control.

Table 7. Cost Benefit Analysis

Description	Treatment Group					Level of signi
	T_0	T_1	T_2	T_3	T_4	
Cost / chick (TK)	57.00±0.00	57.00±0.00	57.00±0.00	57.00±0.00	57.00±0.00	NS
Avg. feed consumed (kg/bird)	3.28±0.00	2.95±0.33	3.26±0.00	3.28±0.00	3.32±0.00	NS
Feed cost /Kg (TK)	56.80±0.00	56.80±0.00	56.80±0.00	56.80±0.00	56.80±0.00	NS
Total Feed cost (TK)	186.51±0.02	167.71±18.90	185.36±0.02	186.49±0.19	188.41±0.03	NS
Cost of Amla juice (TK)	0.00±0.00	8.40±0.00	11.20±0.00	14.00±0.00	16.80±0.00	NS
Miscellaneous cost (Tk/ bird)	45.00±0.00	45.00±0.00	45.00±0.00	45.00±0.00	45.00±0.00	NS
Total cost /bird (Tk)	288.51±0.02	278.11±18.90	298.56±0.02	302.49±0.19	307.21±0.03	NS
Average live weight (kg)	2.22±0.03[a]	2.33±0.04[ab]	2.57±0.01[c]	2.39±0.03[b]	2.36±0.04[b]	*
Sell price / kg live wt. (Tk)	145.00±0.00	145.00±0.00	145.00±0.00	145.00±0.00	145.00±0.00	NS
Sell price /broiler (Tk)	327.07±4.12[a]	338.53±5.23[ab]	373.33±1.56[c]	345.87±4.90[b]	342.73±5.08[b]	*
Net profit / broiler (Tk)	38.56±4.11[a]	60.42±21.50[ab]	74.77±1.57[b]	43.38±5.06[a]	35.53±5.07[a]	*

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).
[a b c] means having different superscript in the same row differed significantly (P<0.05); *indicates 5% level of significance.

Effect of amla juice on lipid profile

Effect of Amla juice on lipid profile of broiler are presented in table 8. Total cholesterol was significantly (P< 0.01) differed among the treatment groups where, T_0 recorded higher level of cholesterol 151.00±0.58 mg/dl blood and lower level of cholesterol (101.33±0.88 mg/dl blood) was in T_3 group. Triglycerides were also statistically significant (P< 0.01) where, T_2 recorded higher level of blood triglyceride 87.00±1.00 mg/dl and T_1 recorded level amount of blood triglyceride (42.33±0.33 mg/dl). High density lipoprotein (HDL) was statistically significant (P< 0.01) where, T_4 recorded higher value (43.33±0.88 mg/dl) and T_0 recorded lower value (36.00±0.58 mg/dl) of blood. Low density lipoprotein (LDL) was also statistically significant (P< 0.01) where, T_0 recorded higher value 99.00±0.58 and T_3 recorded lower value 49.00±0.58 mg/dl blood. Amla treated group was lower in LDL compared to control group.

Data on lipid profile are presented in table 8. The study recorded statistically significant lipid profile parameter among all treatment groups. Total cholesterol was statistically significant (P< 0.05) where, T_3 recorded lower level of cholesterol (101.33±0.88 mg/dl) and T_0 recorded higher level of cholesterol (151.00±0.58 mg/dl) of blood followed by T_1 (145.00±1.15 mg/dl), T_2 (121.67±0.88 mg/dl) and T_4 (105.00±0.58 mg/dl) respectively. Triglyceride was also statistically significant (P< 0.05) where, and T_1 recorded lowest blood triglyceride (42.33±0.33 mg/dl) and T_2 recorded higher blood triglyceride (87.00±1.00 mg/dl) followed by T_0 (71.33±0.88 mg/dl), T_3 (54.00±0.58 mg/dl) and T_4 (48.00±0.58 mg/dl). High density lipoprotein (HDL) was also statistically significant (P<0.05) where, T_0 recorded lowest HDL 36.00±0.58 mg/dl blood and T_4 recorded highest HDL (43.33±0.88 mg/dl) followed by T_2 (40.67±0.88 mg/dl), T_3 (40.67±0.88 mg/dl) and T_1 (38.00±0.58 mg/dl). Low density lipoprotein (LDL) was also statistically significant (P< 0.05) where, T_3 recorded lower value (49.00±0.58 mg/dl) and T_0 recorded higher value 99.00±0.58 mg/dl followed by T_1 recorded 88.67±0.88 mg/dl , T_2 recorded (67.33±1.20 mg/dl) and T_4 recorded (53.00±1.00 mg/dl). Amla treated group registered significantly lower blood cholesterol compared to control group.

The results of the current study revealed that Amla supplement had significantly beneficial effect on blood cholesterol, the increasing level of Amla supplement gradually decreased cholesterol level of blood. Amla supplement showed significantly beneficial effect on blood triglyceride; 1% Amla supplement recorded highest triglyceride 87.00±1.00 mg/dl of blood. Amla supplement had significantly beneficial effect on blood HDL.

Table 8. Effect of amla juice on lipid profile of broiler

Lipid profile (mg/dl)	Treatment Group					Level of sign
	T_0	T_1	T_2	T_3	T_4	
Total cholesterol	151.00±0.58^{e}	145.00±1.15^{d}	121.67±0.88^{c}	101.33±0.88^{a}	105.00±0.58^{b}	*
Triglyceride	71.33±0.88^{d}	42.33±0.33^{a}	87.00±1.00^{e}	54.00±0.58^{c}	48.00±0.58^{b}	*
HDL	36.00±0.58^{a}	38.00±0.58^{a}	40.67±0.67^{b}	40.67±0.88^{b}	43.33±0.88^{c}	*
LDL	99.00±0.58^{e}	88.67±0.88^{d}	67.33±1.20v	49.00±0.58^{a}	53.00±1.00^{b}	*

Values are expressed as mean ± standard error of means (SEM). NS: Statistically not significant (P>0.05).
[a b c d e] means having different superscript in the same row differed significantly (P<0.05); **indicates 1% level of significance.

1.5% Amla supplemented group recorded higher level of HDL mg/dl of blood. Amla had significantly beneficial effect on blood LDL, the increasing the level of Amla supplement gradually decreased LDL of blood in all treated group may be because of Amla fruits are a rich source of ascorbic acid and acts as an antioxidant to prevent the oxidation of LDL and cholesterol (Mathur *et al.* 1996), thus slows atherogenesis. This study seems closely related to the findings of Dalal *et al.* (2018), who recorded an increasing level of Amla supplementation caused decreased serum cholesterol, and gained the best result in 1% Amla supplement. They also recorded an increasing level of Amla supplemented resulted in decreased serum HDL (mg/dl) and higher. The result seems comparable with the findings Aljumaily *et al.* (2019), who found 0.1% Amla supplement recorded lower triglyceride than control; Dalal *et al.* (2018), recorded Amla supplement had similarity with control group serum triglyceride (mg/dl), they also recorded similarity in LDL (mg/dl) with control group.

CONCLUSION

The feeding value of Amla on broiler (Cobb 500) was evaluated in the poultry shed, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. The phytogenic properties of Amla as an antioxidant, anti-stress, antimicrobial, metabolism enhancer, gut microflora manipulation, and better digestion could be the reason for higher production performance, lower serum cholesterol, lower LDL higher and higher HDL, and in Amla Amla-treated group than control group. The higher live weight, better FCR and higher profit can be achieved with 1% Amla juice supplement. So, it can be concluded that Amla juice can be effectively used as an alternative to growth promoters, prebiotics, probiotics and heat stress minimizer in poultry diet. The beneficial influence of the Amla on improved performance and feed conversion ratio could also be explained due to the antioxidant activity of bioactive compounds.

In a nutshell, feeding Amla to broilers seems too good in many aspects. Mainly, it controls heat stress, lipid level, mortality, and boosts up immunity and gut health. Feeding of Amala with 1% of drinking water showed better results than 0.75%, and 1.5% under a managed broiler production system.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Quality Analysis of Kiwifruit Cultivars in Mid Hill Condition of Lumle, Nepal

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(Article received on 2 March 2025; Accepted for 20 May 2025)

ABSTRACT

This study conducted at the Directorate of Agricultural Research (DoAR), Lumle, Kaski (1650m asl) from 2022 to 2023, evaluated the quality attributes of four kiwifruit cultivars: ‘Hayward Oblong’, ‘Hayward Oval’, ‘Allison’, and ‘Bruno-2’. Mature fruits, ripened for two weeks using local ethylene-releasing agents, were analyzed for physical characteristics (individual fruit weight, 5-fruit weight, length, diameter, diameter-to-length ratio) and chemical properties (Total Soluble Solids (TSS) and Titratable Acidity (TA)). Data were statistically analyzed using ANOVA and Duncan’s Multiple Range Test. Results revealed significant genotypic variation: ‘Bruno-2’ consistently showed superior individual fruit weight (28.00g in 2022, 46.1g in 2023) and higher TSS (10.92°Brix in 2022, 15.96°Brix in 2023), while ‘Hayward Oval’ was rounder (diameter/length ratio 1.01 in 2022, 0.89 in 2023) with higher acidity (1.97% TA in 2022, 2.19% TA in 2023). All cultivars exhibited increased fruit weights in 2023, suggesting improved conditions.

Keywords: Fruit diameter, fruit weight, mid-hills, physical parameters, varieties

INTRODUCTION

Global and national significance of kiwifruit cultivation

Kiwifruit (*Actinidia spp*.) has achieved substantial global recognition, primarily attributed to its distinctive flavor profile, exceptional nutritional content and various medicinal properties. It is notably rich in Vitamin C, surpassing the levels found in common fruits such as oranges, pears, and apples. This widespread appeal underscores its growing economic significance as a high-value horticultural crop worldwide.

In Nepal, kiwifruit cultivation represents an emerging and increasingly popular perennial fruit crop among farmers, particularly in recent years. The crop is increasingly acknowledged as a high-value cash crop, presenting a viable pathway to augment agricultural income for rural communities. The agro-climatic conditions prevalent in Nepal's mid-hills and high-hills are highly conducive to kiwifruit cultivation, with optimal growth observed at altitudes ranging from 1200 meters to 2400 meters above sea level. This inherent climatic compatibility positions kiwifruit as a promising alternative for fruit growers in the country's hilly regions, especially in areas situated above the traditional citrus and apple growing zones.

Commercial kiwifruit cultivation in Nepal formally began around 2009 AD, with initial promotional efforts concentrated in districts such as Kavre and Ilam. In Ilam, for instance, cultivation has been ongoing for approximately 15 years, spurred by individual farmer initiatives and collaborative community efforts. The adoption of kiwifruit by farmers in regions like Ilam was often a deliberate response to challenges encountered with traditional crops, such as diminished earnings from corn and difficulties in cardamom sales. This shift towards kiwifruit cultivation highlights a strategic diversification in agricultural practices. Farmers are increasingly recognizing kiwifruit not merely as a novel crop but as a critical component for enhancing economic returns and building agricultural resilience. The long productive lifespan of kiwifruit plants, extending 30 to 40 years, further reinforces its role in fostering long-term income stability for farming households. This move towards high-value crops like kiwifruit reflects a broader national agricultural strategy aimed at increasing farmer profitability and potentially reducing reliance on less lucrative traditional crops, thereby contributing to overall rural economic advancement.

Recent status of kiwifruit production and productivity in Nepal

Kiwifruit production in Nepal has exhibited a consistent upward trend in both cultivated area and total output over recent fiscal years. Data from the Ministry of Agriculture and Livestock Development (MoALD) indicates a significant expansion in the total area under kiwifruit cultivation, increasing from 283 hectares (ha) in Fiscal Year (FY) 2014/15 to 2599 ha in FY 2021/22. Concurrently, national production escalated substantially from 368.1 metric tons (mt) to 7698 mt during the same period. While showing overall growth, productivity has experienced fluctuations, ranging from a low of 3.65 mt/ha in FY 2019/20 to a high of 7.59 mt/ha in FY 2021/22.

The following table provides a detailed overview of the national kiwifruit production trends:

Table 1. Kiwifruit Area, Productive Area, Production, and Productivity in Nepal (FY 2014/15 - 2021/22)

Fiscal Year	Area (ha)	Productive Area (ha)	Production (mt)	Productivity (mt/ha)
2014/15	283	52.5	368.1	7
2015/16	298	58	378	6.6
2016/17	551	186	719	3.86
2017/18	949	322	2188	6.8
2018/19	1362	492	3372	6.86
2019/20	2116	1167	4254	3.65
2020/21	2450	859	6482	7.55

Source: MoALD (2014-2021)

This data provides a clear, chronological perspective on the expansion of kiwifruit cultivation across Nepal. The structured presentation allows for a rapid assessment of the growth in both cultivated area and total production. The inclusion of productive area and productivity metrics offers a deeper understanding of cultivation efficiency over time, highlighting periods of enhanced yield or potential challenges in resource utilization. This comprehensive trend data is fundamental to comprehending the overall trajectory and health of the Nepalese kiwifruit sector.

Regionally, Ilam district stands out as a significant contributor to national kiwifruit production, accounting for approximately 28% of Nepal's total output in 2021, with 1840 tons produced out of a national total of 6482 tons. Province 1, encompassing Ilam, dedicated 1266 ha to kiwifruit production in 2021. Dolakha district also holds a notable share, with 200 ha under kiwifruit cultivation, while Ilam district recorded the highest production volume at 990 mt in 2019.

From an economic perspective, the horticulture sector, which includes fruits, contributes significantly to Nepal's agricultural Gross Domestic Product (GDP), accounting for 39%, with fruits specifically contributing 7.04% of the national GDP (MoALD 2022). Despite increasing domestic production, Nepal continues to import kiwifruit. However, the import value, approximately NPR 61 million in 2021, is estimated to be only about 8% of the value of domestically produced kiwifruit, which stood at NPR 779 million in 2021. This indicates a robust domestic market and considerable potential for further import substitution. The substantial increase in domestic kiwifruit production and the relatively low import value compared to domestic production value suggest that local demand is largely met by internal supply, and increasing production is likely both driven by and stimulates local consumption. This trend positions kiwifruit as a successful example of import substitution within Nepal's agricultural sector. Continued growth could further reduce reliance on foreign imports, conserve foreign exchange, and strengthen the domestic agricultural economy. This also implies that ongoing efforts in market access and value chain development are crucial for sustaining this growth.

Despite the growth in area and production across horticultural crops, the overall productivity of fruits in Nepal has remained comparatively low, averaging around 9-10 mt/ha in FY 2018/19. This figure is considerably lower than that of neighboring countries. This national context underscores the critical importance of enhancing productivity in specific emerging crops like kiwifruit to maximize their economic contribution.

Kiwifruit production and productivity in Gandaki province

Gandaki Province is one of the key regions where kiwifruit cultivation has been established and is subject to ongoing agricultural research. Historical data for FY 2017/18 indicates that Gandaki Province reported a total kiwifruit area of 42 ha, with 13 ha being productive. The province's production for that year reached 68 mt, achieving a productivity of 5.2 mt/ha (NCFD, 2019). At that time, Gandaki Province ranked fifth in terms of kiwifruit area and fourth in production among the provinces of Nepal.

More recent data for FY 2079/80 (2022/23) presents a notable shift in the reported statistics for Gandaki Province. The total area under kiwifruit cultivation was reported as 8 ha, with a productive area of 6 ha. Production for this period stood at 16 mt, and the yield was 2.73 mt/ha.

The following table summarizes the kiwifruit statistics for Gandaki Province across these selected fiscal years:

Table 2. Kiwifruit Area, Productive Area, Production, and Productivity in Gandaki Province (Selected Fiscal Years)

Fiscal Year	Total Area (Ha.)	Productive Area (Ha.)	Production (ton.)	Productivity (ton/Ha.)
2017/18	42	13	68	5.2
2022/23	8	6	16	2.73

Source: NCFD, 2019; MOALD, 2022/23

This table provides specific, localized data for Gandaki Province. By presenting data from two distinct fiscal years, it facilitates a direct comparison of trends within the province. A comparison of the 2017/18 data with the 2022/23 data for Gandaki Province reveals a significant reduction in reported kiwifruit cultivation area and production. This contrasts sharply with the overall national trend of increasing kiwifruit production. This apparent reduction necessitates further investigation to understand its underlying causes. It could indicate a genuine decline in kiwifruit farming within Gandaki Province due to specific local challenges, such as market access issues, disease outbreaks, shifts to other more profitable crops, or adverse climate impacts. Alternatively, it might reflect changes in data collection methodologies or reporting practices, potentially leading to an underestimation of cultivation in more recent years. It is also possible that the 2022/23 data represents only a subset or specific type of cultivation that is not directly comparable to the earlier figures. For a comprehensive understanding, this apparent decline represents a critical area for subsequent research to ascertain the precise causes and their implications for regional agricultural policy and development. Within Gandaki Province, the Directorate of Agricultural Research (DoAR) in Lumle, Kaski, situated at an altitude of 1650 meters above sea level, serves as a pivotal research site for kiwifruit varietal evaluation. Studies conducted at this facility, such as the one from 2022 to 2023, are instrumental in assessing the performance of various kiwifruit cultivars under the specific mid-hill conditions of the province, thereby directly contributing to the optimization of local production practices.

Challenges and opportunities in Nepalese Kiwifruit sector

Despite the increasing popularity and significant potential of kiwifruit cultivation, the sector in Nepal faces several notable challenges. A primary constraint is the scarcity of high-quality saplings, which often compels farmers to utilize unauthorized planting material due to the absence of effective regulatory systems for fruit nurseries. Furthermore, a widespread issue is the limited adoption of modern agricultural technologies; many farmers continue to employ traditional farming techniques and lack adequate knowledge regarding proper training, pruning, and girdling methods essential for optimal kiwifruit production. Additional challenges include the prevalence of nematodes, which can cause significant damage to kiwifruit plants, and substantial post-harvest losses resulting from inadequate handling methods in sorting, grading, and packaging. Market access and a considerable disparity between farm-gate and retail prices also pose economic difficulties for farmers. The simultaneous presence of favorable climatic conditions and rising demand, alongside critical constraints like the lack of quality saplings and limited technology adoption, points to a disconnect between the inherent potential of the sector and its realized output. The issue of unauthorized saplings highlights a systemic failure in regulatory oversight and supply chain management, while the persistence of traditional farming methods indicates a pronounced need for more effective agricultural extension services and farmer education programs. This suggests that while Nepal possesses the natural conditions and market interest for a thriving kiwifruit industry, its full potential is being hampered by structural issues related to agricultural policy, the dissemination of research findings, and the development of essential infrastructure. Addressing these bottlenecks through targeted interventions, such as the establishment of certified nursery development programs, the provision of accessible and practical training and improvements in post-harvest facilities is crucial for fostering sustainable growth and maximizing the economic benefits for kiwifruit farmers.

Conversely, the opportunities for expanding kiwifruit cultivation in Nepal are substantial. The country's diverse climatic zones offer broad suitability for kiwifruit, particularly in the mid-hills. There is also a burgeoning demand for kiwifruit, both domestically and with significant potential for export, which presents a considerable market opportunity. The sector benefits from support provided by various governmental and non-governmental organizations, including the Prime Minister Agriculture Modernization Project (PMAMP), research centers like TFRDC, NGOs, cooperatives, and local municipalities. These entities offer crucial production inputs and technical services to farmers, thereby cultivating a supportive environment for sectoral growth.

Rationale for varietal evaluation and quality analysis

The diverse agro-ecological conditions across Nepal's mid-hills necessitate localized research to identify the most suitable kiwifruit cultivars for specific environments. Studies, such as those conducted at the Directorate of Agricultural Research (DoAR) in Lumle, Kaski, are vital for evaluating the quality attributes of different kiwifruit genotypes under local conditions. This research directly addresses the critical role of genotype-environment interaction in determining fruit quality and overall performance.

The evaluation of cultivars, including ‘Hayward Oblong’, ‘Hayward Oval’, ‘Allison’, and ‘Bruno-2’, provides valuable insights into their performance across key parameters such as fruit weight, dimensions, total soluble solids (TSS), and titratable acidity (TA). Findings from such studies, for instance, indicating that Bruno-2 consistently excels in fruit weight, length, and sweetness (TSS), while Hayward Oval demonstrates superior roundness and acidity (TA%), offer clear guidance for varietal selection based on specific market preferences. This differentiation allows growers to choose cultivars best suited for particular market segments, whether prioritizing size and sweetness or shape and tanginess.

The observed increase in fruit weight across all cultivars from 2022 to 2023 in the Lumle study highlights the potential for improved agronomic practices and favorable environmental conditions to enhance overall productivity. This observation is particularly relevant given the broader national challenge of low fruit productivity in Nepal. Such research is crucial for developing and disseminating best practices that can bridge this productivity gap. By identifying cultivars that perform optimally within specific Nepalese contexts, these studies directly contribute to improving overall production volume and fruit quality. This, in turn, strengthens the kiwifruit value chain and supports the economic advancement of the nation. The approach taken in studies like the Lumle evaluation, which explicitly links cultivar traits to market preferences and distinct market segments, represents a significant progression. This moves beyond purely agronomic assessment to integrate considerations of consumer demand. This signifies a shift towards market-oriented agricultural research, where scientific findings directly inform commercial decisions for farmers and other stakeholders. By understanding which cultivars are best positioned to meet specific market demands, research can optimize profitability and ensure the long-term sustainability of the kiwifruit industry in Nepal. This is particularly important for a high-value crop like kiwifruit, where specific quality attributes and traits can command premium prices in the market.

MATERIALS AND METHODS

Experimental Site and Plant Material

This study was conducted from 2022 to 2023 at the Directorate of Agricultural Research (DoAR), Lumle, Kaski, located at an altitude of 1650 meters above sea level. Four kiwifruit (*Actinidia spp.*) cultivars '**Hayward Oblong', 'Hayward Oval', 'Allison'** and **'Bruno-2'** were selected for evaluation. All cultivars were cultivated under uniform agronomic and management practices.

Mature fruits were harvested at the fully ripe stage. Following harvest, fruits were subjected to a post-harvest ripening process for two weeks under ambient conditions using ethylene-releasing agents (ripe bananas and apples) placed in the packing cartons. After ripening, the fruits were transported to the DoAR laboratory for subsequent physical and chemical analyses.

Physical Characterization

From the harvested lot, fruit samples uniform in shape, size, and weight were selected for evaluation. Individual fruit weight was recorded using a digital precision balance. Fruit length and diameter were measured using a digital vernier caliper, and the diameter-to-length (D:L) ratio was subsequently calculated.

Chemical Analysis

The total soluble solids (TSS) content was determined using a handheld refractometer (calibrated with distilled water), with values expressed in degrees Brix (°Brix). Titratable acidity (TA) was assessed by titrating the extracted juice with 0.1 N NaOH solution and expressed as a percentage.

Statistical Analysis

Data were compiled in Microsoft Excel and analyzed using GenStat software, version 18 (VSN International, 2015). Analysis of variance (ANOVA) was employed to detect significant differences among varietal means. Mean comparisons were conducted using Duncan's Multiple Range Test (DMRT), and least significant differences (LSD) were calculated for all significant traits. Correlation analysis was also performed to explore the relationships among fruit traits, TSS, and TA.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

RESULTS AND DISCUSSION

Results

The kiwi fruit varietal trial conducted at DoAR, Lumle in 2022 and 2023 aimed to evaluate fruit quality attributes among different genotypes under mid-hill conditions. The study compared four genotypes Allison, Bruno-2, Hayward oblong, and Hayward oval on parameters such as fruit weight, dimensions, total soluble solids (TSS), and titratable acidity (TA).

In 2022, **Bruno-2** recorded the highest average individual fruit weight (28.00 g) and 5-fruit weight (140.0 g), while **Allison** had the lowest at 15.48 g and 77.2 g respectively. **Hayward oval** showed a superior diameter/length ratio (1.01), indicating a rounder shape. TSS was statistically non-significant (p=0.111), ranging from 10.60°Brix (Allison) to 11.62°Brix (Hayward oval), whereas TA showed significant differences (p=0.008), with **Hayward oval** having the highest acidity (1.97%).

Table 1. Fruit characteristics of different varieties of Kiwi-fruit at DoAR, Lumle during in 2022

Variety	Individual fruit wt.	5 fruit wt.	Fruit length (mm)	Fruit diameter (mm)	Fruit diameter/ length ratio	TSS	TA (%)
Allison	15.48 c	77.2 c	32.21 c	27.77 c	0.86 b	10.60	1.77 ab
Bruno-2	28.00 a	140. a	43.26 a	32.77a	0.76 c	10.92	1.48 b
Hayward oblong	22.76 b	113.8 b	38.52 b	30.92 b	0.80 c	11.04	1.43 b
Hayward oval	22.88 b	113.6 b	33.11 c	33.26a	1.01 a	11.62	1.97 a
Mean	22.28	111.2	36.78	31.18	0.86	11.04	1.664
CV (%)	12	12.1	5	3.1	3.8	5.6	14.4
P-Value	<.001	<.001	<.001	<.001	<.001	0.111	0.008
LSD (0.05)	3.59	18.11	2.453	1.306	0.043	0.834	0.3211

In 2023, all genotypes exhibited increased fruit weights. **Bruno-2** remained dominant with 46.1 g individual fruit weight and 231 g for 5 fruits, followed by Hayward types (35–35.7 g). Fruit length was highest in **Bruno-2** (55.4 mm), and lowest in **Hayward oval** (40.5 mm). The roundest shape again belonged to **Hayward oval** (diameter/length ratio of 0.89). TSS was significantly higher than in 2022 and ranged up to 15.96°Brix in **Bruno-2**, while **Hayward oval** had the highest TA (2.19%). Overall, **Bruno-2** was best for fruit size and sweetness, while **Hayward oval** stood out for roundness and acidity. These varietal differences offer clear direction for varietal selection based on market preference size and sweetness (Bruno-2) vs. shape and tanginess (Hayward oval).

Table 2. Fruit characteristics of different varieties of Kiwi-fruit at DoAR, Lumle during in 2023

Genotypes	Av. Individual fruit wt.(g.)	Av. 5 fruit wt.	Av. Fruit Length (mm)	Fruit Diameter (mm)	Fruit diameter /length ratio	TSS (0 brix)	TA (%)
Allison	31.3c	176.9	47.4b	35.15	0.75b	15.03	1.54
Bruno-2	46.1a	231	55.4a	37.57	0.68c	15.96	1.26
Hayward oblong	35b	174.4	45.8bc	34.59	0.76b	12.59	1.39
Hayward oval	35.7b	156.9	40.5c	36.2	0.89a	11.19	2.19
Mean	37	184.8	47.3	35.88	0.77	13.69	1.6
CV (%)	23.8	23.8	11.4	6.4	5.8	9.8	61.4
P-value	0.027	0.025	<.001	0.106	<.001	<.001	0.313
LSD (0.05)	9.72	48.49	5.96	2.542	0.049	1.476	1.081

Discussion

The current study conducted at DoAR, Lumle, over two consecutive years (2022–2023), revealed significant genotypic variation in fruit quality traits among four kiwifruit cultivars Allison, Bruno-2, Hayward oblong, and Hayward oval grown under mid-hill conditions of Nepal. The results indicated that Bruno-2 consistently outperformed other genotypes in terms of fruit weight, length, and sweetness (TSS), while Hayward oval excelled in fruit roundness (diameter/length ratio) and acidity (TA %).

These findings align with those of Ahmad et al. (2019), who reported that cultivar Bruno showed superior fruit mass and TSS under subtropical conditions in India, suggesting that Bruno-type cultivars may be more responsive to warmer microclimates and longer growing seasons. Similarly, Poudel et al. (2021) observed that fruit size and TSS in Bruno were notably higher compared to Hayward cultivars in trials conducted in eastern Nepal. This supports our findings where Bruno-2 recorded the highest TSS (15.96 °Brix) and fruit weight (46.1 g) in 2023.

The increase in fruit weight across all cultivars from 2022 to 2023 in the current study could be attributed to improved agronomic practices or favorable environmental conditions, as also noted by Ghosh et al. (2020), who emphasized the role of climate and cultural practices in fruit development of *Actinidia* species. The sharp increase in Allison's average fruit weight from 15.48 g in 2022 to 31.3 g in 2023 illustrates the strong influence of seasonal variability, which was also documented by Li et al. (2020) in their multi-year kiwifruit cultivar evaluations in China.

In contrast to Bruno-2's sweetness dominance, Hayward oval exhibited higher TA levels (2.19% in 2023), aligning with consumer preferences in niche markets that value tangy flavor profiles. According to McAneney et al. (2018), acidity contributes significantly to the sensory experience of kiwifruit and can enhance perceived freshness. This indicates that Hayward oval may cater to a distinct market segment where high acidity and round fruit shape are desirable.

Interestingly, despite Hayward oval's moderate fruit weight (35.7 g) and lower TSS, its fruit shape (diameter/length ratio = 0.89) was the highest, consistent with results reported by Biasi and Antognoni (2017), who found that consumer preference in European markets often favors rounder fruits for ease of packaging and aesthetic appeal. This suggests potential for Hayward oval in premium markets despite its lower sugar content.

The non-significant differences in TSS in 2022 but significant variation in 2023 highlight the importance of genotype-environment interaction. Studies by Wang et al. (2022) have shown that TSS and TA in kiwifruit are highly influenced by both genotype and microclimatic factors, especially light exposure and soil nutrition factors likely at play in the DoAR, Lumle trial.

Collectively, the findings of this study reaffirm the importance of varietal selection for optimizing fruit quality under specific agro-ecological conditions. Bruno-2 emerges as the most suitable cultivar for high-yield and sweetness-oriented markets, while Hayward oval holds promise for fresh fruit segments demanding rounder, more acidic fruits. The study adds to the growing body of evidence suggesting that cultivar performance in kiwifruit is highly context-specific and should be matched carefully with target market demands and site conditions.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

CONCLUSION

Kiwifruit cultivation in Nepal is a rapidly expanding agricultural sector, driven by its high economic potential and suitability to the country's mid-hill agro-climatic conditions. National production and cultivated area have shown substantial growth over the past decade, indicating a robust domestic market and significant opportunities for import substitution. While this growth is promising, the sector faces challenges such as the availability of quality saplings, limited adoption of modern farming technologies, and post-harvest losses. These issues highlight systemic gaps in agricultural policy, research dissemination, and infrastructure.

Within this national context, Gandaki Province has historically contributed to kiwifruit production. However, recent data suggests a notable decrease in reported cultivation area and production in the province, a trend that warrants further investigation to understand its underlying causes, whether they are genuine declines or data reporting discrepancies. Research initiatives, such as those conducted at DoAR, Lumle, within Gandaki Province, are crucial for identifying optimal cultivars and refining agronomic practices tailored to local conditions. This research plays a vital role in enhancing productivity and ensuring that varietal selection aligns with specific market demands, thereby maximizing economic returns for farmers. Ultimately, bridging the gap between scientific research and market-driven agricultural practices is essential for the sustainable growth and profitability of Nepal's kiwifruit industry.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Evaluating the Impact of Plant Growth Hormones on Growth and Yield of Summer Squash

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ABSTRACT

The field experiment was conducted at the Directorate of Agricultural Research, Tarahara, Sunsari, during the summer months of March to May 2023 to study the effect of plant growth hormone on the growth and yield of squash (Cucurbita pepo L.). It was a randomized complete block design (RCBD) experiment with six treatments and four replications. The treatments included T1 (NAA - 50 PPM), T2 (NAA - 100PPM), T3 (NAA - 150PPM), T4 (control), T5 (GA3 - 100PPM), and T6 (GA3 - 150PPM). Observations showed that plants treated with GA3 at 150 PPM (T6) exhibited maximum height and an increased number of branches at 45 DAS. Additionally, the highest fruit yield per plant (884.95 g) was obtained from plants receiving the recommended NPK concentration (200:180:80 kg/ha) (T6). The greatest fruit length and diameter were recorded in T1 and T6, measuring 22 cm and 77.4 mm, respectively. Growth and yield parameters were considerably lower in the control plot. Therefore, it can be concluded that treatment T6 (GA3 at GA3-150 ppm) showed a superior effect on the growth and yield of summer squash compared to other treatments, and its application in the field could help increase production and productivity.

Keywords: GA3, plant height, production, summer squash, yield

INTRODUCTION

Zucchini or summer squash (Cucurbita pepo) is one of the most significant crops of the Cucurbitaceous family among other types of squash. Zucchini is very polymorphic, which implies that it is very genetically diverse and differs in characteristics broadly. One of the squashes which are favored most during summer in the United States of America and in Europe is this squash (Usman, 2007). All the types of zucchini are plant species (Cucurbita pepo L) (Agyarko

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

and Adomako, 2007). Zucchini was a product of America, but it is currently a crop grown across markets. The total coverage land area of summer squash in Nepal is 1922 ha, with a production of 24,509 Mt and a yield of 12.75 Mt/ha (MoALD, 2022). Zucchini is a healthy vegetable that contains vitamins, minerals, as well as dietary fiber (Paris, 1996).

This is a relatively new crop in Nepal, which is progressively assuming high economic value. Zucchini farming is practiced on drip irrigated soils during spring-summer to summer-fall seasons so as to meet the huge demand of this fresh vegetable in the country and abroad markets (Contreras et al., 2017). Cucurbitaceous crops such as zucchini are very important in terms of the global economy, and they are important in the provision of important nutrients and dietary fiber to individuals worldwide. These are crops; they have different squashes, pumpkins, melon, and cucumbers, and they are used not only as vegetables but also as a fruit.) As young fruits can be consumed as cooked vegetables and curries, zucchini can also be termed as medicinal plants because of its various medicinal values(Kaur and Rattan, 2021). A short-season crop that is easy to grow, summer squash is adapted to growth in temperate and subtropical climes and is produced in most areas. The global output of summer squash was more than 6,300,000 metric tons per year in the back quarter of the eighties (FAO statistics or Fruit and Vegetable Markets, 1992).(Paris, 1996). One of the most significant treatment beliefs is the growth regulators, which are nowadays being applied in the agricultural sector and which, in most cases, alter the plant growth and the following fruiting. Growth regulators are dignified as one of the biggest treatments, used in modern days in agriculture, which in the maximum state help improve plant growth as well as the subsequent fruiting. They are used to promote seed germination, vegetative growth, flowering, and fruiting in a variety of vegetable crops as gibberellins and Auxin. One of the vitamins is vitamin C, also called growth-regulating factor, and it controls numerous processes in the cell. Gibberellic acid is one of such plant growth regulators, which has become capable of manipulating numerous growth and development phenomena in numerous crops. GA3 is another substance that promotes growth processes in plants, enhancing stem cell elongation (Akter et al., 2007). NAA (Naphthaleneacetic acid) is an artificial plant hormone, which is widely utilized in the farming industry as a means of plant development stimulation. NAA can trigger root growth on summer squash plants, and thus it is useful during transplanting or plant establishment in general, as roots are important in providing nutrients to the plants accordingly. (Dalai et al., 2015).

NAA is also reported to increase fruit set in most of the crops by inducing the production of the fruiting bodies and by augmenting the ovarian development. It may be used to aid in producing more fruits in summer squash and in getting uniform growth of fruits. NAA sometimes produces increased fruit size in summer squash when applied. This is usually a result of more cell division and stretching in the fruit tissues.

MATERIALS AND METHODS

The current experiment, which has the title of Different Plant Growth Hormones on Growth and Yield of Summer Squash, was conducted in the summer months of March to May of 2024 in the Directorate of Agricultural Research, Koshi province, Tarahara, Sunsari, NARC. The research was done to determine the right way of plant hormonal practice that suits the growth and productivity of summer squash. The harvesting was done 4 times in total. Below is a discussion of the details of materials used and methods adopted in the course of the research.

The experiment was conducted at the Directorate of Agricultural Research, Province 1, Tarhara, Sunsari, NARC. The experimental site covered Tarhara, which is located in the eastern Terai of Nepal, and the field was at an elevation of 130 meters above sea level. It was situated at 26°47'45 " N latitude and 87°28'11 " E longitude. The region receives an average annual rainfall of 1435.3mm, with maximum and minimum air temperatures of 39.2 °C and 11.8 °C, respectively (DHM, 2022).

During the time that the last crop was harvested, the land was plowed well with the help of a 4-wheel tractor with a cultivator. A rotavator was used to break clods down and thoroughly till the soil. All the land was smoothed so that stubble and weeds were totally removed in the experiments. Plots were prepared in a pre-designed pattern, a bit higher to avoid flooding. A drainage trench was also cut around the trial plot area to allow water to flow effectively when it rains.

The summer squash requires a lot of irrigation during the initial stages of transplanting, and as the plants grow, they need less water. In particular, they require watering once every 20days after transplanting. It prefers the temperature of 18-35o °C. Whereas it can survive the dry conditions in its maturity, it also requires sufficient moisture in its vegetative and flowering phases. During the vegetative to flowering, the plants are maintained irrigated at least two or three times each week to guarantee optimum growth and development.

Under Randomized Complete Block Design (RCBD), there were six treatments repeated four times and used in the experiment. The experimental field was composed of 159.74 m 2. Top 24 experimental units were created, i.e., 1.2*2.5 m2 in size.

RESULTS AND DISCUSSION

The recorded values showed that the highest temperature was recorded as 40 °C on the 15th day of transplanting throughout the period of research in the months of March to June 2008. On the same note, the lowest temperature was observed on the 9th day of transplanting, i.e., 29th of March, with 12.5 oC. Based on the figures and graph, they have shown that the highest rainfall was registered as 84.1 mm on a total of 45 days during which the squash was transplanted, i.e., the 16th of May. This was the climatic condition as a whole throughout the research period, from transplanting to harvest.

Effect of hormones on the growth of plant height

The growth hormone was proven to increase the height of the squash plants, as shown in the experiments. The treatment T6, which consisted of GA3-150 ppm, produced the tallest plants in all the stages of growth. T6 plants had an average height of 48 cm at 30 DAS, and plant height gradually increased to 62 cm at 45 DAS, 62 cm, which means that they had the highest average plant height. The treatment was found to be highly superior with the greatest statistical significance at 45DAS, which implies that the treatment had a positive effect in enhancing the healthy growth of plants. Comparatively, Treatment T2 has shown equivalent results of significant plant height improvement, yet not good enough to be compared to T4. T3 attained an average height of 59 cm, which means efficient growth but not much compared to T4. The height of the plants that were subjected to treatments T1 and T2 was obtained. The T1 group averaged 56 cm, with the T2 group averaging 61.3 cm, and both recorded a huge improvement. The hormone-free control treatment, T4, was always of the shortest plant level, the average plant height was 24 cm in length, and it is clear that in order to achieve the best results in plant growth, it is important to apply the hormone. On the whole, the findings demonstrate the effectiveness of utilizing growth hormone management strategies, especially with, in appreciably growing squash and weight.

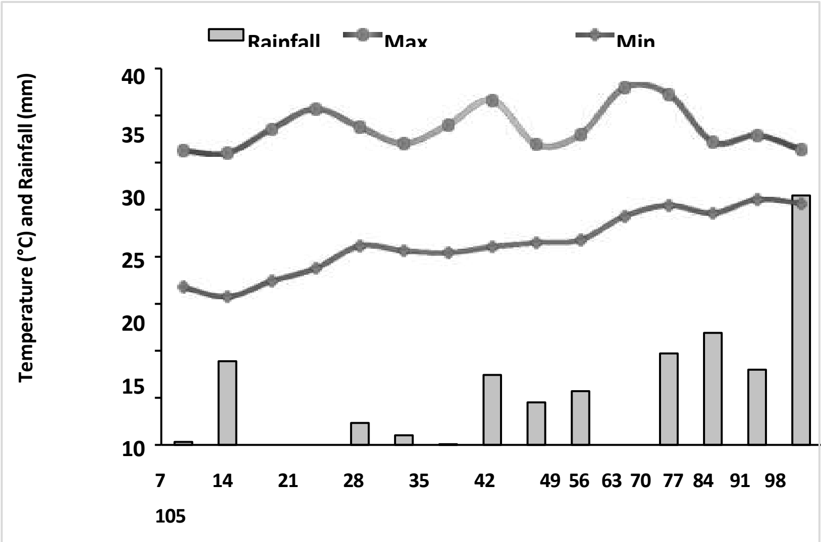

Figure 1. Climatic conditions (temperature and rainfall) during the crop period in days after sowing

Table 1. Effect of hormones on the growth of plant height

Treatment	15DAS(Average)	30DAS(Average)	45DAS(Average)
T1	29.065^{b}	39.70^{abc}	52.625^{bc}
T2	31.1^{ab}	40.95^{ab}	55.450^{ab}
T3	31.1^{ab}	40.35^{ab}	53.775^{abc}
T4	25.3^{c}	36.50^{c}	47.750^{d}
T5	29.15^{b}	37.50^{bc}	50.025^{cd}
T6	33.1^{a}	42.55^{a}	57.250^{a}
Grand Mean	29.80	39.59	52.81
CV%	7.55	5.87	5.37
SEM	0.46	0.47	0.58

Effect of hormones on the growth of branches

The experimental outcomes used to understand the influence of various doses of hormonal treatments on the development of squash primary branches were clear. T6 was the highest in all, with an average of 15.6 cm in all the stages of growth. This amounted to a total average T6 of 20.87cm of primary branches, which was much larger compared to other treatments to enhance branch development. It has been treated with T4 but was not as effective as T3. It averagely 15.6 cm primary branches, whereby at 15, 30, and 45 DAS, there were significant differences (F-value: ***), showing that though T3 enhanced branch growth as compared to the control level, it could not attain the level realized by T6. The intermediate levels of the branch counts were obtained with treatments T1 and T5, made up of NAA-50PPM and GA3-100 PPM. Means of T1 and T5 were 19.2 and 18cm, respectively, of the primary branches. There were considerable differences between both treatments, and the Treatment T2 and the Treatment T6, which were applied using the average counts of branch numbers of 20.875, respectively. Although such treatments were found to be superior to the control, their performance was weaker than T4. This was the case of treatment T4, where there was no hormone present, and the mean number of primary branches was 15.6. This outlines the importance of hormonal treatment in stimulating the growth of branches. In general, the findings reveal the usefulness of employing hormonal control measures, particularly when they are integrated with organic manures such as vermicompost, in enhancing a healthier extension/growth of perennial branches and general growth of fruits and plants.

Table 2. Effect of hormones on the growth of branches

Treatments	Average branches
T1	19.200[ab]
T2	18.000[abc]
T3	16.500[bc]
T4	15.600[c]
T5	18.300[abc]
T6	20.875[a]
Grand mean	18.08
CV%	11.325
SEM	0.42

Effect of the hormone on the number of fruits per plot

- The research on the impact of hormonal treatments on the quantity of fruits per plot showed that there were great differences in the number of fruits per plot at different growing stages (15, 30, and 45 days since planting, DAS).
- T6(GA3- 150 PPM) had the highest number of Fruits per plant (29), which was much higher as compared to other treatments.
- T6 has the largest number of fruits, and this value is 29 after T3 was achieved with 27.25. T4 gave a marginal average of 14 fruits in a single plot, whereas all the treatments gave the highest average.

- These were followed by T3(NAA-150PPM) and T1 (NAA-50PPM), which averagely 27.25 and 24 pods respectively over stages.
- The relationship between the number of fruits and the control treatment (T4) was similar, with the lowest fruits registered at every stage and an average of 14 fruits per plot.
- The advantage of such treatments in terms of the number of fruits per plot emphasizes the significance of the fruit development subject.

Effect of hormones on the growth of fruit length

The research conducted based on the comparison between the effects of different treatments on different growth stages of fertilizers on the length of fruit (cm) indicated a significant difference, especially at 30 DAS. The pod length did not vary much in most of the treatments at 45 DAS, except in the control treatment (T4), which had significantly the shortest length (14.53 cm) as compared to T6 GA3-150ppm, which recorded the longest length of fruit at 23.6 cm, which was closely followed by other treatments. Greater differences were also detected once the plants grew. T6 remained the leader in the highest length of fruits at 23.6 cm, quite above all other treatments. This was continued until T6 recorded the highest length of fruits, which averagely at 23.6 cm, respectively.

Table 3. Effect of hormone on the growth of the Average no. of fruit/ plot

Treatment	Average no. of fruit/ plot
T1	24.00^{ab}
T2	19.50^{b}
T3	27.25^{a}
T4	14.00^{c}
T5	20.50^{b}
T6	29.00^{a}
Grand Mean	22.375
CV%	15.42277
SEM	0.70

Average fruit length at all developmental stages of T6 was recorded at 23.6 cm, which was the highest amongst all treatments. Comparatively, treatments T3, T1, T2, T3, T5 were also rated relatively high in pod, similar to mitra, and the mean length of fruit in each of them was 23.6 cm, which was very not from those of treatment T6. On the contrary, the control treatment (T4) recorded the shortest fruits in every stage, with an average length of 14.53 cm. This evidence reveals the high potential of the treatment using hormones and especially vermicompost-enriched treatment (T6) on improving the length of the fruits during the growth period of the crop. It brings out the need to use hormonal approaches in ensuring maximum crop growth and productivity.

Table 4. Effect of hormones on growth of fruit length

Treatment	Average fruit length
T1	22.000[a]
T2	16.550[de]
T3	19.10[bc]
T4	14.525[e]
T5	18.050[cd]
T6	21.450[ab]
Grand mean	18.6125
CV%	8.547685
SEM	0.32

Effect of hormones on the growth of fruit diameter

The research analyzing the outcome of the influence of the various hormonal treatments on the pod diameter (cm) at different stages of growth (15, 30, and 45days after sowing, DAS) displayed the severity of the differences among the treatments. T6 (GA3-150PPM) generated the highest fruit diameter (7.74 cm) compared to the control (T4), which had a 3.78 cm diameter; this was greatly significant. TL maintained the lead in fruit diameter in all stages as the crop grew and recorded 6.27 cm fruit diameter, which made it to give average fruit diameter of 7.74 cm, the largest among all treatments.

The other treatments, which were T1(NAA-50ppm), T5(GA3-100ppm), exhibited fairly high fruit diameters as well, with the mean of 6.275 and 5.775, respectively. The control treatment (T4), on the other hand, reported smaller fruit diameters at every given time in the study period, and its concentration produced an average fruit diameter of 3.783 cm.

These results demonstrate that the application of fertilizers, particularly the enriched treatment (T6), significantly enhances fruit diameter at various growth stages. The findings highlight the importance of appropriate hormones in improving fruit quality and overall crop performance.

Table 5. Effect of hormones on growth of fruit diameter

Treatment	Average fruit diameter
T1	6.275[b]
T2	4.725[bc]
T3	4.880[bc]
T4	3.783[c]
T5	5.775[b]
T6	7.740[a]
Grand mean	5.529667
CV%	21.84
SEM	0.25

Effect of hormone on fruit weight per plot (kg)

The research on the influence of various hormonal therapies on the fruit weight per plot(kg) at different stages of growth revealed that there was significant variation between the different treatments. T6 (GA3-150PPM) recorded the highest weight of fruits per plot of 8.52 kg, and this was highly significant over the control (T4), 4.90 kg. T3 remained a top average fruit weight per plot leader (7.69 kg) as the crop grew. This was followed by other treatments (T3(NAA-150ppm), T1(NAA-50ppm) which recorded relatively high averages of fruit weight per plot (7.69 kg and 7.65 kg, respectively).

Table 6.Effect of hormone on fruit weight per plot (kg)

Treatment	Average FWPPKG
T1	7.65000[a]
T2	5.59250[bc]
T3	7.68625[a]
T4	4.90250[c]
T5	6.23000[b]
T6	8.52250[a]
Grand mean	6.763958
CV%	10.19
SEM	0.14

On the contrary, control treatment (T4) recorded the minimum value of fruit weight per plot (kg) across the experiment, and the value produced an average fruit weight per plot (kg) of 4.9 kg. treatment (T6), which significantly improves fruit weight per plot (kg) at different growth stages. The results indicate the significance of proper hormones in enhancing the quality of fruits.

Effect of hormone on average fruit weight

The research on the influence of differing hormonal regimes on the weight per single fruit (grams) of different growth periods, 15 and 30 days after sowing and 45 days after DAS, found significant differences. The fruit produced by T 6 (GA3-150PPM) was heaviest an average fruit weight being 389.2 grams, which was much bigger than the rest of the treatments.

Table 7. Effect of hormone on average fruit weight

Treatments	Average fruit weight, g.
T1	312.325[ab]
T2	291.000[bc]
T3	320.025[ab]
T4	254.500[c]
T5	307.575[b]
T6	346.550[a]
Grand mean	305.33
CV%	8.31
SEM	5.17

Other treatments, though, like T3 (NAA-150 PPM) and T1(NAA-50 PPM), had significant fruit weights, but this was always lower compared to the results that were obtained in T6. The maximum, minimum, and average weights of fruits of the T3, T1 and T2, and T5 were 320.025 grams, 312.325 grams and 291 grams, and 307.575 respectively. Conversely, fruit yield was the least in the control treatment (T4) over the whole time.

CONCLUSION

The Plant growth hormonal practices also had a great influence on the growth, yield, yield attributes, and economic factors of the summer squash. One of the methods in which application of GA3-150ppm, the recommended dose, i.e., (280:180:80) N: P_2O_5: K_2O kg/ropani, applied plot amounted to significantly high fruit weight.. Moreover, growth and yield attributes also offered improved outcomes when NAA-100ppm and GA3 were used. There was also a high net return and benefit-cost ratio of the appropriate use of these hormones compared to other sources of fertilizer.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Dynamics of Income Inequality among Rice Growers in North West, Nigeria

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ABSTRACT

These studies focused on measurement and dynamics of income inequality among rice growers in North West, Nigeria. A multi-stage sampling design was utilized to select 200 rice growers in North West, Nigeria. Primary data were used based on a well-structured questionnaire. The questionnaire was subjected to validity and reliability test. The data were analyzed utilizing descriptive statistics, Gini-Coefficient, Probit Dichotomous regression model, and Kendall's coefficient of concordance. The result shows that the mean age of the rice farmers was 43 years, the farmers had 14 years' experience in rice farming and spent an average of 11 years in attending school education. Furthermore, 80% of the farmers were married, 60% of them were male, 65% had extension contact and 57% belonged to cooperative society. Approximately, 75% of the rice growers belong to high income inequality group, while 25% of the rice growers belongs to low income inequality group. The significant drivers of income inequalities were education and experience at 1% probability level. A t-test results further showed that the t-calculated value of 17.434 which is greater than the t- tabulated value of 1.96 at 5% significance level. This suggests a statistical difference between the average cost (687,251.24) and average returns (1,875,000) of rice production. The substantial positive difference between returns and costs (1,187,748.76) strongly shows that rice production in the study area is economically viable. The challenges encountered by the farmers include lack of land ownership, lack of access to technology, inadequate credit access, poor market information and inconsistent government policy and support.

Keywords: Average return, cost, drivers, economic viability, income inequality

INTRODUCTION

The wealth and income disparity has been widening in both developed and developing nations over the last four decades (Oxfam, 2017). Economic disparity has reached severe proportions in Nigeria, and it manifests itself in the everyday struggles of the majority of the population against the outrageous wealth amassed by a select few. In contrast, nearly 112 million people lived in poverty in 2010 (Oxfam, 2017). According to the latest comprehensive data on global poverty, 736 million people (10% of the global population) lived in extreme poverty in 2015, down from 1.85 billion (35%) in 1990 (World Bank, 2018b). Economic inequality either in terms of income, expenditure, or wealth has long been recognized as major obstacle to poverty reduction at global, continental, and national levels (Ravallion, 2014). Reducing inequality within and between countries is part of the Sustainable Development Goals (SDG 10) that many countries aim to achieve by 2030 (Kunuwotor et al., 2020). A vicious cycle that undermines social cohesiveness, peace, and general development is created when income inequality, a powerful force impeding economic growth, combines with inadequate funding and capital availability (World Bank 2022). Poverty refers to the rate of change in the mean income of a population and the change in the income distribution, suggesting that poverty stems from changes in the average income or income distribution (World Bank, 2021). Poverty rates are more pronounced among smallholder farmers, who constitute the majority of the labour force in the agricultural sector in sub-Saharan Africa, particularly Nigeria (World Bank, 2021). Even with a steady increase in spending and Nigeria's ranking as Africa's seventh-largest oil producer and exporter with the highest average real GDP growth rate of 7.0, the country continues to struggle with extreme poverty and huge income disparity. Comparing Nigeria to other nations, it has some of the greatest levels of inequality in the world (World Bank 2019). Approximately 63% of Nigerians are classified as multi dimensionally poor (National Bureau of Statistics, 2022). A delicate balancing action is required in Nigeria, where the agricultural industry struggles with issues like income disparity, poverty, unemployment, insecurity, and inadequate finance (Saini & Kaur, 2022). Other issues include access to capital, extension services, improved seedlings, and land resources. The income distribution and productivity of farmers have been notably influenced by the lack of access to money, the expensive cost of improved seedlings and technology, the significant economic inequality among farmers, and the inefficiencies in government programs and efforts (Saini & Kaur, 2022). Lower-income farmers face poverty and low productivity due to a lack of finance, limited access to capital, extension services, and expensive agricultural supplies.

Estimates of inequality are crucial for policy concerns since they hinder economic growth (OECD, 2015). Because higher income groups are less likely to consume than lower income groups, there is a negative correlation between income disparity and aggregate demand. People's trust in the government is negatively impacted, and corruption and nepotism are increased (OECD,2015). There is a significant disparity in income between rural and urban areas of Nigeria (Akpan et al., 2020). Due to the fact that a high degree of income inequality creates an environment that is not conducive to economic growth and development, variances in the amount of money earned by people in rural areas are also becoming more prevalent, which may be closely related to the growing aspect of poverty, even among rural households (Akpan et al., 2020). This disparity in wealth or income between rural and urban areas typically explains rural-urban migration and impedes food security. Policymakers in Nigeria have long been concerned about the rising level of income inequality, which is not surprising given that poverty and inequality are positively correlated; as the rate of inequality rises, the poverty rate also rises. A growing body of evidence suggests that rising influence of the rich and stagnant incomes of the poor and middle class have a causal effect on income inequality crises, and thus directly detrimental to short and long-term growth. Furthermore, studies of Anyiam et al. (2023) have argued that a prolonged period of higher inequality in advanced economies was associated with the global financial crisis by intensifying leverage, extending credit excessively, relaxing mortgage underwriting standards, and allowing lobbyists to push for financial deregulation. With rice being a vital industry and one of the widely consumed agricultural commodities in Nigeria, efforts are being made to increase farmers' incomes through farming. Rice production can be used to develop the nation's economy, preserve the majority of rice farmers' foreign exchange, and enhance their revenue distribution. According to Anyiam et al. (2023), a number of microenterprises, particularly those that handle rice before and after harvest, have the potential to significantly reduce income disparity and support the economic growth of nations like Nigeria. With consumption predicted to increase at a rate of 5.1% per year and production reaching 36 million metric tons (MT) by 2050.

Rice (*Oryza sativa*) is one of the most important staple foods for about half of the human race (Food and Agriculture Organization, 2020). It ranks third after wheat and maize in terms of worldwide production, with the expansion of the cultivated land area which has witnessed steady rise in production and consumption in Nigeria. Despite several interventions of government at different level to eradicating hunger, poverty, malnutrition and boost in production especially in rice farming; poverty and vulnerability of smallholder farmers has constantly witness a decline in recent years. Government effort through poverty alleviation, access to food and reduction in income inequality has evidences of remarkable success but the impact on the livelihood of the smallholder farmers is not felt. Income inequality has been a problem affecting every nation in the world especially in sub-Saharan Africa, Nigeria is not left out (FAO, 2021). Today, two of every five sub-Saharan Africans live in extreme poverty, and they do so in the mist of the world severe wealth and income inequality (World Bank, 2019b). Income inequality possess an adverse socio-economic and political consequence with the potential to cause instability in the economy and unsustainability of resources (International Monetary Fund, 2023). Income inequality is the extent to which income is evenly distributed within a population, low income rice farmers consume majority of their farmer produce and have very little to improve on their income, while high income rice farmers expand their economies of scale to generate more income, this consequently leads to income disparity.

Rice being a vital staple food in Nigeria can serve as a means of conserving foreign exchange for the rice farmers, increase their income and also contribute to the economy at large. Small businesses especially those involved in value addition can help reduce income inequality and contribute to economic growth and development of Nigeria. In Nigeria, rice has witnessed boost in yearly production due to the initiatives and programs from the government at various tiers to boost agricultural production through ban of imported rice, subsidies, supply of improved seeds, these has resulted to rise in the price and quantity of locally produced rice. However, this has not reflected on the income of the rice farmers in the regions, income and poverty still persist among rice farmers (Anigbogu, 2019).

The main aim of this study was to measure the dynamics of income inequality among rice growers in North West, Nigeria.

MATERIALS AND METHODS

These studies were investigated in North West, Nigeria. The simple random sampling approach was utilized to select Kaduna and Kano States because rice is predominantly grown in the two states. A simple random sampling approach was utilized to select 200 rice producers within the two states. The approach was utilized because it avoids element of bias in selecting the rice growers. Secondly, the sampling approach gives the probability for every grower to have equal chance of being selected. The disadvantages of the simple random sampling approach were under-representation of certain sub-groups, difficulty accessing lists of the full population, time consuming, the process may cost individual a substantial amount of capital, cumbersome, sample selection bias can occur, and challenging when the population is heterogeneous and widely spread. The sample frame of rice producers approximately 400 respondents. The total sample number consists of 100 rice growers selected each from the two states, respectively. Primary data of cross-sectional sources were used based on a well-structured questionnaire that was subjected to validity and reliability test.

This sample number was estimated based on the established formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{400}{1+400(0.05)^2} = 200 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
n = The sample number
N = The total number of rice growers,
e = 5%

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

The data obtained were analyzed using descriptive statistics, Gini-coefficient, Probit dichotomous regression model, and Kendall's coefficient of concordance.

Probit Dichotomous Regression Model (PDRM)

The model following the research of Itse et al. (2023) and Olaitan et al. (2024) is explicitly stated as:

$$Y_i = \alpha_0 + \sum_{i=1}^{k} \alpha_k X_{ij} + \cdots \alpha_n X_n + \mu_i \qquad (2)$$

$$Y_i = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \mu_i \quad (3)$$

$$Y_i = \begin{cases} 1, if \text{ GC} > 0.5, \text{High Inequality} \\ 0, \text{if GC} \leq \ 0.5, \text{Low Inequality} \end{cases}$$

Where,

Y_i = The Dependent Variable, $(1, \text{if GC} > 0.5, \text{High Inequality}; 0, \text{if GC} \leq 0, 0.5, \text{Low Inequality}\ )$

α_0 = Constant Term

α_1 - α_6 = Regression Coefficients

X_1 = Age (Years)

X_2 = Education in Years

X_3 = Farm Size (Hectare)

X_4 = Experience in Rice Farming (Years)

X_5 = Membership of Cooperatives (1, Members; 0, Otherwise)

X_6 = Amount of Credit Accessed (Naira)

μ_i= Error Te

Gini-Coefficient (GC)

The choice of this formula follows the research of Taru and Lawal (2011). The Gini-Coefficient is given as:

$$GC = 1 - \sum_{i=1}^{n} X_i Y_i \dots \dots \dots . . (4)$$

Where,

GC = Gini Coefficient

X_i = % Share of Each Class

Y_i = Cumulative % of their Sales

Kendalls' Coefficient of Concordance (W)

The choice of this formula follows the studies of Amesimeku and Anang (2021). The Kendalls' Coefficient of Concordance (W) is stated below:

$$W = \frac{12S}{m^3(n^3 - n) - mT} \qquad (5)$$

Where:
n = Number of Attributes or Objects that is Evaluated by Respondents
m = Number of Respondents
S = Sum Overall Subjects
T = Correction Factor estimated for Tied Ranks

$$T = \sum_{k=1}^{g} (t_k^3 - t_k) \qquad (6)$$

Where;
t_k= Number for Tied Ranks for each (k) in 'g' Groups of Ties
Friedmans' Chi Square (χ^2)

$$\chi^2 = m(n-1)W \qquad (7)$$

The t-Test of Difference Between Means
This is stated thus:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (8)$$

Where,
$\overline{X}_1$= Mean of Values in Group 1
$\overline{X}_2$= Mean of Values in Group 2
s_1^2, s_2^2 = Standard Deviation in Group 1 and Group 2
$n_1 n_2$= Number of Observation in Group 1 and Group 2

RESULTS AND DISCUSSION

The Continuous Variables of Farm-Specific and Socio-Economic Characteristics of Rice Growers
The result in Table 1 provided a comprehensive overview of the socio-economic characteristics of rice-based farmers in the study area. Here's a discussion of each of the mean values and their implications:

Age

The mean age of the farmers was 43 years; this suggests that rice growing was primarily undertaken by young individuals. This young farmer can easily adopt modern technologies; as older farmers are often more resistant to change (Anthony, 2023).

Experience

The number of years a farmer spent in farming gives an indication of the practical knowledge he\she has gained on how to cope with production, since experienced farmers are better risk managers than inexperienced ones. The rice farmers had an average of 14 years of experience which reflects that the farmers have deep knowledge of local rice farming practices. This result is in consonance with the findings of Alabi et al. (2023), who corroborates that farmers with longer years of farming experience would accumulate more and better knowledge and skills in making informed farm decision.

Education

The mean years of schooling among rice growers was estimated at 11 years. According to Alabi et al. (2022) who noted that low educational attainment among farmers limits their ability to adopt modern farming technologies, understand extension services, and access financial resources, and this perpetuates low productivity.\

Household Size

Household labour helps to mitigate/ cope with the issue of scarce and costly hired labour and help reduce the cost incurred in labour purchase. The mean household size was evaluated at 8 persons; the result is in line with Anthony (2023) who reported that large household size complement labour and enhance productivity by reducing the cost of hired labour.

Farm Size

The results suggest that the average rice grower cultivates 1.43 hectares. This could mean that the farmers are smallholder farmers. Smallholder farmers are predominant in the sub-Saharan Africa.

Output

The average rice yield was estimated 3 tons per hectare, suggesting that the farmers were efficient and productive, which points that there are potentials of increase in output.

Table 1. The continuous variables of farm-specific and socio-economic characteristics of rice growers

Variables	Description of Variables	Mean	SD
Age	Age of the respondents (years)	43	07.92
Experience	Number of years spent in rice farming	14	5.03
Education	Number of years spent in school education	11	2.86
Household Size	Number of people per household	8	3.09
Farm Size	Cultivated Farm Land in Hectares	1.43	0.90
Output	tons/hectare	3	0.89

Source: Field Survey (2024), SD-Standard Deviation

The Categorical Variables of Socio-Economic Features of Rice Growers

Marital status

Table 2 revealed that most of the respondents are married (80%), with smaller proportions being single (20%). Marital status is often associated with greater responsibility and household labour availability. This is also consistent with the studies of Alabi (2023) who observed that marital status enhances social stability and increases the likelihood of resource pooling for agricultural activities.

Gender

The result shows that 60% of the farmers were male, while 40% were male. This could imply that men play a significant role in agricultural activities.

Extension Contact

The result reveals that 65% of rice farmers reported having contact with extension agents, while 35% did not. While, a majority of farmers benefit from extension services, the remaining 35% highlight gaps in coverage. This result in consistence with the study of Oluwole and Odebode (2015) who reported that farmers who regularly interact with extension agents are more likely to adopt modern technologies, improve their efficiency and productivity.

Cooperatives Organization

The result revealed that 57% of the rice farmers were members of farm-based organizations, while 43% were not. Membership in such organizations facilitates access to inputs, credit, and collective marketing opportunities. This study is in agreement with outcomes of Barungi et al. (2016) who observed that participation in farmer groups enhances resource access and provides a platform for collective action, which is critical for smallholder farmers.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Table 2. The Categorical Variables of Socio-Economic Features of Rice Growers

Variables	Frequency	Percentage
Marital Status		`
Single	40	20.00
Married	160	80.00
Gender		
Male	120	60.00
Female	80	40.00
Extension Contact		
Yes	130	65.00
No	70	35.00
Cooperatives		
Yes	110	55.00
No	90	45.00
Total	**200**	**100.00**

Source: Field Survey (2024)

Measurements of Income Inequalities among Rice Growers

Table 3 displayed a significant disparity in income levels among rice growers with 75% of rice growers experiencing high inequality, while 25% reflecting low inequality. This outcome is in agreement with the research of Anyiam et al. (2023).

Table 3. Measurements of Income Inequalities among Rice Growers

Measurement	Frequency	Percentage
≥ 0.5 (High Inequality)	150	75.00
< 0.5 (Low Inequality)	50	25.00

Source: Field Survey (2024)

Dynamics of Income Inequality among Rice Growers

The result of the Probit regression analysis as displayed in Table 4 revealed that the pseudo R square value of 0.7402. This indicates that the model explains approximately 74% of the variations in the outcome variable. The Log likelihood function value of -152.82 indicates the overall model is highly significant at 1% probability level. The chi square of 6 degrees of freedom and p-value of 0.000 further suggests that the independent variable influence the probability of the outcome.

Education
The result shows that education is positive and significant at 1% probability level. This suggests that for each additional year of schooling, output is expected to improve by 0.3472 units. This is in line with the findings of Alabi et al. (2021), who reported that education helps farmers to make better informed decision and increase welfare and productivity.

Experience
This finding shows that an increase in total crop output is associated with an increase in experience by 0.3696 units. This relationship is highly statistically significant at the 1% probability level. This suggests that the farmer enjoys increased income, improved food security and poverty alleviation in the study area.

The Constraints Faced by Rice Growers
The results of Kendalls' coefficient of concordance as presented in Table 5 revealed a significant, moderate, consensus among rice growers regarding the major challenges they encountered. Lack of land ownership was seen as the most critical issue, aligning with studies of Ani et al. (2022) who highlighted that land tenure security as a fundamental factor influencing agricultural productivity and investment.

Lack of access to technology (Rank 2) and lack of access to inputs (Rank 3) underscores the persistent challenges in agricultural development, particularly in developing countries. Limited access to modern farming technologies (e.g., improved seeds, machinery) and essential inputs (e.g., fertilizers, pesticides) significantly hinders productivity (World Bank, 2020). Inadequate credit accessed (Rank 4) remains a significant constraint with a mean of 24.48. Access to affordable credit is crucial for smallholder farmers to invest in inputs, technology, and other productivity-enhancing measures (Alabi et al., 2023).

The high mean suggests that financial constraints continue to impede rice farming operations in the study area. Poor market information and access ranked 5 and lack of education and training ranked 6 with a mean of 23.30 and 23.25, respectively, these highlights the importance of market linkages and human capital development. The farmers need timely and accurate market information to make informed decisions, also education and training are essential for adopting new techniques and improving farm management (Alabi et al., 2023). The lower ranks of inconsistent government policy (Rank 7) and lack of government support (Rank 8), with mean values of 23.24 and 23.12, respectively while still representing challenges, were perceived as less critical on average compared to the other factors. However, inconsistent policies can create uncertainty and discourage investment in the agricultural sector (Jayne et al., 2018).

Table 4. The Results of Maximum Likelihood Evaluation of the Probit Regression Model

Variables	Parameters	Coefficient	Standard Error	$P > \|Z\|$
Constant	α_0	2.834***	0.3080	0.000
Age	α_1	0.0472	0.0787	0.834
Education	α_2	0.3472***	0.0423	0.000
Farm Size	α_3	0.0571	0.0713	0.906
Experience	α_4	0.3696***	0.1827	0.000
Cooperatives	α_5	0.1732	0.3330	0.782
Amount of Credit Accessed	α_6	0.0382	0.0955	0.820
Diagnostic Statistics				
LR_{χ^2} (6)	69.47***			
Pseudo R^2	0.7402			
LLF (Log Likelihood)	-152.82			
Prob $>_{\chi^2}$	0.00000***			

Source: Field Survey (2024),

*Significant at $(P < 0.10)$., **Significant at $(P < 0.05)$, ***Significant at $(P < 0.01)$.

Difference Between Costs and Returns in Rice Farming per Hectare

The result displayed in Table 6 shows that the t- calculated value of (17.434) is significantly greater than the t- tabulated value of (1.96), this suggests that there is a statistical difference in the cost and returns in the rice farming per hectare at 5% significant level.

This implies that the observed difference between the average costs (₦687,251. 24) and average returns of (₦1,875,000) further suggests that the rice production in the study area is economical viable. This aligns with the studies of Anthony (2023) who noted that rice farming is profitable.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Table 5. The Kendall's Coefficient of Concordance Results of the Challenges Faced by Rice Growers

Challenges	Overall Rank	Mean Rank Score
Lack of Land Ownership	1	25.87
Lack of Access to Technology	2	25.64
Lack of Access to Inputs	3	25.43
Inadequate Credit Accessed	4	24.48
Poor Market Information and Access	5	23.30
Lack of Education and Training	6	23.25
Inconsistent Government Policy	7	23.24
Lack of Government Support	8	23.12
	200	
Kendall's Coefficient (W)	0.394	
Chi Square	547.31	
df	7	
F-Critical	37.81	
F-Calculated	127.032	
Asymptotic Significance e	0.0000	

Source: Computed from Field Data (2024)

Table 6. The t-Test of Difference Between Costs and Returns in Rice Farming per Hectare

Variable	Estimates
Costs (Naira)	687,251.24
Returns (Naira)	1, 875,000
Standard Deviation Cost	273,915.62
Standard Deviation Returns	689,539.96
t-Calculated	17.434
t-Table	1.96

Source: Field Survey (2024)

CONCLUSION

The study revealed that the difference between the average costs of (₦687,251. 24) and average returns of (₦1,875,000) was estimated at (₦1,187,748.76), this further suggests and highlights that the rice production in the study area is economical viable and profitable if resources are optimally utilized. All stakeholders must therefore endeavor to play their part in ensuring that policies and initiatives are targeted to farmers to encourage the rice production, boost productivity, enhance income and welfare of the farmers.

The result revealed that 75% of the rice farmers experience high income inequality which was further reinforced that disparity in socio-economic characteristics such as access to credit, education, experience, cooperative membership and land size contributed to income inequality thereby impacting on the economic disparity of welfare, income, and poverty status of the farm household.

The finding is also in agreement with the hypothesis that significant difference exist among the challenges faced by rice farmers in the study area, particularly with land ownership, technology, credit and input access. The consequences of income inequality include poverty and food insecurity, reduced agricultural productivity, and social and economic disparities.

RECOMMENDATIONS

In addressing the income inequality among rice growers, the following recommendations were made:

(i) Land Reforms: Ensure equitable access to land through land reforms which can help reduce income disparities among rice groups
(ii) Investment in Infrastructures: Investment in infrastructures like roads, irrigation facilities, storage facilities, access to market, and power supply
(iii) Access to Credit and Financial Services: Ensure adequate supply of credit to rice groups at low interest rate, this will enable the rice groups to invest in their farms and enhance their productivity
(iv) Agricultural Extension Services: The rice groups should be trained and provided with technical assistance, this will help them utilized new technologies, enhance their income and productivity.
(v) Market Access and Information: The rice groups should be supported with access to market through cooperatives association and market information services, this will enable the rice growers to sell their produce at better prices
(vi) Policy Interventions: Government should provide policies such as subsidies, tax break, supply of improved seeds, fertilizer subsidy, and subsidy on agrochemicals this will address income inequality and support peasant farmers.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

An Overview of Bee Keeping in Rupandehi District, Nepal over Seven Years

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ABSTRACT

Beekeeping is a high-value income-generating agricultural activity in Nepal. However, there is a lack of intensive information related to beekeeping. We conducted a comparative study among the beekeepers in 2014 and 2021 to assess the status of bee keeping in a gap of seven years in Rupandehi district. Result revealed a slight increase in honey production averaging 21.35 and 25.45 kg/ year/hive in 2014 and 2021, respectively. The average number of beehives per beekeeper increased from 39 in 2014 to 42 in 2021. We report that primary bottlenecks to beekeeping are lack of foraging area, pesticide poisoning, pests, diseases, and lack of government subsidiary. The lack of foraging area was mainly attributed to rapid population growth and unplanned urbanization. The problem of pesticide intoxication was found to worsen during 7 years in the study area. Governmental incentives to beekeepers, and stricter rules on pesticide application could encourage beekeepers to get involved in bee keeping. Rigorous documentation on beekeeping can help realize the potential of honey production, and to come up with efficient mitigation measures towards problems associated in beekeeping.

Keywords: Beehives, foraging, frequency of harvesting, honey, pesticides

INTRODUCTION

Beekeeping contributes less than 1% of National GDP, but it is one of the most profitable occupation in Nepal (Devkota, 2020). Besides, beekeeping is a key factor to sustainable agriculture and helps uplift the production rate of agricultural outputs through pollination (Kaluza et al., 2018). Beekeeping is promoted globally as a flourishing instance of an alternative livelihood project (FAO, 2011). Beekeeping is traditionally associated with Nepalese agriculture and animal husbandry in a subsistence scale. In Nepal, bee keeping holds a great prospect of income generation and is being promoted for marginalized farmers (Schouten, 2020). Beekeeping as an enterprise is accepted and adopted at a growing rate in Nepal in recent years which is the lucrative source of income (Adhikari, 2018). The data available on statistical information on Nepalese Agriculture suggests that there is an increase in number of beehives from 225,000 to 242,000 and honey production from 3,000 MT to 3,990 MT in the period of 2014/2015 to 2018/19 (MoALD, 2020). Eighty percent of the total pollination is carried out by insects and bees are responsible for 80% of the insect pollination (Thapa, 2006). *Apis mellifera* L. is highly valued in the ecosystem as it contributes for the pollination services in the extensive agricultural and food crops thereby holding the position being a single species serving as the most frequent pollinator and possessing the positive association with the crops globally (Cane et al., 2006; Garibaldi et al., 2013). Beside *Apis mellifera*, an exotic species of honey bee, four native species of honey bees are found in Nepal, namely: *Apis laboriosa, Apis dorsata, Apis florea,* and *Apis cerana*. Bee keeping of *Apis cerana* started to practice in 1960 and *Apis mellifera* in 1990 after it was introduced from Europe in Nepal (Thapa et al., 2018). Besides nutritional importance, the bee products such as honey, propolis, bee venom, royal jelly are known to have nutraceutical benefits. In Nepal, most of the honey produced are multifloral and some unifloral honey is also in existence. Starting up the business with low financial inputs and resources, one can get fast return within a year has tempted the people towards beekeeping.

Natural enemy of the bee, climate change, bee diseases, lack of foraging land, pesticide poisoning and insufficient financial reserves are the major factors that has left behind bee keeping in jeopardy (Aryal et al., 2015; Bhattarai et al., 2020). The expected gain has not been received by the beekeepers because of existing challenges including logistic and financial constraints. Despite possessing tremendous benefits, the systematic study and documentation of the findings is modest, which is a major setback for further understanding the prospects and bottlenecks of beekeeping. There is still paucity of bee keeping development in the context of Nepal. There is a need of farsighted vision and explicit policy for better management and development of sector of bee keeping in Nepal. Currently, beekeeping studies are fewer in comparison to cereal and other cash crops in Nepal. There is no extensive record of research activities in beekeeping in Rupandehi district, which is one of the potential district for bee keeping. Our study emphasizes on understanding the status of bee keeping, assess its challenges and strengths, provide succinct summary of beekeeping equipment used by beekeepers and to highlight the change in production and management practices in beekeeping over 7 years in Rupandehi district. The current study attempts to point out the existing setback for the successful beekeeping enterprise.

MATERIALS AND METHODS

Study Area

The survey was conducted in Rupandehi district of Terai region as it is one of the potential districts for beekeeping at Western Nepal. We conducted a survey in 2014 and a follow up survey after seven years in 2021 with the farmers associated with *A. mellifera* for bee keeping. A. mellifera is the most commonly reared bee in Nepal among beekeepers (Aryal & Dhakal, 2020). The survey sites of beekeepers in 2014 were Butwal Sub-Metropolitan municipality (former Sau-Farsatikar), Sainamaina municipality (former Saljhundi), Kanchan rural municipality (former Gajedi), Devadaha municipality, Siyari rural municipality (former Mainahiya VDC), Siyari (former Chiliya VDC), Siddharthanagar Municipality and Tillottama Municipality (former Shankarnagar VDC) of Rupandehi. These sites were chosen based on the higher number of beekeepers in the area. In 2021, the survey sites were extended to 13 local level units viz. Butwal Sub metropolitian city, Devdaha Municipality, Lumbini Municipality, Sanskritik Municipality, Sainamaina Municipality, Siddharthanagar Municipality, Tilottama Municipality, Gaidahawa Rural Municipality, Kanchan Rural Municipality, Marchawari Rural Municipality, Mayadevi Rural Municipality, Omsatiya Rural Municipality, Siyari Rural Municipality and Suddodhan Rural Municipality due to increased number of bee keepers in these areas. The Map of Nepal showing Rupandehi district and its all local level bodies is shown in figure 1(A) and 1(B).

Study population and sample size

A total of 34 and 89 bee keepers were randomly selected in 2014 and 2021 respectively. As there were less bee keepers in 2014, the sample size was 34 where it was increased to sample size of 89 in 2021 due to increase in number of bee keepers. We categorized beekeeping into three classes as

a. **Small scale** (Hobby beekeepers)- less or equal to 10 hives,
b. **Medium scale** (taking it as side business)- 11 to 50 hives,
c. **Large scale** (Beekeepers taking it as main business)- more than 50 hives**.**

Data collection

In order to obtain primary data, interviews were conducted with bee keepers and with key informants. Key informants were chosen based on information from Agriculture Knowledge Centre (Former District Agriculture Development Office)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

and Federation of Nepal Beekeepers. Face to face interviews were conducted with respondents at their home with the questionnaires which were pre-tested to 10% of respondents. In the same way, key informants were interviewed. The information obtained from the interview were cross checked during the focus group discussion (FGD). Progressive farmers, Agriculture Knowledge Centre officials, NGO staffs and cooperative officials who were chiefly engaged in bee sector were chosen as key informant person. All respondents consented to the interview.

Data analysis

Collected data were tabulated using MS-Excel Ver. 2016. Graphical representation of the data was done using MS Excel and maps were created using Arc GIS v 10.8

RESULTS AND DISCUSSIONS

Socio-demographic characteristics

The details on socio demographic character of respondents in 2014 and 2021 is shown in table 1.

Table 1. Socio-demographic characteristics of beekeepers in Rupandehi district, Nepal in 2014 and 2021

Description/ Year	2014 (N= 34)	2021 (N= 89)
Age of respondents		
18-30	11.76%	12.36%
31-43	32.35%	20.22%
44-56	47.06%	33.71%
57-69	8.82%	33.71%
Gender		
Male	94.12%	77.53%
Female	5.88%	22.47%
Marital status		
Married	97.05%	95.50%
Unmarried	2.95%	4.5%
Educational status		
Illiterate	5.88%	8.99%
Basic Level Education	52.94%	50.56%
Secondary level education	32.35%	19.1%
University	8.82%	21.35%

'N' refers to total number of respondents

In 2014, out of 34 respondents, only 8.82% (n=3) of the respondents belonging to the age group of 57- 69 years were involved in beekeeping. However, in 2021, out of 89 respondents, 33.71% (n= 30) of age group 57-69 years actively engaged in beekeeping in 2021. A decline in the involvement of people of age group (44 -

56 years) in beekeeping from 47.06% in 2014 to 33.71 in 2021 was observed. Only 4 respondents out of 34 in 2014 and 11 out of 89, in 2021 were in the age group of 18- 30. Our results suggest that the young age group is not actively engaged in beekeeping. Majority of the respondents were male (n=32) in 2014 and (n=69) in 2021. Only in two out of 34 households, female were found to be actively engaged in bee keeping in 2014 and 20 out of 89 in 2021. This suggests an increase in the role of women in beekeeping in the span of seven years. Almost all beekeepers were found to be married i.e. 33 (97.05%) in 2014 and 85 (95.50%) in 2021. People who acquired basic level education were frequently recorded in both study years i.e. 52.94 % in 2014 and 50.56% in 2021. However, there seemed considerable involvement of the people with University education in the recent study (21.35%) while it was recorded only 8.82% involved in 2014 in Rupandehi district of Nepal. Two respondents in 2014 and eight respondents in 2021 had no former education.

Number of hives

There were 39 beehives per household on average in 2014 and 42 beehives per household on average in 2021, suggesting an increase in the number of bee hives. This increase in the beehives can be attributed to the increased attraction towards beekeeping. The average number of bee hives in 2021 in Rupandehi district was similar to the average number of bee hives in Chitwan (Bhattarai et al., 2020). Shrestha (2017) reported 34.54 hives per household in Bardiya which is slightly less than reported in our study in both years.

In 2014, 23.5% (n=8) of the participating farmers were found to be hobby beekeepers and reared bees for their recreational purpose in subsistence level with ≤ 10 bee hive. However, in 2021, the number of bee hives increased considerably to 41.57% (n=37). Likewise, the majority of the respondents, 64.7 % (n=22), were categorized as medium scale beekeepers, with 11 to 50 beehives reported in 2014 and 32.58% (n=29) in 2021. There was a decreasing trend among medium scale beekeepers from 2014 to 2021. In 2014, 11.8% (n=4) of the farmers were producing honey in large scale, taking it as a main business in commercial level which increased to 25.84% (n=23) in 2021, suggesting the increased interest in beekeeping in a commercial scale.

Honey production

Average honey production was 25.45 kg/ year per hive in 2021, an increase from 21.35 kg/year/hive reported in 2014 (figure 3). The average annual honey production in 2021 per hive from *A. mellifera* in the study area was similar to 24.064 kg per hive in

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Chitwan (Bhandari & Kattel, 2020), and 23.5 kg honey per hive per year in Dang as reported by Budhathoki-Chhetri et al (2021). The honey production in our study area was slightly less than in Bardiya where 34.6 Kg/hive was reported by Shrestha (2017), 36 kg/ hive/year in Chitwan district as reported by Dhakal et al. (2017) and 40.71 kg/hive/year in Karaj state, Iran (Vaziritabar & Esmaeilzade, 2016). These results signify more production than that of our study area. We found that Honey and bee wax were the major bee product and by product, respectively.

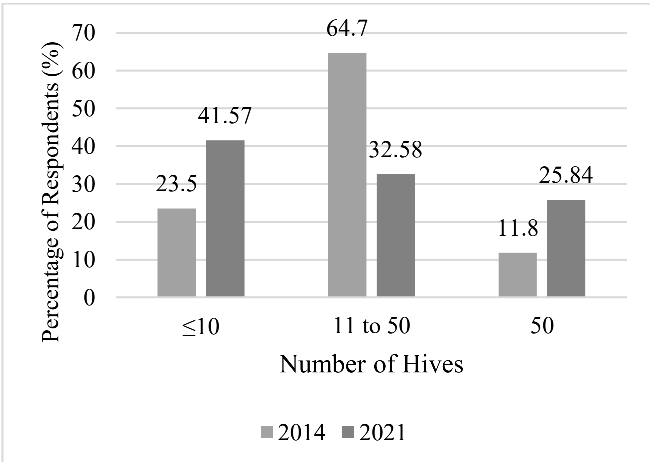

Figure 1. Beekeepers expressed as percentage of total respondents with their hive number in Rupandehi district in 2014 and 2021

Frequency of honey harvesting

Management practices coupled with number of bee hives, foraging of bee, species of honey bee, climatic conditions are the factors that influence the production of honey from honey bee and so the harvest times (Bhusal & Thapa, 2005; Budhathoki-Chhetri et al., 2021). The frequency of honey harvesting by the beekeepers in 2014 and 2021 is shown in table 2. It was found that middle scale beekeepers harvest the honey 4-6 times in a year but with proper foraging honey could be harvested up to 8 times a year. Similarly, most of the small scale or hobby keepers harvested 2-3 times a year. Our study conducted in 2014 showed that 17.65% (n=6) beekeepers harvested the honey less than 4 times a year, 55.88% (n=40) harvested 4-6 times a year and 26.47% harvested 7-8 times. Moreover, harvest of the honey for less than 4 times was done by 52.8% (n=47), 4-6 times by 44.94% (n=40) and 7-8 times by 2.25% (n=2) beekeepers in 2021. Lack of foraging area and increased insecticide application in agricultural field can be the reason for decrease in harvest time in 2021 compared to 2014.

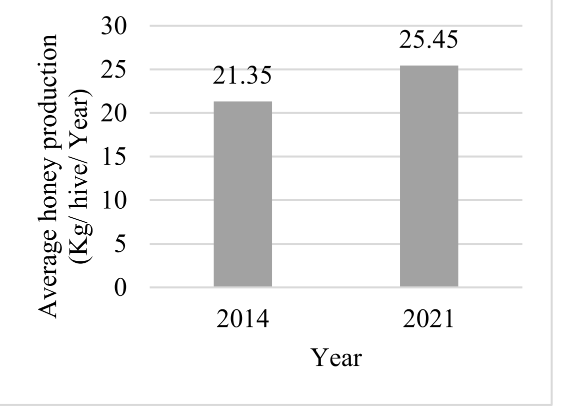

Figure 2. Average honey production (Kg/hive/year) in 2014 and 2021 at Rupandehi district, Nepal

Equipments used for bee keeping

Most of the bee keepers had essential equipments needed for the smooth beekeeping practices. Of the surveyed farmers, majority of the farmers were equipped with necessary tools in the study carried in both years ie. 2014 and 2021 (table 3). It was found that 100% of the surveyed farmers had knives and honey collecting buckets in both study years. Second most available equipment that respondents owned was brush (94.11%), followed by bee gloves (79.41%) and smoker and bee viel (64.70%). Few farmers (32.35%) had honey extracter in 2014.

But according to the some respondents, the use of smoker was concerning, as farmers associated it with the mortality of the bees. We reported that the use of bee gloves was not common among beekeepers in both years, even when the beekeepers own it. Farmers surveyed in both years percieved that working with bare hands during hive management and harvesting was more ‘bee-friendly’. 88.76% of the respondents had brush and bee gloves (88.76%) followed by bee veil (87.64%) and smoker being 84.26% in 2021. We report 62.92% farmers had honey extractor, which depicts that in comparison to other equipment, bee keepers had few honey extractors in 2021.

The brush was used for cleaning the hive and bee veil during the peak harvesting period. Only few respondents had honey extractor in the study carried in both years.

The commerical beekeepers, taking beekeeping as a main profession had honey extracting device and used it when required. Small scale farmers borrow it from the large scale farmers and cooperative during honey extracting period. It was found that some of the medium scale farmers had their own honey extractor and some of them bought it jointly or from cooperative and used it as per need during harvesting seasons. After extracting honey, the by product wax was recycled to make the frame foundation for next generation bees.

Table 2. Honey Harvesting times by the bee keepers in 2014 and 2021 at Rupandehi district, Nepal.

No. of Harvest per year	2014	2021
<4	17.65%	52.8%
4 to 6	55.88%	44.95%
7 to 8	26.47%	2.25%

The major production problem in Ethiopia was high cost and lack of availability of modern equipment and accessories (Abebe et al., 2016), and it represents the dire necessity of availability of equipment and accessory at low cost. However in our case, most of them had basic equipment. In both years, farmers had concerns with government for not subsidizing bee equipment.

Honey buyers

In 2014, it was reported that the 44.11% (n=15) of the respondents sold the produced honey to local people and did not involve a middleman when selling to the wholesaler. But majority of the respondent 55.89% (n=19) were reported to sell their products to local people cum wholesaler (Table 4). Likewise, in 2021, we found similar findings in terms of sale of the honey to the wholesaler (table 4). Only a single respondent was reported to sell the honey directly to the wholesaler (Table 4). However, there was an increase in honey sales to the local people (77.52%). There was a marked reduction in honey sales to local people and wholesaler (Table 4). The selling was preferred to the local people only because the production was not high and honey demand was high in the local community. Local people visited the beekeepers themselves to buy honey reducing transportation costs to the farmers. Similar result was reported by Shrestha (2017) in Bardiya, Nepal. We found that the beekeeper in Rupandehi district were not involved in long marketing channel of their products and no involvement of middlemen was reported.

Table 3. Respondents with their equipments in 2014 and 2021 at Rupandehi district, Nepal

Equipment	2014 (N= 34)		2021 (N= 89)	
	Yes	No	Yes	No
Smoker	64.70% (22)	35.30% (12)	84.26% (75)	15.74% (14)
Bee veil	64.70% (22)	35.39% (12)	87.64% (78)	11.24% (11)
Brush	94.11% (32)	5.89% (2)	88.76% (79)	11.24% (10)
Bee gloves	79.41% (27)	20.59% (7)	88.76% (79)	11.24% (10)
Knife	100% (34)	0% (0)	100% (89)	0% (0)
Honey collecting bucket	100% (34)	0% (0)	100% (89)	0% (0)
Honey extractor	32.35% (11)	67.65% (23)	62.92% (56)	37.08% (33)

*Figures in parenthesis denote the corresponding number

Table 4. Honey buyers in Rupandehi district, Nepal in 2014 and 2021

Honey buyers	2014	2021
Local	44.11%	77.52%
Wholeseller	0	1.13%
Local+ Wholeseller	55.89%	21.35%

Foraging

Foraging is a peculiar characteristic of honeybees which refers to the association between honey bee colony and the surrounding environment whereby honey bees extract pollen, nectar and resin from the plants. Foraging has tremendous benefits behind it as it encourages not only for the plant pollination but also useful for colony (Abou-Shaara, 2014). Foraging was found to have a remarkable increase in the number of bees and honey production, thereby increasing the harvest per year. It is deemed that the foraging activity of honeybees starts in the morning time and ends in the evening time.

Our study conducted in 2014 revealed that 24 (67.65%) farmers practiced foraging in honeybee but there was a reduction in practice of foraging of honeybee (60.67%) in 2021 (figure 4). The main reason for this reduction in foraging practice was found to be a reduction in foraging land. Reduction in foraging land was due to clearing of *Dalbergia sissoo* Roxb tree from the Churiya range which seriously damaged the habitat of the important bee flora [Rudilo, (*Pogostemon glaber* Benth)] which was an important source of nectar. In both studies, large scale farmers and medium scale farmers were observed to transport their bee hives for foraging purposes during off season. Most of the farmers were observed to take their beehives to Dang, Chitwan, Kapilvastu and Mahottari for foraging. The beehives were kept in the jungles which were rich in foraging trees (*Dalbergia sissoo* Roxb.*,* *Pogostemon benghalensis* (Burm. f.) Kuntze, *Rhododendron ferrugineum* L.*,* *Diploknema butyracea* (Roxb.) H.J.Lam, *Fagopyrum esculentum* Moench, *Litchi chinensis* Sonn., etc.) and mustard was found to be the main cash crop during the foraging season. During foraging, transportation was the main problem which often caused mechanical injuries to bee frames, increasing stress in bee, and thereby reducing the production significantly. There was a higher honey production in migratory system of beekeeping in comparison with non-migratory system. Thus, respondents realize foraging is a crucial practice for commercial honey production. Feeding material has direct and positive role to affect the honey production (Devkota et al., 2016; Shrestha, 2017). Knowledge on bee flora along with its flowering time and behaviour is vital for the bee keepers (Rijal et al., 2018). Proper and sufficient knowledge is fundamental requirement before starting of bee keeping (Bista & Shivakoti, 2001; Adhikari & Ranabhat, 2011).

Involvement of the respondents in Bee keeping training

Various trainings were made available to the farmers by various Non-Governmental Organizations (NGO's), Agriculture Knowledge Centre, Federation of Nepal Beekeepers to provide routine trainings related to apiary and bee keeping to the farmers to increase their positive attitude, knowledge, practice and behavior towards apiculture. Among the surveyed farmers in 2014, 76.48% (n=26) had trainings in apiculture but 23.52% (n=8) had not received any form of trainings (Figure 5). This result is consistent with findings of Bhandari (2020) in Pyuthan district where majority of the farmers were trained. There was change in involvement of the farmer in training of bee keeping in 2021 and we reported only 65.16% (n=58) of the farmers were benefitted by training while 34.84% (n=31) farmers were deprived of any forms of training (Figure 5). Those who did not receive any form of training conducted the bee keeping on their personal experiences and guidance from farmers nearby. Paudel (2003) suggested that local institution should be involved in providing training on latest and affordable technology of bee keeping for the farmers.

Constraints

Pest problem faced by beekeepers of Rupandehi district, Nepal in 2014 and 2021 is shown in table 5. Of the beekeepers surveyed, we report all the beekeepers found hornets (Vernacular name: *Aringal*) as major insect threatening their enterprise in both 2014 and 2021. The problem was followed by mites, ants, bird, wax moth, lizard, rats and squirrel in 2014 and by ants, bird, lizard, mites, wax moth, squirrel and rats in 2021. The problem of ants was minimized by stacking the foundation on the bowl containing water or oil.

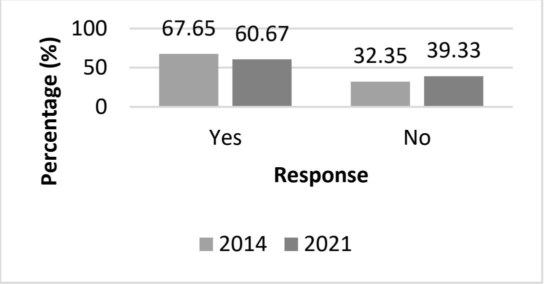

Figure 3. Involvement of beekepers of Rupandehi district, Nepal in foraging in 2014 and 2021

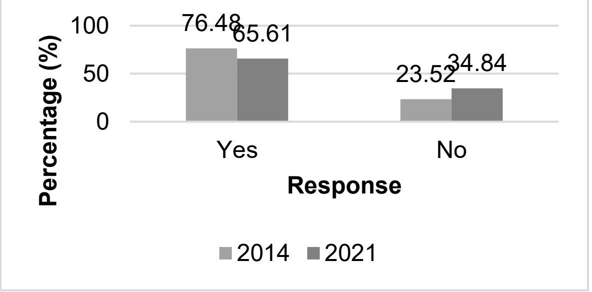

Figure 4. Beekeepers of Rupandehi district, Nepal involved in bee keeping training in 2014 and 2021

The problem of mites seemed to decrease, and the issue of ants was increased in 2021 considerably compared to 2014. We came to know that mites were a minor problem for small beekeepers, and it was a serious bottleneck for both medium and large beekeepers. Similarly, in contrast to the findings obtained from 2014, the problem of rat and squirrel experienced by beekeepers decreased from 32.29% to 3.37% and 26.24% to 7.86% respectively in 2021. This shows that the problem of rodents in bee keeping is not a major problem in bee keeping in present days, but it was one of the major factors of hindrance of successful beekeeping in 2014. In contrast to our study, the major pest was ant followed by lizards, and wasps in Gorkha district (Pudasaini, 2018).

Table 5. Pest problem faced by Bee keepers of Rupandehi district, Nepal in 2014 and 2021

2014				2021			
Pests	**%**	**N=34**	**Rank**	**Pests**	**%**	**N=89**	**Rank**
Hornet	100	34	1st	Hornet	100	89	1st
Mites	55.88	19	2nd	Ant	77.52	69	2nd
Ants	50	17	3rd	Bird	65.16	58	3rd
Bird	47.05	16	4th	Lizard	53.93	48	4th
Wax moth	44.11	15	5th	Mite	44.94	40	5th
Lizard	38.23	13	6th	Wax Moth	21.34	19	6th
Rats	32.29	11	7th	Squirrel	7.86	7	7th
Squirrel	26.24	9	8th	Rats	3.37	3	8th

Beekeepers shared that insufficient foraging land was hurdle for beekeeping and the existing foraging land was also being constricted. The problem of transportation was reported in case they took bees for foraging. The concerned authority is not able to give sufficient support to the beekeepers in terms of training the farmers, developing the efficient marketing channel and distribution of bee equipment. Farmers admitted that the application of pesticide in agricultural land had directly affected the number of bee population in a colony and also decreased honey production. Similar constraints in bee keeping was reported by Bhandari & Kattel (2020). The treatment of bee disease is not handy because farmers are not aware about the symptoms and cure of bee diseases in both years which is similar as reported by Bhandari & Kattel (2020). The constraints during production were similar to findings of Bhattarai et al. (2020). High cost and limited availability of modern equipment and accessories as major constraint was reported by Shrestha (2017) in Bardiya district. Majority of the respondents in our study area were acquainted with the knowledge of role of honey bees in pollination and similar finding was also reported in Gorkha district (Pudasaini, 2018)

CONCLUSION

Rupandehi district is one of the potential districts for rearing *Apis mellifera*. The average honey production was increased to 25.45 kg/ hive/ year from 21.35 kg/ hive/ year in span of seven years. The problem relating to foraging is also concerning, and indiscriminate use of the pesticide in agricultural crops. Concerned government authorities, Non- governmental organizations and farmers themselves should focus on the improved management practice to reduce the production problem. Government sector should work on the production problems faced by farmers like decrease in the bee forage area, insufficient certification, lab tests, insecticide poisoning, providing incentives etc. to motivate the farmers to have beekeeping as the primary occupation. It can play a great role in the upliftment of the economy of the people of Rupandehi as well as can aid to the nation's economy.

SUGGESTIONS FROM BEEKEEPERS

Farmers suggest that frequent seminars and training should be conducted to facilitate the farmers to operate managerial activities efficiently. Concerned authorities should give due attention to expanding the land meant for foraging. Farmers have also pleaded for the development of efficient transportation systems to take bees for foraging. Bee keeping should be strengthened by the introduction of new technology by ensuring the insurance facilities to the beekeepers. Further, a diagnostic laboratory for detection of disease and treatment of honey bee is of great necessity in our study area as per bee keepers.

ACKNOWLEDGEMENT

We extend our acknowledgement to Ms. Meena Pandey and Mr. Alok Dhakal for their immense help during manuscript preparation. The authors are indebted to all the respondents, key informants, participants of focus group discussion who provided their knowledge, experience and other related information on bee keeping. We are profoundly thankful to the administration of Paklihawa Campus for their support.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES, July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Farm Level Challenges and Factors Affecting the Sources of Income among Pepper Farmers in Kaduna and Kano States, Nigeria

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ABSTRACT

This study investigated farm level challenges and factors affecting the sources of income among pepper farmers in Kaduna and Kano States, Nigeria. A simple random sampling design was utilized to select 200 pepper growers. Primary data were employed utilizing a well-structured questionnaire. Data were evaluated utilizing descriptive statistics, Gini-Coefficient, Kendall's coefficient of

concordance, and Multinomial Logit model. The results show that the mean age of pepper farmers was 46 years, with a
n average of 13 years of attendance in school education. They are smallholder farmers with an average of 1.27 ha of pepper farms. Approximately, 70% (140) of pepper farmers belong to high income inequality group, while 30% (60) belongs to low income inequality group. The main sources of income include farm income (34.04%), non-farm income (27.66%), and off-farm income (25.53%). The significant factors affecting the sources of farm income among pepper growers include education ($P < 0.01$), experience ($P < 0.05$), access to market ($P < 0.01$) and access to inputs such as fertilizer usage ($P < 0.01$). The significant factors affecting the sources of non-farm income include age ($P < 0.01$), cooperative membership ($P < 0.10$), and access to market ($P < 0.01$). The study recommended improved infrastructures such as better roads, irrigation systems, and improved market access. Furthermore, improved access to credit, and providing fertilizers, pesticides, and improved seeds at subsidized rate can reduce farmers' costs and increase productivity.

Keywords: Farm level challenges, income inequality, Nigeria, pepper farmers, sources of income

INTRODUCTION

Spices play a vital role in our food through its flavor, taste and aroma which are acceptable to consumers (Yahaya et al., 2020). Pepper is the third most popular vegetable in the world behind tomatoes and onions. It is one of the essential vegetables that is cultivated in sub-Saharan Africa (Olutumise, 2022). Pepper (*Capsicum species),* particularly chili pepper, is a widely cultivated and economically important crop in Nigeria, serving as a staple spice, vegetable, and a significant source of income for numerous rural households (Alabi et al., 2023). Nigeria is a major producer of pepper in Africa, with states like Kaduna, Kano, Katsina, and Plateau being prominent cultivation centers (National Bureau of Statistics, 2020). The crop's importance extends beyond household consumption, contributing significantly to food security, poverty alleviation, and rural development through employment and income generation along its value chain (Dennis and Kentus, 2018). Pepper cultivation forms a crucial part of the agricultural landscape, particularly within irrigation schemes and rain-fed farming systems. The diverse agro-climatic conditions in these regions support various pepper varieties, catering to both domestic and international markets (Olutumise, 2022). The economic contribution of pepper farming to the livelihoods of smallholder farmers in these states cannot be overemphasized, as it often serves as the primary source of income, spice for cooking food, enabling farmers to meet household needs, invest in education, and accumulate assets (Alabi et al., 2023). Despite its immense potential, pepper production in Nigeria, is faced with challenges that significantly impact farm productivity, profitability, and consequently, the income-generating capacity of farmers. The output of pepper is 30% lower in developing nations that in advanced ones, even with the increased production and high market price of pepper. The pepper sub-sector is characterized by smallholder farmers that faced the challenges of poor quality, poor output, little value addition price unpredictability, and supply disruptions. To cope with the inherent uncertainties and challenges of pepper farming, smallholder farmers in Nigeria often adopt diversified income strategies. Their income sources typically extend beyond the income from sale of pepper. For many pepper farmers, the revenue generated from the sale of fresh and/or dried pepper constitutes the largest share of their household income (Idowu & Adebayo, 2017). More so, studies indicated that pepper production can be profitable in Nigeria, with positive net farm incomes reported in various regions (Mohammed, 2015; Adaigho & Tibi, 2018; Alabi et al., 2023). However, the magnitude of this income is highly variable, influenced by factors such as yield, market prices, access to efficient marketing channels and information, seasons and lack value chain addition. Gender differentials in profitability have also been observed, with male farmers often achieving higher gross margins due to factors like access to resources and extension services (Alabi et al., 2023). To mitigate the risks associated with price fluctuations, pest outbreaks, or adverse weather conditions, many pepper farmers engage in crop diversification. This involves cultivating other food crops like rice, maize, sorghum, millet, tomatoes, or legumes alongside pepper (Abdullahi & Bala, 2020). This strategy provides alternative income streams, spreads agricultural risks, and can enhance soil health through rotational cropping (Abdullahi and Bala., 2020). Furthermore, pepper farmers are likely to integrate of livestock rearing with crop farming which is a common practice among rural Nigerian farmers, including those involved in pepper production (Abubakar & Umar, 2017). Raising small ruminants (goats, sheep), poultry, or even cattle provides additional income from the sale of animals or their products (milk, eggs). Livestock also serves as a crucial source of manure for crop fertilization and acts as a readily available asset for emergency cash needs during periods of low agricultural income. Recognizing the limitations and risks of relying solely on agriculture, many pepper farming households engage in various off-farm and non-farm income-generating activities. These can include petty trading, artisanal work (e.g., tailoring, carpentry), wage labor on other farms or in non-agricultural sectors, and remittances from family members working in urban areas (Umar & Danladi, 2018; Adeoye & Oladele, 2017). These income sources are critical for supplementing agricultural earnings, particularly during lean seasons, and for providing a safety net and cushion effect against agricultural shocks. Studies of Hayran & Gul (2019) showed that off-farm income can positively affect the technical efficiency and boost productivity of agricultural production especially among pepper farmers by allowing farmers to invest in better inputs and technologies (Hayran & Gul, 2019). The extent and type of off-farm engagement are often influenced by factors such as age, household size, education levels, and proximity to urban centers (Hayran & Gul, 2019). High levels of income inequality among pepper farmers can lead to various negative socio-economic consequences. It can perpetuate poverty within the farming communities, hinder investments in education and health, and potentially contribute to social unrest (World Bank, 2019). Addressing these disparities is crucial for fostering inclusive growth and sustainable development in Nigeria's agricultural sector. Policies aimed at improving access to resources, strengthening farmer cooperatives, enhancing market linkages, and providing targeted support to vulnerable groups (e.g., women) are essential to mitigate income inequality among pepper farmers.

Farm-Level Challenges in Pepper Production

Pepper production in Nigeria is characterized by several constraints that limit optimal yield and farmer profitability. These challenges are agronomic, environmental, economic, and institutional or political.

Agronomic and Environmental Constraints.

One of the primary challenges is the prevalence of traditional farming practices and limited access to improved seed varieties (Olowu et al., 2018). Many smallholder farmers rely on recycled seeds, which often result in lower yields and increased susceptibility to pests and diseases. Pest and disease infestations are a major biotic constraint, with issues like pepper leaf curl virus, bacterial wilt, and various insect pests significantly reducing crop yields (Adedeji et al., 2020). Farmers often struggle with effective and affordable pest management strategies, leading to substantial post-harvest losses. Moreso, Climatic variability and change pose significant threats to pepper cultivation, especially in rain-fed systems. Unpredictable rainfall patterns, prolonged dry spells, and occasional flooding lead to crop failures and reduced productivity (Federal Ministry of Agriculture and

Rural Development, 2019). While, irrigation systems exist, particularly in states like Kano, access is not universal, and even irrigated farms can be affected by water scarcity or mismanagement. However, soil fertility degradation due to continuous cultivation without adequate nutrient replenishment is another critical issue. Poor soil management practices and limited use of appropriate fertilizers contribute to declining yields over time (Mohammed & Abdullahi, 2017).

Economic and Market Challenges

Price unpredictability is a pervasive problem for pepper farmers. The perishable nature of pepper, coupled with poor market linkages and the dominance of middlemen, often forces farmers to sell their produce at low prices immediately after harvest, diminishing their profit margins (Mohammed, 2015; Adekunle & Ayodele, 2018). This fluctuation makes income planning difficult and exposes farmers to significant financial risk. Furthermore, Limited access to credit facilities from formal financial institutions is a major impediment to investment in improved inputs, new technology adoption, and mechanization (Nweke & Okoro, 2019). Farmers often rely on personal savings or informal lenders, which may come with high-interest rates, further constraining their economic growth (Mohammed, 2015). High cost of farm inputs, including fertilizers, improved seeds, and agrochemicals, also reduces profitability, particularly for resource-poor farmers (Mohammed, 2015). Finally, infrastructural deficiencies, such as poor rural road networks, exacerbate marketing challenges by increasing transportation costs and leading to higher post-harvest losses due to spoilage during transit (Usman & Sani, 2017). The lack of adequate storage and processing facilities further limits farmers' ability to add value to their produce and access distant markets.

Income Inequality among Pepper Farmers in Nigeria

Despite the efforts of pepper farmers to diversify their income sources, significant income disparities persist within these farming communities, contributing to broader rural income inequality in Nigeria. Income inequality has been a problem affecting every nation in the world especially in sub Saharan Africa Nigeria is not left out (FAO, 2021). Income inequality possess an adverse socio economic and political consequence with the potential to cause instability in the economy and unsustainability of resources (International Monetary Fund, 2023). Income inequality is the extent to which income is evenly distributed within a population (IMF, 2023). low income pepper farmers consume majority of their farmer produce and have very little to improve on their income, while high income pepper

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

farmers expand their economies of scale to generate more income, this consequently leads to income disparity. Income inequality among pepper farmers is often rooted in differential access to productive resources and opportunities (Alabi et al 2023). Access to land, plays a crucial role in determining yield and income potential. Farmers with larger landholdings or secure land tenure tend to achieve higher returns (Mohammed, 2015). Similarly, access to credit and capital significantly influences a farmer's ability to invest in improved seeds, fertilizers, irrigation equipment, and other yield-enhancing technologies. However, gender-based disparities are also a significant driver of income inequality in pepper farming. Female pepper farmers often face more severe constraints in accessing productive resources such as land, credit, and extension services compared to their male counterparts (Alabi et al., 2023). This unequal access translates into lower productivity and consequently, lower incomes for female-headed households or farms primarily managed by women, as evidenced by lower gross margins for female pepper farmers in Kaduna State (Alabi et al., 2023). Education level and access to agricultural extension services and market information play a crucial role in income differentiation. Farmers with higher levels of education are more likely to adopt improved farming practices, diversify their income sources effectively, and engage in more profitable market linkages (World Bank, 2019). Conversely, farmers with limited education and extension contact often remain in traditional, low-yield farming systems, widening the income gap. The structure of the pepper value chain, particularly the dominant role of middlemen, often contributes to income inequality. Smallholder farmers, lacking direct market access and storage facilities, are vulnerable to exploitation by intermediaries who buy at low farm-gate prices and sell at significantly higher retail prices (Sani & Garba, 2020). This reduces the share of the final product value that accrues to the farmers, thereby exacerbating income disparities. The lack of collective bargaining power among unorganized farmers further compounds this issue.

Farmers in remote areas with poor road networks face higher transportation costs and limited access to lucrative markets, reducing their effective income (Usman & Sani, 2017). Conversely, those closer to urban centers or major markets may have better opportunities to sell their produce at favorable prices. Regional disparities in infrastructure development, such as irrigation facilities, also create income gaps, with farmers in well-irrigated regions like parts of Kano often having more stable and higher incomes compared to those solely reliant on rain-fed agriculture.

MATERIALS AND METHODS

This study was carried out in North West, Nigeria. The simple random sampling design was utilized to select Kaduna and Kano States because pepper is predominantly grown in the two states. A simple random sampling design was utilized to select 200 pepper growers within the two states. The approach was used because it avoids element of bias in selecting the respondent. Secondly, the sampling design gives the likelihood for every grower to have equal chance of being selected. The disadvantages of the simple random sampling design were under-representation of certain sub-groups, time consuming, difficulty accessing lists of the full population, the process may cost individual a substantial amount of capital, cumbersome, sample selection bias can occur, and challenging when the population is heterogeneous and widely spread. The sample frame of pepper producers approximately 400 respondents. The total sample number consists of 100 pepper growers selected each from the two states, respectively. Primary data of cross-sectional sources were utilized based on a well-planned questionnaire that was subjected to validity and reliability test.

This sample number was estimated based on the established formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{400}{1+400(0.05)^2} = 200 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
n = The sample number,
N = The total number of pepper producers,
e = 5%
The data obtained were analyzed using descriptive statistics, Gini-coefficient, Kendalls' coefficient of concordance, Multinomial Logit model, and t-test statistics.

Gini-Coefficient (GC)
The choice of this formula follows the studies of Taru and Lawal (2011). The Gini-Coefficient is given as:

$$GC = 1 - \sum_{i=1}^{n} X_i Y_i \ldots\ldots\ldots.. (2)$$

Where,
GC = Gini Coefficient
X_i = % Share of Each Class
Y_i = Cumulative % of their Sales

Kendalls' Coefficient of Concordance (W)
The choice of this formula follows the studies of Amesimeku and Anang (2021). The Kendalls' Coefficient of Concordance (W) is stated below:

$$W = \frac{12S}{m^3(n^3 - n) - mT} \qquad (3)$$

Where:
n = Number of Attributes or Objects that is Evaluated by Respondents
m = Number of Respondents
S = Sum Overall Subjects
T = Correction Factor estimated for Tied Ranks

$$T = \sum_{k=1}^{g} (t_k^3 - t_k) \qquad (4)$$

Where;
t_k= Number for Tied Ranks for each (k) in 'g' Groups of Ties
Friedmans' Chi Square (χ^2)

$$\chi^2 = m(n-1)W \qquad (5)$$

Multinomial Logit Regression Model (MLRM)
The general MLRM following Maharazu et al. (2024) is defined as:

$$P_r(y_i = j) = \frac{\exp\,(X_i\beta_j)}{1 + \sum_{k=0}^{j} \exp(X_i\beta_j)} \ldots\ldots\ldots\ldots\ldots (6)$$

and to ensure identifiability,

$$P_r(y_i = 0) = \frac{1}{1 + \sum_{k=0}^{j} \exp(X_i\beta_j)} \ldots\ldots\ldots\ldots\ldots (7)$$

$$Z_i = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \mu_i \ldots (8)$$

Where,
Z_i = Sources of Income (1, Farm Income; 2, Non-Farm Income; 3, Off-Farm Income)
β_0 = Constant Term

β_1 - β_6 = Regression Coefficients
X_1 = Age in Years
X_2 = Education (Years)
X_3 = Experience in Pepper Farming (Years)
X_4 = Cooperative Memberships (1, Member; 0, Otherwise)
X_5 = Access to Market (Kilometer)
X_6 = Farm Size (Hectares)
X_7 = Access to Input (Fertilizer Usage in Kg)
μ_i= Noise Term

The t-Test of Difference Between Means
This is stated thus:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (9)$$

Where,
$\overline{X}_1$= Mean of Values in Group 1
$\overline{X}_2$= Mean of Values in Group 2
s_1^2, s_2^2 = Standard Deviation in Group 1 and Group 2
$n_1 n_2$= Number of Observation in Group 1 and Group 2

RESULTS AND DISCUSSION

Summary Statistics of Pepper Farms and Farmers Features
The Table 1 provided a comprehensive overview of the socio-economic characteristics of pepper farmers. Here's a discussion of each of the mean values and their implications:

Education
The mean years of schooling of pepper growers was 13 years, Low educational attainment among farmers limits their ability to adopt modern farming technologies, understand extension services, and access financial resources, and this perpetuates low productivity (Alabi et al., 2022).

Age

The mean age of the pepper farmers was 46 years; this suggests the dominance of young farmers in the study area and that pepper growing was primarily undertaken by young individuals. This young farmer can easily adopt modern technologies, as older farmers are often more resistant to change (Alabi., 2023).

Experience

The number of years a farmer spent in farming gives an indication of the practical knowledge he\she has gained on how to cope with production, since experienced farmers are better risk managers than inexperienced ones. The rice farmers had an average of 14 years of experience which reflects that the farmers have deep knowledge of local pepper farming practices. This result is in consonance with the findings of Alabi et al. (2023), who corroborated that farmers with longer years of farming experience would accumulate more and better knowledge and skills in making informed farm decision.

Household size

Household labour helps to mitigate/ cope with the issue of scarce and costly hired labour and help reduce the cost incurred in labour purchase. The mean household size was 8 persons; the result is in line with Anthony (2023) who reported that large household size complement labour and enhance productivity and reduce the cost of hired labour.

Extension Contact

The result shows that 57% of crop farmers had contact with extension agents, while 43% did not. While more than half of the farmers benefit from extension services, a significant proportion remains excluded, which limits the dissemination of modern farming practices. This this in line with the assertions of Oluwole and Odebode (2015) who highlighted the importance of extension services in improving farmers' knowledge, productivity, and income. However, gaps in coverage remain a challenge in rural Nigeria.

Cooperative Memberships

The result show that 72% of crop farmers belong to farm-based organizations, while 28% do not. Membership in such organizations is relatively low, limiting farmers' access to collective resources, credit, and markets. This highlights the need to promote group-based initiatives to improve farmers’ bargaining power. This result is in agreement with the findings of Barungi et al. (2016) who emphasized the role of farmer organizations in improving resource access, capacity building, and market linkages for smallholder farmers.

Table 1. Summary Statistics of Pepper Farms and Farmers Features

Variables	Unit of Measurement	$\bar{X}_i$	SD
Education	Years	13	4.74
Age	Years	46	6.87
Experience in Pepper Farming	Years	12	4.02
Household Size	Number	9	3.52
Extension Contact	1, Contact, 0; No Contact	0.57	0.16
Farm Size	Hectares	1.27	0.42
Cooperative Memberships	1, Member; 0, Non- Member	0.72	0.17
Output of Pepper	Tons per hectare	3.0	0.17
Price per ton	Naira per tone	350,000	59.781

Source: Field Survey (2024)   1 USD = 1, 500 Naira

Farm size

Table 1 further suggested that the average pepper farmer cultivates 1,27 hectares. This could mean that the farmers are smallholder farmers. Smallholder farmers are predominant in the sub-Saharan Africa.

Output

The average rice yield is 3 tons per hectare suggesting that the farmers were efficient and productive, which points that there are potentials of increase in output.

Measurements of Income Inequalities among Pepper Growers

The result presented in Table 2 suggested a significant disparity in income levels among pepper growers with 70% (140 pepper growers) majority experiencing high inequality, while 30% (60 pepper growers) reflecting low income inequality. This is in agreement with the research of Anyiam, et al. (2023).

Table 2. Measurements of Income Inequalities among Pepper Growers

Measurement	Frequency	Percentage
≥ 0.5 (High Inequality)	140	70.00
< 0.5 (Low Inequality)	60	30.00

Source: Field Survey (2024)

Sources of Income among Pepper Growers

The result presented in Table 3 showed that the farm income is the dominant source, contributing 34.04% of the growers' income. The non-farm income and off-farm income makes up 27.66% and 25.53% respectively of the income, suggesting that a significant portion of households also engage in secondary activities to supplement their earnings. This result is in line with Sahara et al. (2023) who asserted that farmers in Ghana generate income from multiple sources, including pepper and other commodity farming, as well as non-farm activities and households with diverse income sources generally have relatively sustainable livelihoods.

Table 3. Sources of Income among Pepper Growers

Source of Income	*Frequency	Percentage
(a) Farm Income		
(i) Crop Income	120	25.53
(ii) Livestock Income	40	08.51
Sub-Total	160	34.04
(b)Non-Farm Income	130	27.66
(c) Off-Farm Income	120	25.53
(d) Others	60	12.77
Total	470	100.00

Source: Field Survey (2024) *Multiple Choices

Factors Affecting the Sources of Farm Income among Pepper Growers

The chi–square probability as shown in Table 4 revealed that the statistics of likelihood ratio was highly significant at ($P < 0.0000$), this suggests that the model has strong explanatory power. The pseudo R^2 of 0.8025 revealed that 80.25% of the variations in the dependent variable was due to the variations in the independent variables included in the model. This confirmed that the pepper growers choice of the sources of income could be due to fitted covariates, the R^2estimated the goodness of fit and therefore the model have performed well.

Education

The result suggest that education was positively significant at 1% probability level. This indicates that higher levels of education are associated with an increased likelihood of deriving income from farming activities. This is consistent with the findings of Alabi et al. (2021) that highlighted the role of education in improving agricultural productivity, adoption of improved technologies, and better farm management practices.

Experience

This showed that experience is positive and significant at 5% probability level. This suggested that for each additional year of farming, income is expected to improve by 0.2302 units. This result is in line with findings of Alabi et al. (2021), who reported that experience helps farmers to make better informed decision, increase productivity, management of risks and increase income.

Access to Market

The results in Table 4 further showed that access to market improves farm income by 0.2027 units, this result is statistically significant at 1% probability level. Access to market enables farmers to sell their produce at favorable prices, reduce post-harvest losses, and respond to market demand, thereby increasing income and welfare of the farmers (Omiti et al., 2018).

Access to Input, Fertilizer Usage

The coefficient for access to input, fertilizer usage is 0.2109 and highly significant at ($P < 0.01$) with a marginal effect of 0.2037. This indicates a significant positive relationship, implying that better access to inputs, particularly fertilizers, increases farm income when properly and efficiently utilized. More so, proper use of fertilizers and modern inputs leads to increased agricultural productivity, improved yields and which in turn boost farm income (Ayuya et al., 2015).

Factors Affecting the Sources of Non-Farm Income among Pepper Growers

Age

The coefficient for age on non-farm income was 0.2074. Similarly, to non-farm income, age was statistically significant at 1% probability level. This suggests that age have a statistically significant impact on a pepper grower's propensity to engage in non-farm income activities. The young farmers tend to engaged in other income generating activities easily which can improve income and welfare.

Cooperative Membership

This shows that cooperative membership is positive and significant at 10% probability level. It suggests that cooperative membership significantly increases the likelihood of a pepper grower deriving income from non-farm sources. This could be the benefits enjoyed as cooperatives might offer training programs in non-farm skills, facilitate access to credit for non-farm ventures, or create networks that lead to off-farm employment opportunities for their members

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

(Fischer & Qaim, 2012). This highlights the multifaceted benefits of cooperative engagement beyond just agricultural production.

Access to Market

This strong positive relationship indicated that better access to markets significantly increases the likelihood of deriving multiple income apart from pepper farming. This is a critical factor for agricultural profitability, farm household welfare and poverty alleviation, as it enables farmers to sell their produce aside pepper at favorable prices, reduce post-harvest losses, and respond to market demand (Omiti et al., 2018).

The Challenges Faced by Pepper Growers

Table 5 presented the Kendall's Coefficient of Concordance results, ranking challenges faced by pepper growers. The Kendall's W (0.283, χ^2 = 792.4, p = 0.000) indicated a significant difference of the constraints among farmers.

Lack of Improved Seeds

Lack of improved seeds seen as the most critical issue with a mean value of 40.97, highlighting that lack of improved seeds as a fundamental factor influencing agricultural productivity and investment this is also in agreement with the studies Ayanwale et al. (2018).

Table 4. Factors affecting the Sources of Income among Pepper Growers

Factors	Par	Farm Income		Non-Farm Income	
		Coefficient	ME	Coefficient	ME
Age (X_1)	β_1	0.2207	0.3408	0.2703***	0.2704
Education (X_2)	β_2	0.2420***	0.2924	0.2074	0.2207
Experience (X_3)	β_3	0.3804**	0.2302	0.2042	0.1847
Cooperative Membership (X_4)	β_4	0.1070	0.2307	0.2018*	0.2483
Access to Market (X_5)	β_5	0.2027***	0.2104	0.2309***	0.2706
Farm Size (X_6)	β_6	0.2309	0.2025	0.2317	0.2530
Access to Input, Fertilizer Usage (X_7)	β_7	0.2109***	0.2037	0.2109	0.2801
Constant	β_0	2.3012**		3.0248**	
Log Likelihood = -97.415					
Wald Chi Square = 2648.26					
Pseudo R^2 = 0.8025					
Prob $>\chi^2$ = 0.0000					

Source: Field Survey (2024), Par = Parameter, Reference Group = Off-Farm Income; *-Significant at ($P < 0.10$), **-Significant at ($P < 0.05$), ***-Significant at ($P < 0.01$)

Lack of Fertilizer and Pesticides

Lack of fertilizer and pesticides ranking second with a mean of 40.74 which underscores the persistent challenges in agricultural development, particularly in developing countries. Limited access to modern farming technologies and essential inputs such as fertilizers, pesticides significantly hinders productivity and resilience (World Bank, 2020). These are input-related constraints that directly reduce yield and profitability.

Climate Change

Climate change was ranked 3rd, indicating farmers' awareness of its adverse effects on yield, growing seasons, and pest pressure. This outcome is consistent with findings by Tambo and Abdoulaye (2013) who documented that farmers lack access to vital information on how to adapt to climate changes (e.g., climate-smart agriculture, water conservation techniques). This also reduces their ability to mitigate risks such as floods, droughts, and pests.

Low and Unstable Product Prices

This challenge has a mean value of 39.58 suggesting that volatile market prices reduce income predictability and discourage investment in pepper farming. Market and price instability is a common economic barrier to sustainable pepper production (FAO, 2019).

Inadequate Infrastructure (Roads)

Poor road conditions limit market access, increase post-harvest losses, and reduce profitability and farmers' income. This is also in consonance with assertion that infrastructure development is critical for connecting rural farmers to markets (World Bank, 2007). Infrastructure development, such as better roads and transportation services, can mitigate this constraint.

Lack of Extension Services

Ineffective extension services limit farmers' access to modern agricultural techniques, innovations, and critical information. Improving these services through training, resources, and better outreach can enhance farm productivity and resilience.

Pest and Disease Management

Farmers lack sufficient knowledge about pest and disease management, pest outbreaks reduce their ability to boost production, output, enhance productivity which translates to higher income. Extension services, farmer training programs, and awareness campaigns on pest and disease management in agriculture can address this knowledge gap.

Inadequate Storage Facilities

The cost of water storage solutions is a major constraint. Access to affordable water storage systems, such as tanks and wells, is crucial for managing water resources efficiently and ensuring crop survival during droughts.

Table 5. The Kendall's Coefficient of Concordance Results of the Challenges Faced by Pepper Growers

Challenges	Type of Constraints	Overall Rank	Mean Rank
Lack of Improved Seeds	Production	1	40.97
Lack of Fertilizer and Pesticides	Production	2	40.74
Climate Change	Production	3	40.53
Low and Unstable Product Prices	Market and Economic	4	39.58
Inadequate Infrastructure (Roads)	Market and Economic	5	38.40
Lack of Extension Services	Production	6	38.35
Pest and Disease Management	Production	7	38.34
Inadequate Storage Facilities	Production	8	38.22
Lack of Access to Credit	Financial	9	38.19
Lack of Information	Market and Economic	10	37.99
Underutilization of Labour	Production	11	37.77
Overutilization of Inputs	Production	12	37.61
Low Education Level	Other	13	36.97
Lack of Government Support	Market and Economic	14	36.60
Post-Harvest Handling	Production	15	36.47
Kendall's Coefficient (W)		200	
Chi Square		0.283	
df		792.4	
F-Critical		14	
F-Calculated		94.40	
Asymptotic Significance		254.70	

Source: Computed from Field Data (2024)

Lack of Access to Credit

Many farmers are constrained by financial resources and credit facilities. This restricts their ability to invest in farm inputs and equipment, limiting productivity and output. There is the need for financial literacy programs, agricultural loan awareness campaigns (Alabi et al., 2023).

Lack of Information

Lack of information limits farmers' ability to prepare for adverse weather events, market demands, price stability. Improving early warning systems and

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

dissemination of information can help farmers take proactive measures to protect their crops, boost productivity and increase efficiency.

Underutilization of Labour

The lack and underutilization of available farm labour is a significant constraint. This issue can lead to reduced productivity, delayed planting and harvesting, and increased labour cost. Overutilization of Inputs, low education level, lack of government support and post-harvest handling where seen as lower challenges encountered by the pepper farmers in the study area.

The Difference between Costs and Revenue in Pepper Farming per Hectare

Since the t- calculated (23.11) is significantly greater than the t- tabulated (1.96), this suggested that there is a statistical difference in the cost and returns in the pepper farming per hectare. This implies that the observed difference between the average costs (₦456, 030.12) and average returns of (₦1,050, 000) further suggests that the pepper production in the study area is economical viable with an average difference of (₦593, 969.88). This aligns with the studies of Olutumise (2022) that pepper farming is profitable.

Table 6. The t-Test of Difference Between Costs and Returns in Pepper Farming per Hectare

Variable	Estimates (Number)
Costs	456,030.12
Returns	1,050,000
Standard Deviation Cost	293,703.40
Standard Deviation Returns	467,317.74
t-Calculated	23.11
t-Table	1.96

Source: Field Survey (2024)

CONCLUSION

The study focused on farm level challenges and factors affecting the sources of income among pepper farmers in Kaduna and Kano States, Nigeria. A simple random sampling design was employed to select approximately 200 pepper growers.

The study confirmed that pepper farming is profitable in the study area. The null hypothesis is rejected, while the alternative hypothesis is accepted. The estimated returns of pepper farming per hectare (₦ 1,050, 000, SD = 467, 317.74) was significantly greater than the cost (₦ 456,030.12, SD = 293, 703.40) at 5% level of probability. There are significance differences among the challenges faced by pepper growers. The null hypothesis was rejected, while the alternative hypothesis was accepted. The Kendall's W (0.283, χ^2 = 792.4, p = 0.000) indicated a significant difference of the challenges among growers.

The major challenges faced by pepper farmers include lack of improved seeds (1st, mean rank = 40.97), lack of fertilizer and pesticides (2nd, mean rank = 40.74), climate change (3rd, mean rank = 40.53), and low and unstable product prices (4th, mean rank = 39.58). The main challenges faced by pepper growers are production constraints, and also, market and economic constraints.

There is a significant relationship between socio-economic factors and sources of income among pepper growers. The null hypothesis was rejected, while the alternative hypothesis was accepted. The significant socio-economic factors influencing sources of farm income among pepper growers include education (0.2420, marginal effect = 0.2924) at 1% probability level and experience (0.3801, marginal effect = 0.2302) at 5% probability level. Similarly, the socio-economic factor influencing sources of non-farm income among pepper growers include age (0.2703, marginal effect = 0.2704) at 1% probability level.

The study established that there is income inequality among pepper farmers in the study area. The null-hypothesis was accepted, while the alternative hypothesis was rejected. Approximately 70% (140 pepper growers) belongs to high income inequality group, while, 30% (60 pepper growers) belongs to low income inequality group.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made:

(i) **Improved Access to Credit**- Government and financial institutions should provide credit to pepper growers at low interest rate devoid of cumbersome administrative procedures. This will enable the pepper growers to invest in inputs and technology.

(ii) **Subsidized Inputs:** The farm inputs such as fertilizer, pesticides, and other inputs should be subsidized at affordable rate, as this can reduce cost and increase productivity.

(iii) **Improved Infrastructure:** The feeder roads should be constructed, investing in irrigation facilities systems, improve market access, and storage facilities will reduce post-harvest losses.

(iv) **Government Policies**-Government should make favorable policies that will stabilize pepper prices and address market fluctuations.

(v) **Value Added Production-**The pepper growers should engage in value added production, this include processing pepper into powder and other products

(vi) **Extension Services:** This will educate farmers on the best practices for pest control, cultivation and marketing of produce.

(vii) **Crop Diversification:** Pepper farmers should grow other crops alongside pepper to diversify income sources.

(viii) **Livestock Integration:** Pepper growers should integrate livestock farming into pepper farming, this will provide manure and other benefits.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Exogenous Application of Gibberellic Acid, Salicylic Acid, and Calcium Chloride on Physical Properties and Shelf Life of Tomato

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ABSTRACT

The study was conducted from May 2nd to June 19th of 2024 at HICAST, Kirtipur. A Completely Randomized Design (CRD) comprising ten treatments with three replications was executed to evaluate the physical characteristics and shelf life of tomato fruits of the 'Srijana' variety treated with GA_3(O.1%, 0.2%, and 0.3%), $CaCl_2$ (0.5%, 1%, and 1.5%), and SA (0.1mM, 0.2mM and 0.3mM). The statistical analysis of data was completed using GenStat and Microsoft Excel. The quality parameters were evaluated after 15 days of storage and 25 days of storage. All the tested treatments were stored at an average room temperature of 26.9±2 °C (dry) and 20.5±2 °C (wet). They showed a significant delay in weight loss and spoilage percentage in treated tomato fruits compared to the control set. GA_3 treatments were the most effective, with 0.1% of GA_3 (T1) resulting in the least spoilage (34.1%), reduced weight loss (17.85%), the highest firmness (1.5 kg/cm^2), and the longest possible extension of the average shelf life to 29 days. With the increasing storage period, the ripening progressed, marked by the declining values of firmness on the 25th day. A particularly noteworthy observation is that the higher concentrations of $CaCl_2$ (1.5%) provided significantly better results than lower concentrations (0.5% and 1%). 0.3 mM of SA was more effective than lower concentrations, though higher concentrations might yield even better outcomes.

Keywords: Concentrations, exogenous application, physical characteristics, quality, yield

INTRODUCTION

Nepal is the land of wonder with agro-climatic variability (NHS, 2016) and unique agro-ecological zones favored by varying altitudes, topography, and aspects offering vast opportunities for the production of different types of horticultural crops *i.e.*, fruits, vegetables, flowers, spices, and other plantation crops (Thapa and Dhimal, 2017). Owing to this, agriculture plays a dominant role in the Nepalese economy, contributing about 23.95% to the nation's GDP in the fiscal year 2022/2023. Whereas within horticultural crops; vegetables have contributed 14.46% to the AGDP of Nepal (MoALD, 2023).

Tomato, the poor man's apple, is one of the major fresh vegetables grown in Nepal belonging to the Solanaceae family and ranks 3rd position in terms of area (Ha), production (Mt), and yield (Mt/Ha) following the Cole crops (MoALD, 2023). Even though it is perennial in its native habitat, it is often grown as an annual crop. Botanically it is a berry fruit, however, it is categorized under vegetables for culinary purposes (MoEF&CC / IIVR, 2016). Tomatoes are consumed in different forms such as raw, cooked, sauces, salads, and even drinks. It is both a nutritionally and medicinally important crop, rich in powerful antioxidants such as lycopene, carotenoids, and flavonoids. These compounds are not only beneficial for health but also play a crucial role in preventing cancer, cirrhosis, and acidosis and neutralizing everyday toxins (Mallick, 2021). Despite the increasing production and domestic and international demand for tomatoes, Nepal still imports most of the tomatoes from India, China, Bangladesh, the UAE, and Qatar valued at over NPR 499,530,810 (TEPC, 2022). With issues such as subsistence farming, linkage to the international market, transportation facilities (CASA, 2020), lack of technical know-how, and traders' monopoly in price fixation (Kafle and Shrestha, 2017), the major factor contributing to the lack of supply of tomatoes is its "Perishable nature" and consequently prone to price fluctuations. The solution to the perishability of tomatoes lies both in the pre-harvest and post-harvest factors that can extend the shelf life and maintain the quality through the application of optimal technological levels (Mir and Beaudry, 2002). Among several post-harvest treatments such as refrigeration, freezing, use of high temperatures, and modified atmosphere packages (Mir and Beaudry, 2002), treatment with phytohormones, growth regulators and various chemical calcium compounds are alternative technologies to maintain and improve fruit quality (Aguilar-Ayala and Herrera-Rojas, 2023). During storage, exogenous application of certain chemicals such as Calcium chloride and PGRs such as Gibberellic acid and Salicylic acid which retard the ripening process can prove to be extremely valuable.

Gibberellins (GAs) are phytohormones that regulate plant growth and development.Its chemical formula is $C_{19}H_{22}O_6$. The effects of exogenous GA_3

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

treatment have been studied in different crops which showed that it could improve nutritional traits, retard decrease in ascorbic acid concentration, increase total phenolic content in tomatoes (Demes *et al*., 2021), inhibit the expression of fruit ripening regulators e.g., Ripening inhibitor (RIN) (Zhang *et al*., 2023) and prolong fruit ripening time. Calcium is an essential plant nutrient for plant growth and development and is present in the cell wall as a binding agent (Bhattarai and Gautam, 2006). Researchers have reported that calcium treatment contributes to cell-wall integrity, maintenance of firmness, delays softening and decay (Pila *et al*., 2010), inhibits ethylene production, and lowers respiration rates (Mansourbahmani *et al*., 2017). $CaCl_2$ is affordable and relatively easy to prepare therefore its adoption is feasible for marginal farmers in developing countries to reduce postharvest losses in tomatoes (Arah *et al.*, 2016). According to Bhattarai and Gautam (2006), it is not toxic even in higher concentrations making it safer to use. Salicylic acid ($C_6H_4(OH)CO_2H$) is an endogenous plant growth regulator and a natural phenolic acid. Exogenous application of SA treatment benefits postharvest storability in horticultural commodities by delaying fruit ripening, reducing cell wall degrading enzyme activity, maintaining cell membrane properties, improving fruit taste, retaining nutrient content, and enhancing antioxidant activity hence extending and improving the shelf life (Wang *et al*., 2022). Salicylic acid is considered a safe substance that can be put on vegetables and fruits in lower concentrations (Nicktam*et al*., 2023).

MATERIALS AND METHODS

Procurement of tomatoes

The “Srijana” variety of tomatoes was procured from farmers in Shankharapur municipality, Sankhu, Kathmandu. Fresh healthy tomatoes harvested in the turning and pink /breaker stage, evenly proportioned, unbruised, and with no injury and signs of disease, were selected and collected.

Experimental site

The experiment was conducted in the Horticulture laboratory of the Himalayan College of Agricultural Sciences and Technology. The research was performed in ambient storage conditions. A thermometer was used to measure the dry and wet temperatures in the research space. The observation room's temperature was recorded daily.

Experimental design and treatment details

The Completely Randomized Design (CRD) was used with 10 treatments and three replications of each treatment.

Table 1. Treatment Details

SN	Treatment	Treatment details
1	T1	0.1% Gibberellic Acid (Dipped in 0.1% GA_3 for 20 mins)
2	T2	0.2% Gibberellic Acid (Dipped in 0.2% GA_3 for 20 mins)
3	T3	0.3% Gibberellic Acid (Dipped in 0.3% GA_3 for 20 mins)
4	T4	0.5% Calcium chloride (Dipped in 0.5% $CaCl_2$ for 20 mins)
5	T5	1% Calcium chloride (Dipped in 1% $CaCl_2$ for 20 mins)
6	T6	1.5% Calcium chloride (Dipped in 1.5% $CaCl_2$ for 20 mins)
7	T7	0.1 mM Salicylic Acid (Dipped in 0.1 mM SA for 20 mins)
8	T8	0.2 mM Salicylic Acid (Dipped in 0.2 mM SA for 20 mins)
9	T9	0.3 mM Salicylic Acid (Dipped in 0.3 mM SA for 20 mins)
10	T10	Control (Dipped in distilled water for 20 mins)

The tomatoes were cleaned, washed, sterilized using sodium hypochlorite (500ppm for 10 min), and air dried before dipping in respective chemical solutions. A sample size of 10 tomatoes was allocated for each treatment. After treatment, the fruits were kept in a makeshift aluminum bowl. Data were taken in alternate day intervals until signs of decay or spoilage were observed and then, the physical parameters were analyzed after 15 days of storage and on the 25th day of storage until commercial condition. The ambient temperature of the storage room was noted.

Parameters observed

Physiological weight loss (PLW %)

To calculate the PLW% of the tomato, the initial weight was recorded before the application of the treatments and then at alternate day intervals during storage using a digital sensitive balance. Finally, the following formula was used to calculate the PLW %:

$$\text{PLW \%} = \frac{\text{wt. of sample at first interval-wt. of sample at second interval}}{\text{wt. of sample at first interval}} \times 100$$

Fruit length and diameter (cm)

A vernier caliper was used to measure both the fruit length and diameter of the tomato in cm. The fruit length was measured longitudinally while the diameter was measured transversely.

Firmness (Kg/cm^2)

The firmness of the fruits was determined using a penetrometer having varying pressure tester knobs. After the selection of the appropriate pressure tester knob for tomato fruits, the plunger was held against the surface of the fruit and forced into it with a steady pressure. This action provided the force necessary for breaking the flesh in Kg/cm^2 on the pressure tester which was recorded as the firmness of the given fruit.

Spoilage percentage

Spoilage % was determined by the visual observation. The fruits exhibiting signs of rotting such as the development of spots on the skin of fruits, and softening were considered as spoiled. The spoilage % was then calculated by dividing the number of spoiled fruits by the initial number of all fruits times 100.

Color

Color was evaluated using a standardized color chart by the Royal Horticulture Society (2019). The color of the fruit was matched to the closest on the color chart to determine the color intensity or shade of it to the maximum acceptable stage of tomato.

Shelf life

Tomato's shelf life was determined by calculating the number of days required to attain the last stage of ripening and then at the point where the fruit could still be sold *i.e.*, it remained acceptable for marketing.

Marketable fruit (%)

Marketable fruit was determined by using the following formula.

$$\text{Marketable fruit} = \frac{\text{initial weight} - \text{damage weight}}{\text{initial weight}} \times 100$$

Statistical analysis

Data was systematically arranged using observed parameters, and analysis of variance was performed using EXCEL and GENSTAT. The available literature was used to assist in the analysis of the data and the discussion of the findings.

RESULTS AND DISCUSSION

Physiological loss in weight

After harvest, tomato fruits transform from maturity to senescence, leading to gradual weight loss and increased spoilage. The data presented in Figure 3 illustrates the physiological weight loss (PLW) in tomatoes during the storage period of 15 days. Results indicated that the PLW of the control group (T10) was the highest at 34.09% and the lowest in tomatoes treated with 1.5 % $CaCl_2$ (16.81%). Treatments, T1 (GA_3-0.1%), T5 ($CaCl_2$-1%), and T9 (SA-0.3mM) were found to be significantly (p<.001) effective in reducing weight loss in tomato fruits.

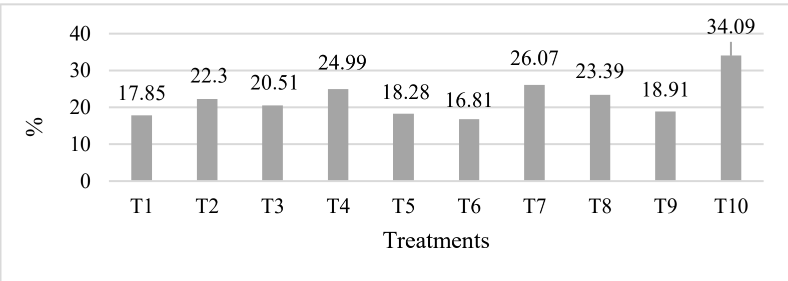

Figure 1. Effect of different treatments on physiological loss in weight

Weight loss in fresh tomatoes is primarily attributed to respiration and transpiration (Demes *et al*., 2021). Thus, reducing the rate of water loss and enzyme activities would lead to reduced weight loss. The results in the present study reveal that the higher concentrations of calcium chloride (1% and 1.5%) were the most effective in reducing weight loss, aligning with the results reported by Demes *et al*. (2021). Calcium forms a network with pectin in the fruit cell wall that restricts moisture loss, leading to reduced weight loss (Genanew, 2013). Similarly, gibberellic acid is a phytohormone that reduces fruit loss by decreasing respiration and delaying senescence (Aguilar-Ayala and Herrera-Rojas, 2023). Singh and Patel (2014) also reported that the GA_3 treatment in tomatoes decreased the tissue permeability, thereby reducing the rate of water loss and delaying ripening. Similar findings were demonstrated by Chen *et al.* (2020), who noted that the exogenous application of GA_3 delayed the ripening time through the regulation of transcript levels of ethylene-related genes. With the delayed aging of fruit, the loss of water, flavor, and nutrition is also significantly reduced (Zhang *et al.*, 2023).

Chavan and Shakhale (2020) found that salicylic acid caused a very gradual increase in weight loss in tomatoes during storage. This is further supported by Ünal *et al.* (2021) who reported the lowest weight loss in tomatoes treated with 1mM and 0.5mM SA stored at ambient temperature. SA has been reported to cause the closing of stomata in fruits which resulted in suppressed respiration rate and minimized weight loss (Tareen *et al.*, 2012).

Fruit length and diameter

The initial average mean length and diameter were recorded at 4.36 cm and 4.19 cm, respectively (Figure 4). After the 10th day of storage, the results indicated that none of the treatments maintained the initial average fruit length and diameter. With lengths 4.32 cm and 4.29 cm, it is evident that treatments T1 (0.1% GA3) and T7 (SA 0.1 mM) were effective in preserving fruit length,*i.e.*, closest to the initial average. Similarly, treatments T7 (SA 0.1 mM) and T8 (SA 0.2 mM) were the most effective in maintaining a diameter of 4.15 cm and 4.16 cm, respectively, *i.e.*, close to the initial average diameter of 4.19 cm. However, these differences were not statistically significant.

Firmness (kg/cm^2)

Firmness is closely associated with the ripening stage and is an important judgment factor, after visual appearance, for consumers. Table 2 represents the firmness of tomatoes during 15 days of storage at ambient temperature. Maximum firmness was recorded in treatment T1 (0.1% GA_3) valued at 1.5 kg/cm^2, followed by T6 ($CaCl_2$ 1.5%), measuring 1.42 kg/cm^2. On the contrary, the lowest firmness was observed in treatment T8 (0.2 mM SA) followed by T7 (0.1 mM) and the control. The firmness continued declining with the storage period and during the 25th day of storage, among the remaining treatments (T1, T2, T3, T4, T5, and T6) it was observed that the firmness declined by 23.95% in T4 (the least) followed by T2 (25.38%) while others have firmness declined by not more than 50%, which indicates the effectiveness of GA_3 and $CaCl_2$.

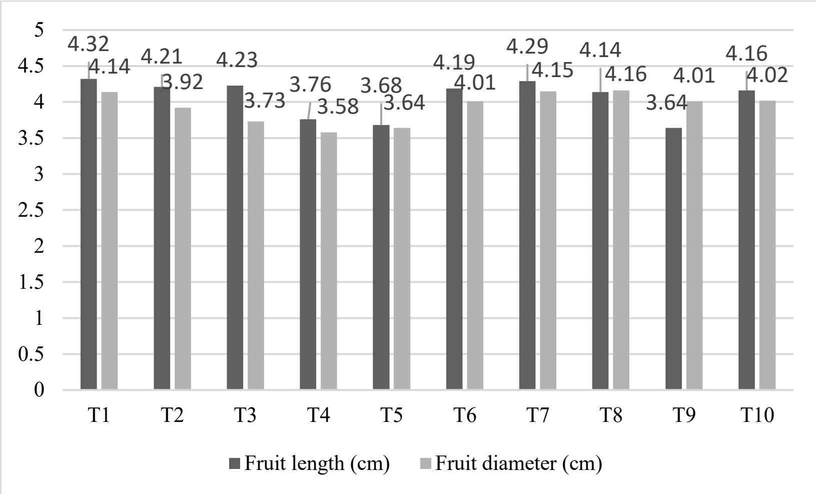

Figure 2. Effect of different treatments on mean length and diameter

These findings are supported by the research of Demes *et al*. (2021) who demonstrated that the same concentrations of $CaCl_2$ and GA_3*i.e.*, 1.5% and 0.1% were the most effective in delaying the fruit softening in tomatoes. It may be due to the inhibiting action of GA_3 that inhibits ethylene biosynthesis and activation of ripening regulator genes as per the study of Li *et al*. (2019). Likewise, higher concentrations of $CaCl_2$ 1% and 1.5% were effective in maintaining the firmness in tomatoes which is per the findings of Gharezi *et al*. (2012) who treated cherry tomatoes with varying concentrations of $CaCl_2$ and concluded that calcium dipping retarded the metabolism, slowed respiration rate and hence improved the firmness of tomatoes. An extension of this idea can be found in the study of Li *et al*. (2012), that the addition of calcium improves cell wall rigidity and inhibits the activity of enzymes like Polygalacturonase, which causes softening of fruits (Gautam and Bhattarai, 2009). The results of the present study revealed significant retention of firmness through the application of SA as reported earlier by Chavan and Shakhale (2020) in tomatoes. Like GA_3 and $CaCl_2$, SA also causes inhibition of cell wall and membrane degrading enzymes such as polygalacturonase, lipoxygenase, cellulase, and pectin methyl esterase and therefore, a lower rate of ethylene production (Nicktam *et al*., 2023).

None of the treatments was significant in maintaining the length and diameter, representing the inevitable physiological changes and shrinkage that occurs in fruit after harvest. Ghareziet *al*. (2012) also noticed a similar result in cherry tomatoes treated with calcium chloride where all the tomatoes shrunk in size regardless of the treatment.

Table 2. Effects of different treatments on Firmness (kg/cm^2)

Treatment code	**Treatments**	**Firmness (kg/cm^2)**
T1	0.1% GA_3	1.5
T2	0.2% GA_3	1.23
T3	0.3% GA_3	1.32
T4	0.5% $CaCl_2$	1.05
T5	1% $CaCl_2$	1.1
T6	1.5% $CaCl_2$	1.42
T7	0.1mM SA	0.91
T8	0.2mM SA	0.88
T9	0.3mM SA	1
T10	Control	0.95
	SE±M	**0.08**
	LSD at 5%	**0.18**
	CV%	**9.1**

SE±M = Standard error of differences of mean, LSD= Least Significant Difference, CV = Coefficient of Variation

Spoilage %

The treatment T1 (0.1% GA_3) was found to have significantly lowest spoilage % *i.e.*, 34.81%, followed by T6 (1.5% $CaCl_2$) with 35.07% and T9 (0.3 Mm SA) with 35.26% during the storage period, as shown in Table 3. Whereas, the highest spoilage was recorded in the treatment T10 or the control (64.63%). Comparing the LSD value at 5% with the mean differences of the treatment, it is found that the treatments T1, T5 (1% $CaCl_2$), T6, and T9 (0.3 mM SA) are significantly different than the control, indicating their effectiveness in reducing the spoilage percentage. In like manner, Singh and Patel (2014) also reported the maximum decrease in decay loss in tomatoes treated with GA_3 on the 12^{th} day of storage and suggested it was due to a decrease in the ripening process during the storage period.

Spoilage % increases with the increased rate of ripening during which the cell wall breaks down due to the action of hydrolases leading to fruit softening (Gautam and Bhattarai, 2006). This cell wall carbohydrate metabolism and the consequent loss of firmness have been associated with increased susceptibility to fungal infections (Conway *et al*., 1987). In the present study, the majority of the spoiled tomato fruits exhibited a distinctive woolly mold appearance and emitted a foul odor which can be a sign of fungal infection.

Color of the tomato

Initially the fresh, visually appealing and pink stage tomato was selected and grouped into treatment which was compared. On the initial observation day, color closely matched 55A on the color chart. The treatments maintained consistent color change from pink stage (55A) to red stage (44B) throughout the ambient storage conditions aligning with Yang *et al.* (2022) findings.

Shelf life days and marketable fruit%

Shelf life and marketable fruit percentage during postharvest treatments on tomatoes are summarized in Figure 5. The data represented shows shelf life and marketable fruit% % were significantly ($p < 0.05$) affected by GA_3, $CaCl_2$, and SA during the storage period. The fruits treated with T1, T6, and T9 extended the average shelf life to almost twice that of the control (15 days). Fruits treated with T1 (0.1% GA_3) had the longest possible average shelf life of 29 days followed by those treated with T6 ($CaCl_2$ 1.5%) at 27 days and T9 (0.3 mM SA) at 24 days. In the same fashion, the results for marketable fruit% follow almost the exact pattern where T1, T6, and T9 have twice the amount of marketable fruit than in control (35.57%) *i.e.*, 65.2%, 64.94%, and 64.74%, respectively.

These results also support the view of Pila *et al*. (2010) who reported that the fruits treated with 0.1% GA_3, 1.5% $CaCl_2$, and 0.4mM SA had the most significant impact on the shelf life than other concentrations and control, and caused the extension of storage life by 18, 17 and 15 days respectively. GA_3 and $CaCl_2$ were found effective over other treatments extending shelf life up to 21 days (Dhami *et al*., 2023) which can be attributed to the negative roles of GA_3 towards the ripening of tomatoes as demonstrated by Li *et al*. (2019). Similarly, Bhattarai and Gautam (2009) reported that the higher the concentration of $CaCl_2$ (1% and 1.5%), the longer the shelf life of tomatoes was than the lower concentrations. Moreover, fruits treated with SA did exhibit longer shelf life days than the control, however, it wasn't as significant as other treatments. This discrepancy might be due to the concentrations of SA used to treat fruits and storage temperature, contrary to Mandal *et al*. (2016) who compared lower concentrations of SA (0.2, 0.4, 0.6, and 0.8 mM) with higher concentrations of SA (1 and 1.2mM) at refrigerated

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

conditions and found that higher concentrations of SA were significantly effective in extending the shelf life of tomatoes up to 32.75 days.

Table 3. Effects of different treatments on Spoilage%

Treatment code	Treatments	Spoilage %
T1	0.1% GA_3	34.81
T2	0.2% GA_3	41.31
T3	0.3% GA_3	39.21
T4	0.5% $CaCl_2$	44.45
T5	1% $CaCl_2$	36.02
T6	1.5% $CaCl_2$	35.07
T7	0.1mM SA	48.61
T8	0.2mM SA	54.25
T9	0.3mM SA	35.26
T10	Control	64.63
	SE±M	**3.62**
	LSD at 5%	**7.61**
	CV%	**20.4**

SE±M = Standard error of differences of mean, LSD= Least Significant Difference, CV = Coefficient of Variation

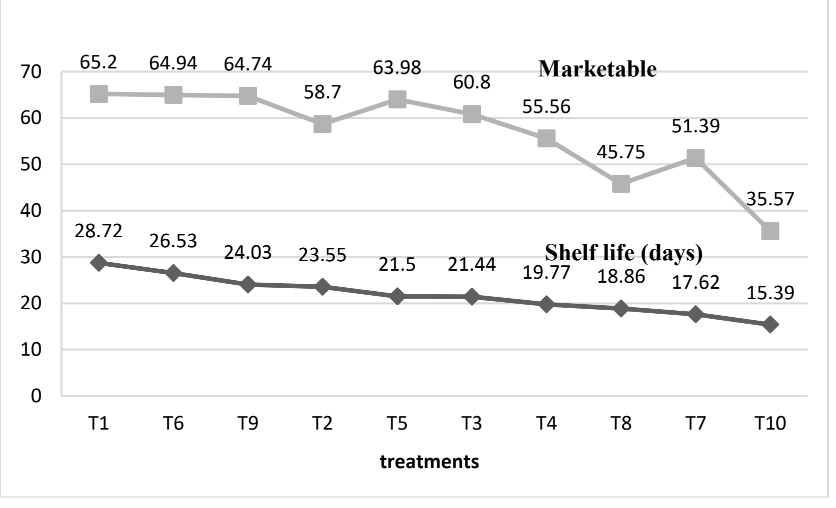

Figure 3. Effect of different treatments on shelf life and marketable fruit, %

Chavan and Sakhale (2020) also treated tomatoes with a higher concentration of SA *i.e.*, 200 ppm SA, and reported those fruits had a storage life of 32 days compared to the control that lasted only for 12 days stored at 24ºC. Likewise, the treatment of tomatoes with 0.75 mM salicylic acid prolonged the shelf life by 7 days along with a lower weight loss percentage and was proved to be more effective than oxalic acid (Kant *et al*., 2013). Similar results were observed by Tareen *et al*. (2012) in peach fruits treated with 2 mmol L^{-1} extending its shelf life up to five weeks without any spoilage stored at 0ºC.

CONCLUSION

Plant growth regulators gibberellic acid (GA_3) and salicylic acid (SA), along with chemical calcium chloride ($CaCl_2$), have shown great potential to positively impact and maintain the physical properties of tomatoes over an extended period.

Overall, the findings indicate that the exogenous application of gibberellic acid, calcium chloride, and salicylic acid successfully extends the shelf life of tomatoes up to 29 days under ambient conditions through the maintenance of physical characteristics, while in some cases even improving them. These treatments offer a safe, eco-friendly, economical, and sustainable alternative to high-tech equipment for effectively reducing post-harvest loss.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Analysis of Carbamate and Organophosphate Insecticides Residue by Rapid Bioassay Pesticide Residue in Vegetables in Bagmati Province Nepal

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ABSTRACT

The excessive use of chemicals, specifically the carbamates and organophosphates, results in pesticide residues in vegetables posing a significant risk and issue of causing both acute and chronic diseases. This study aimed to analyse the pesticide residue levels in vegetables grown in seven districts of Bagmati Province, of Nepal, using Rapid bioassay of pesticide residue (RBPR) technique. The acetyl cholinesterase (AChE) inhibition percentage of spinach, potatoes, and sword beans displayed consistently high inhibition percentages across 888 vegetable samples tested. One of spinach sample turned out to be unsafe for consumption since it exceeded a 45% inhibition threshold. Furthermore, higher pesticides residues were observed in some of the major vegetables like potato, capsicum, sword beans as compared to others. Samples from Bhaktapur district showed the highest carbamate and organophosphate inhibition percentage level, while those from Lalitpur displayed the lowest as compared to the other districts. As per the findings, producer must stick to follow proper pesticide use and follow the practices such as waiting period, in order to safeguard the consumers. This study demonstrates the significance of RBPR as a cost-effective and easy method for timely evaluation of pesticide residues in easily perishable commodities.

Keywords: Acetyl cholinesterase, acute diseases, cost effectivity, inhibition percentage, inhibition threshold

INTRODUCTION

Nepal is an agricultural country, with almost 57.3% of the population engaged in the farming of food and cash crops. A total area of 302,135 hectares (8.97%) of the 3,091,000 hectares of cultivated land are being utilized for the production of vegetable crops that yields 4,376,077 metric tons. Out of 24.10% of GDP that is contributed through agriculture, vegetables make up 3.9% of AGDP (MoALD, 2023/24). Pesticides are broad spectrum substances that are used to control pests and disease carriers. However, they are being used haphazardly without the rational consideration of their doses, rates, waiting period, etc. on crops- that leads the commodities unsafe for consumption. The world's population is increasing substantially, while there is the arithmetic increase in the food production that has resulted in disparity between supply and demand (Upadhyaya & Bhandari, 2022). Agriculture is forced to increase the output due to this imbalance. To fulfil the increasing food demand farmers have shifted to use chemicals such as synthetic fertilizers and pesticides and produce the desired crop yields (Kumar et al., 2011). Pesticides act as the poisons, play a significant role in pest control but also possess substantial hazards. This problem is widespread around the world, including Nepalese food commodities too. Pesticide poisoning is an emerging health issue, especially in the developing countries. Around 700 people each day around the world suffer from the exposure. There are numerous problems linked with the long-term such as immunological suppression, hormone disturbance, and cancer (Brouwer et al. 1999). The use of pesticides in Nepal has steadily increased, attaining 396 g a.i./ha and is 1.60469 a.i.kg/ha in vegetables (PPD, 2015). Eggplant and tomatoes are the most pesticide-used crops, that has been problematic to both consumers and the surroundings (PPD, 2014). Pesticide application is increasing every year, and Nepalese people continue to face a serious risk from the chemicals in their food (Ghimire and GC, 2018; Khanal et al., 2021).

The list of Organophosphate class that are used in Nepal are Acephate, Azamethiphos, Chlorantraniliprole, Chlorpyrifos, Dimethoate, Ethion, Malathion, Phenthoate, Profenofos, Quinalphos, Temephos and Carbamates class are Propoxur, Thiodicar. In contrast banned pesticides of organophosphate are Chlorpyrifos and in use but prohibited in tea fields are Ethion, Quinaphos (Nyaupane, 2021). Due to inadequate rules and regulations, limited user understanding of hazards, improper use of personal safety devices, inappropriate handling and the usage of highly toxic pesticides developing countries are more likely to have adverse health consequences. Conventional method of detecting the residue of pesticides like Liquid Chromatography (LC) and Gas Chromatography (GC) are the precise method but they are expensive and tedious. These approaches are not so effective for very perishable crops that require quick and rapid testing (Sharma et al., 2012). Rapid Bioassay for Pesticide Residues (RBPR) is an efficient, economical, and effective procedure for the identification of pesticide residue of organophosphate and carbamate pesticides especially in the vegetables and fruits. Since, it determines the reduction of acetylcholinesterase (AChE) enzymatic activities, being an invaluable method for perishable goods that require rapid evaluation (CAL, 2017). The RBPR technique utilises acetyl-cholinesterase to calculate and determine the residue or inhibition percentage of Organophosphate (OP) and Carbamate. AChE, the molecule used in this method, was taken out from the housefly's brain. The combination of AChE and healthy food sample gives a yellow reaction due to increase in 5-thio-2-nitrobenzaoateanion. The enzymatic activity becomes slows or ceases when insecticide is present. The speed of inhibition of colour development is reflected by quantity and the toxicity present in the chemical (Khanal et al., 2023).

The objective of the research was to use Rapid Bioassay Pesticide Residue (RBPR) to analyse the carbamate and organophosphate inhibition percentage in different vegetable commodities, and pesticide inhibition percentage across different districts to assure compliance with the recommended levels and protect consumer's health.

MATERIALS AND METHODS

Site and crop selection

For the pesticide residue analysis, seven districts of Bagmati Province of Nepal; Chitwan, Dhading, Makwanpur, Kavrepalanchok, Kathmandu, Bhaktapur and Lalitpur (Fig. 01) were chosen on the year 2024. The districts were chosen randomly so that it represents the sample of Bagmati province as a whole various crops were selected for various selected districts. Season of cultivation, availability of different vegetables in the market and the obtained secondary data were taken into account while selecting the crops. The study was based on the primary data obtained from Rapid Bioassay of Pesticide Residue (RBPR) Laboratory unit Kalimati, Kathmandu, under the Central Agricultural Laboratory.

Sample collection

The vegetable samples for the study were collected from 7 districts, Chitwan (21 crops), Dhading (18 crops), Makwanpur (16 crops), Kavrepalanchok (18 crops), Kathmandu (10 crops), Bhaktapur (11 crops), Lalitpur (8 crops). A single, representative sample was taken of each crop type from the district. Each sample

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

was then carefully labelled with a unique identification code (sample identification included the crop name and the district of collection), to ensure that there could be no confusion or loss of identity. The vegetable samples that were collected for the study included different plant parts depending on the crop type. With respect to each crop type, the selected samples were as follows: fruit were collected from balsam apple, bitter gourd, bottle gourd, sponge gourd, brinjal, capsicum, cucumber, green chilli, green peas, pumpkin, tomato; head (whole) were from broccoli, cabbage, cauliflower; leaves from broad leaf mustard; roots from carrot and radish; tubers from potato; whole pod - kidney bean. One gram (1g) sample was taken from each selected plant part.

Chemicals and reagents used

Acetylcholinesterase (AChE), Acetylthiocholine Iodine (ATCI), 5,5' dithio-bis-2-nitrobenzoic acid (DTNB) and sodium phosphate buffer, bromine water (0.4%), ethanol, and distilled water were the chemicals and reagents used for sample extraction and analysis.

Preparation of solution from reagents

The powder form of regents was mixed with the distilled water and stored in the bottle to create a solution for the test. Approximately, 30mg of AChE and 216mg of ATCI was then dissolved in 10ml and after dividing into the proportions, 19.8mg of DTNB was dissolved in 50ml of distilled water or equivalent or following the bottle's direction and preserved at **below 0°C**. Buffer solution was placed at room temperature. One percentage of bromine concentration was made. The date of preparation and volume was mentioned in label after preparation of solution from reagent.

Sample extraction process

The sample extraction was carried out in two consecutive test tubes each for carbamate and organophosphate. At first, plant tissue of 1-2 grams was cut into small pieces and placed in the test tubes. Following this, in the test tubes 1 ml and 2 ml with 95% ethanol (AR grade) were added respectively and after that it was shaken for 20 seconds using a vortex mixer and left to stand for three minutes in case of carbamates while for organophosphate analysis, it was left to stand for 20 minutes, after adding 100 µl of 1% bromine water in order to remove the excess bromine water. Then, for analysis, extracted sample's supernatant solution was transferred to the new test tube. When a longer soaking period was anticipated the test tube was shielded with parafilm to avoid evaporation of solvent.

Incubation or analysis of sample extract

Prior to the analysis of extracted sample, a control test and sample test were conducted. The difference between these two tests was regarded to be the enzyme inhibition percentage that is resulted by the residual pesticide present within the sample.

Control test

To conduct the control test, first in 4ml cuvette, 3ml of Phosphate Buffer Solution (PBS) was filled. Then, blank $20\mu l$ of solution of AChE and 20 $\mu l$of 95% ethanol (AR grade) was added. After that, the mixture was mixed for 5 seconds and 2.5 minutes of waiting was done followed by addition of $100\mu l$ of DTNB solution. Finally, 20 µl of ATCI was placed exactly 3 minutes later and it was mixed for 5 seconds in order to initiate the reaction of enzymes.

The control test must show an absorbance range between 0.250 to 0.320 at spectrophotometer(412nm) to ensure validity of enzyme activity. This test is significant because as it represents 100% AChE activity, assist the baseline for calculating pesticide inhibition in sample tests. If this reading falls outside the range, then the test should not be proceeded, or it may lead to faulty results.

Sample test

As in the test, 3ml of PBS was added in 4ml of cuvette along with 20 µl ACHE solution and 20 µl of sample extract. Then, it was mixed well for 5 seconds. 100 µl of DTNB solution was added after 2.5 minutes and waited for 2.5 minutes. Exactly at 3 minutes, when the last reaction was ready, 20 µl of ATCI solution was added and stirred for 5 seconds, then the enzyme reaction begun. By placing the cuvette in spectrophotometer, the absorbance change was read at 412 nm wavelength, and compared with the reading of the control test, and when the inhibition percentage exceeded 35%, the same process was repeated two times for the confirmation.

Data collection

The sample was placed in the spectrophotometer (412nm) and after running the test it took one minute to give the inhibition percentage.

Interpretation of results

Using a spectrophotometer, enzyme inhibition percentage was observed and calculated as follows:

$$\text{Enzyme inhibition (\%)} = \frac{Absorbance\ change\ (control) - Absorbance\ change\ (sample)}{Absorbance\ change\ (control)} \times 100$$

For the inhibition percentage of enzyme that was obtained was interpretated as shown in Table 2
Source: (Chiu et. al., 1991)

Limitation of the study

This research was bounded to the detection of organophosphate and carbamate insecticide residues using the RBPPR technique, groups of pesticides like pyrethroids and neonicotinoids doesn't detect. Based on enzyme activity, RBPR technique only provides partially quantitative output. furthermore, no any other chemicals confirmations GC, MS, or HPLC was performed. Samples were collected from selected districts in Bagmati province during particular period of time without considering seasonal variations and geographical range. There may have been limitations with this study in terms of its sample handling, storage, and the number of different vegetable types evaluated and the human health risk assessment models were not included. These factors could have limited the generalizability and accuracy of the study's findings.

Table 2. Enzyme inhibition percentage and result interpretation

Enzyme Inhibition	**Result Propose**
>45%	Not suggested for consumption purposes
35%-45%	Quarantine for a minimum of 2 days. Repeat the test after washing. If the inhibition percentage is less than 35%, allow it for sale.
<35%	Approve for sale and consumption

RESULTS AND DISCUSSION

PESTICIDE RESIDUE ANALYSIS ON VEGETABLES PRODUCED IN CHITWAN DISTRICT

The average inhibition percentage of carbamate and organophosphate is displayed in Fig. 02. Among all the vegetables examined from Chitwan district the pesticide residue as indicated by the ACHE inhibition percentage, was highest for broccoli (8.0) followed by brinjal (7.36) and the lowest was found in cauliflower and green peas (2.3).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

The inhibition percentage of organophosphate (OP) in Kidney beans (8.6) followed by capsicum (7.8) had the highest inhibition percentage of organophosphate and green chilli (1.3) exhibited the lowest. Capsicum (21.1) exhibited the greatest individual sample inhibition percentage for organophosphate whereas brinjal (20.4) showed the highest for the Carbamate.

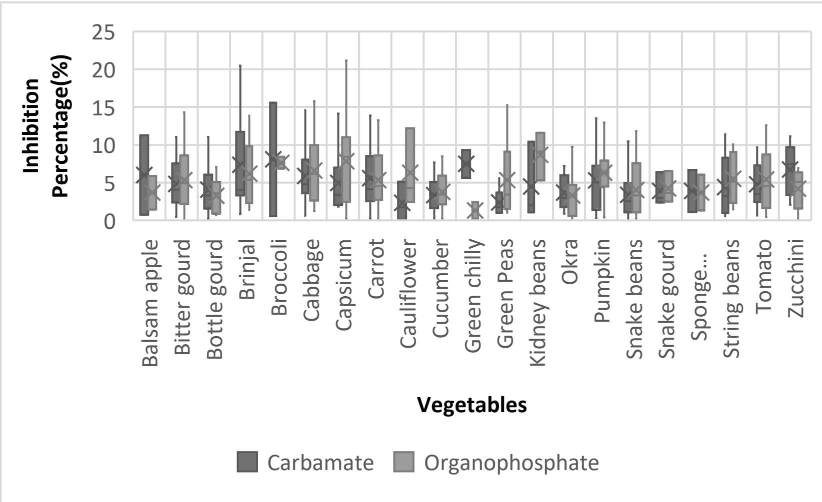

Figure 1. Average carbamate and organophosphate inhibition percentage in Chitwan district across different vegetable samples

PESTICIDE RESIDUE ANALYSIS ON VEGETABLES PRODUCED IN DHADING DISTRICT

For Dhading district, as shown in Fig. 03, sword beans (21.3), followed by green chilly (7.1) showed the highest average inhibition percentage for carbamate and lowest in bottle gourd (2.6). However, for organophosphate residue test, the average inhibition percentage was seen higher in sword beans (22.2) followed by green chilli (9.8) and lowest was depicted in snake beans (3.5). For both the carbamate, and organophosphate the highest individual inhibitory percentage was displayed by sword beans (30.3) and (29.8), respectively.

The residue analysis showed that residue was present in most vegetables, indicating the non-judicial use of pesticides, especially when pesticides were used without adequate understanding of the pre-harvest interval (waiting period). This suggests that farmers need to be taught about proper use of pesticides, and that marketable crops should be constantly tracked throughout the nation. At the same time consumers should also be awared about the residues of pesticides in vegetables. After the conduction of RBPR test on vegetable samples of Bagmati region it was found that Brinjal (20.48%) and sword beans (22.2%) from Dhading, potato (16.7%) from Kathmandu, spinach (27.5%) from Bhaktapur were found to have comparatively higher pesticide residue which was in line with the findings of Kodandaram et al., (2013) which demonstrated that brinjal was grown using high amount of pesticide in brinjal comparing to other vegetables.

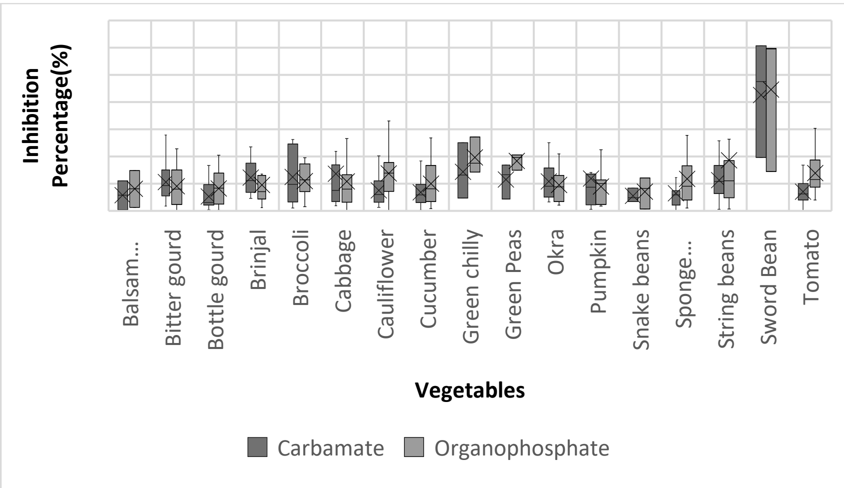

Figure 2. Average carbamate and organophosphate inhibition percentage in Dhading district across different vegetable samples

Pesticide residue analysis on vegetables produced in makwanpur district

As shown in Fig.04, for the case of Makwanpur district, the average inhibition percentage for carbamate was observed the highest in potato (14.5) followed by broccoli (12.5) and lowest in radish (1.2) followed by hatch chilli (2.0).

The highest organophosphate inhibitory percentage was observed in potato (12.6) followed by broccoli (10.2) and lowest was recorded in balsam apple (2.4) subsequently followed by string beans (3.6). Potatoes exhibited the highest individual inhibition percentage for both carbamate (20.7) and organophosphate (19.3).

Pesticide residue analysis on vegetables produced in kavrepalanchok district

The inhibition percentage of carbamate is shown in Fig. 05. Among all the vegetables examined in Kavrepalanchok district the inhibition percentage was highest for carrot (15.2) followed by the potato (13.0) and the lowest in string beans (2.8) and bottle gourd (3.0) subsequently followed by hatch chilly (3.4). The inhibition percentage of organophosphate (OP) pumpkin (12.6) followed by cabbage (11.1) had the highest inhibition percentage of organophosphate and of green capsicum (3.0) exhibited the lowest. Potato displayed the greatest individual sample inhibition percentage for carbamate 29.4 and organophosphate 23.6.

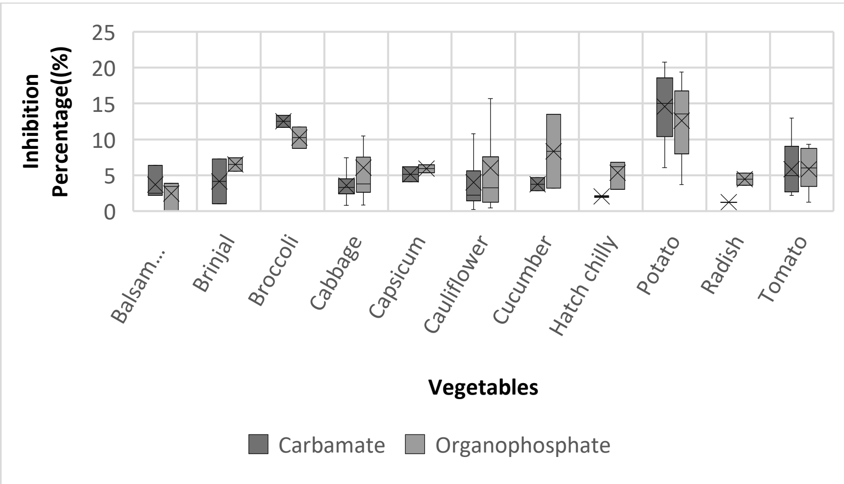

Figure 3. Average carbamate and organophosphate inhibition percentage in Makwanpur district across different vegetable samples

Pesticide residue analysis on vegetables produced in Kathmandu district

Fig.06 demonstrates the average inhibition percentage for carbamate and it was found highest in potato (16.7) which was followed by sword beans (9.4) and least in pumpkin (2.2). Likewise, for the organophosphate the average inhibition percentage was observed highest in potato (13.4), followed by sword beans (12.5) whereas the least was seen in basil (3.0) as shown in the figure. Potatoes exhibited the highest individual inhibition percentage for both carbamate (30.06) and organophosphate (24.03).

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e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

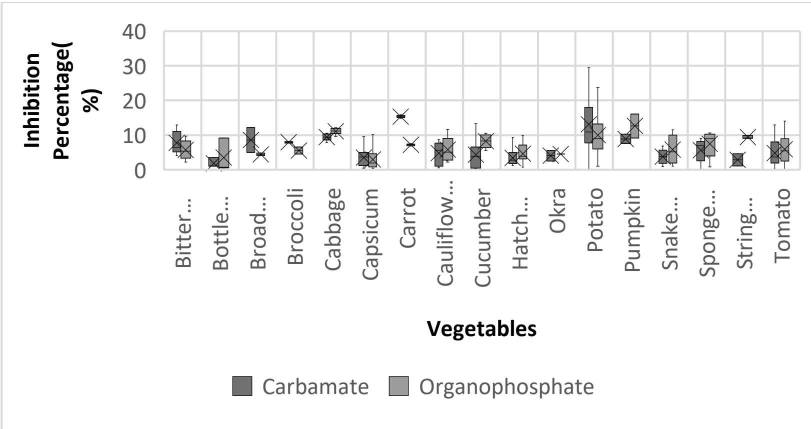

Figure 4. Average carbamate and organophosphate inhibition percentage in Kavrepalanchok district across different vegetable samples

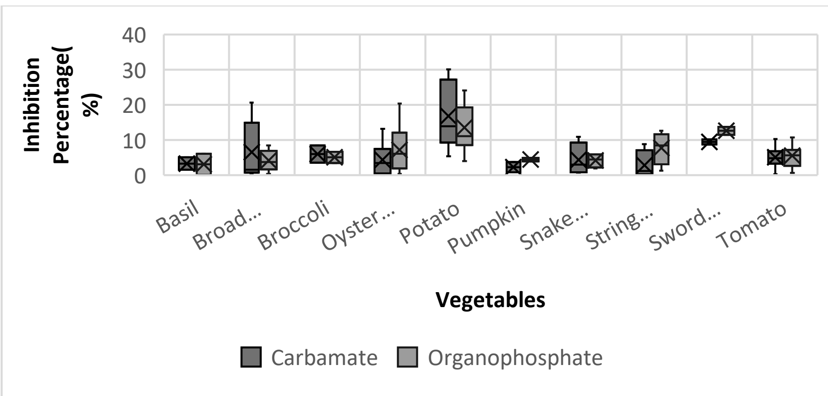

Figure 5. Average carbamate and organophosphate inhibition percentage in Kathmandu district across different vegetable samples

Pesticide residue analysis on vegetables produced in Bhaktapur district

As seen in Fig. 07, the average inhibition percentage for carbamate pesticide in the Bhaktapur district has been found to be greater in spinach (17.5), subsequent to potatoes (15.4), and least in broccoli (4.0), followed by cucumber (4.2). While, spinach (27.5) shows the greatest organophosphate inhibition percent, followed by potatoes (13.4), and cucumber (4.0) shows the least inhibition, followed by cabbage (5.0). Spinach had the highest inhibition percentage (46.4 and 76.2) for carbamate and organophosphate, respectively, which are very harmful for consumption and sale.

Spinach produced in Bhaktapur district showed highest inhibition percentage for organophosphate (76.22%) followed by sword beans (29.86%) of Dhading district. Inhibition percentages of (20.48%) brinjal from Chitwan, (30.33%), sword beans from Dhading, (46.41%) spinach from Bhaktapur and (29.4%) potatoes from Kavre district of Bagmati province were observed for carbamate. Numerous crops, including potatoes and chili, were found to have higher rates of pesticide applications; in the Kavrepalanchowk area, 93% of farmers sprayed pesticides on potato fields two to six times every season, while 6% applied pesticides to potato crops more than ten times in a period of a season (Sapkota et al., 2020).

Two samples (0.22%) delivered more than 35% inhibition percentage, out of permissible levels. Most vegetables cultivated in different districts of Bagmati Province excluding Bhaktapur, seem to have lower traces of organophosphate (OP) or carbamate pesticides. However, the mean inhibitions percentage of spinach (76.22) was greater than the permissible range (<35) and unsafe for consumption. Some sample showed residues were over 70%, indicating that producers were unaware of the recommended waiting period, but could also outcomes from the unacceptable use of carbamate and organophosphate pesticides, overdoses or the mixing of various pesticide formulations. This exercise reflects a failure to ensure pesticides practices by products as well as lack of extension support.

Pesticide residue analysis on vegetables produced in Lalitpur district

As shown in the Fig. 7, the average inhibition percentage for carbamate pesticide in the Lalitpur district was highest in string beans (8.4) and subsequently followed by broad leaf mustard (5.9) and lowest by cauliflower (2.1) followed by button mushroom (2.7). While Tomato (6.2) showed the highest average inhibition percentage for organophosphate followed by broad leaf mustard (5.7) and least by snake beans (0.4) followed by string beans (1.6) as shown in the figure. The most significant individual values for carbamate and organophosphate (12.09) and (10.04) have been shown by broad leaf mustard, which is safe for consumption and sale purpose.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

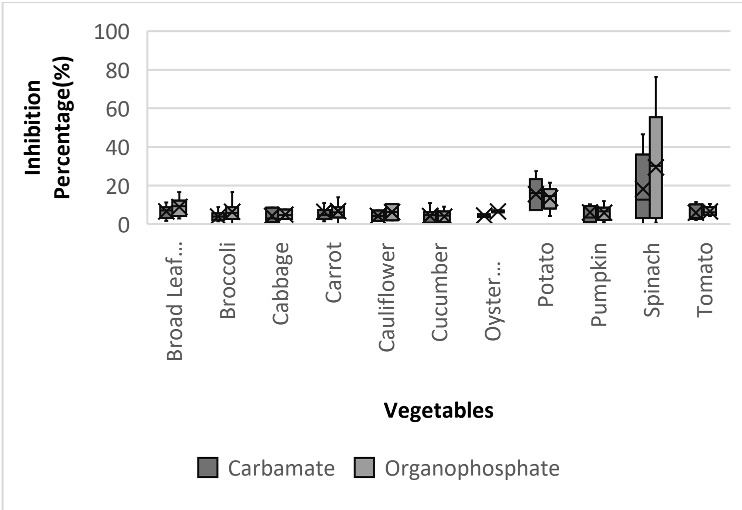

Figure 6. Average carbamate and organophosphate inhibition percentage in Bhaktapur district across different vegetable samples

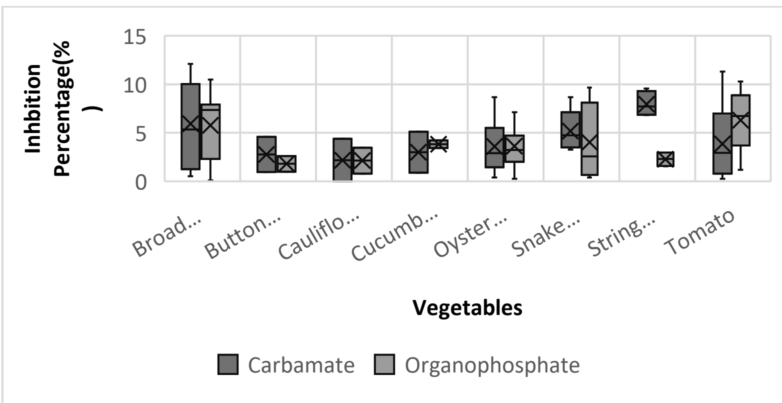

Figure 7. Average carbamate and organophosphate inhibition percentage in Lalitpur district across different vegetable samples

According to Bhandari et al. (2019), 99 % of the brinjal samples had residues, 56 % had several pesticide residues, and 4 % had triazophos [22.5µg/kg] across the EU MRL (European Union Maximum Residue Limit). Crops like brinjal and tomatoes are highly vulnerable to pests, which encourage the farmers to apply pesticides with a great effort to ensure the market quality and quantity. 70% of the potato sample contained pesticide residue, suggesting that the potatoes were

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July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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highly contaminated (Khandekar et al.,1982). In contrast,44% of tomato samples [10.6-1772µg/kg] had levels of chlorpyrifos beyond the EU MRL was surpassed by triazophos in 6% [237-685µg/kg] and omethoate in 3% [27.9µg/kg] of tomato samples (Bhandari et al.,2019). Similarly, Rawal et al. (2013) discovered chilies with more methyl parathion residue (0.025 ppm) than the MRL threshold. The few reasons behind higher pesticide may be overuse of pesticides, failure to observe the preharvest interval as well as high pest pressure in the field.

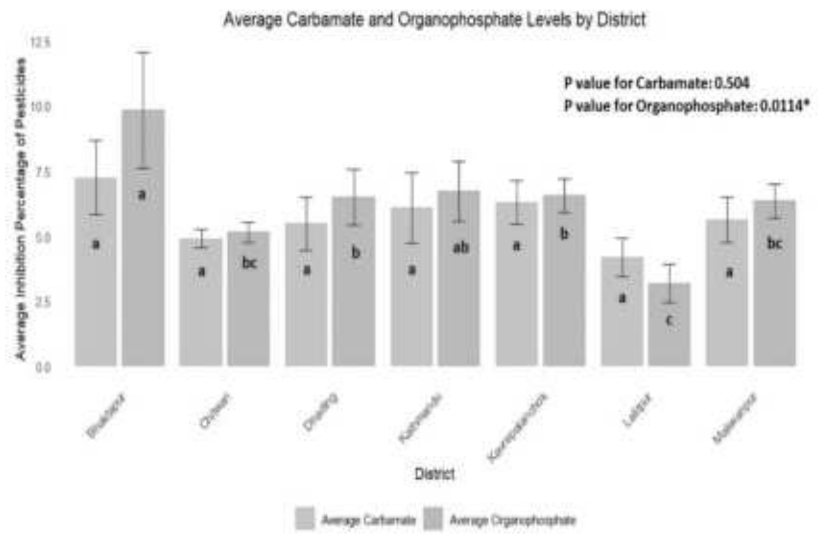

Figure 8. Average inhibition percentage of Carbamate and Organophosphate in seven districts

Chilly samples from Kavre, Bhaktapur, and Rupandehi included methyl parathion, carbendazim, and chlorpyrifos (Bhandari et al., 2019; Rawal et al., 2012). Cucumber samples from Chattradeurali, Dhading, were treated with metalaxyl. Potato samples from Chitwan, Bhaktapur, and Indian Bangali had traces of mancozeb and DDT (Manandhar, 2006; IPEN, 2005). Spinach from Kavre and Bhaktapur had dichlorvos and chlorpyrifos (Rawal et al., 2012; Giri, 2010), while tomato samples from Kavrepalanchowk, Dhading, and Rupandehi shows residues of cypermethrin, mancozeb, carbendazim, and chlorpyrifos (Manandhar, 2006; Giri, 2010; Bhandari et al; 2019).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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Similar results were seen on comparison with other studies. Ghimire et al. (2020) executed the dangerous use of pesticide residues in cauliflower leaves and curds showing the unsuitable use of pesticide is still widespread in Nepal. Similarly, Brouwer et al. (1999) highlighted risk associated with the human health with pesticide exposure, including cancer and hormone disruption. These results align the current study's conclusion of high pesticide residue levels in specific vegetable, making it evident that stronger laws enforcement and farmer education is must needed. The vegetables like brinjal, cauliflowers, tomatoes, potatoes, green beans, and many more that were brought from the neighboring districts or the farms to the central vegetable market were considered safe for the consumption since it displayed little or no use of pesticides (Koirala et al., 2010).

The average inhibition percentage of Carbamate and Organophosphate across seven districts is displayed by fig.8. The highest carbamate inhibition percentage was seen in Kavrepalanchok district (7.69), while the lowest was seen in Lalitpur (4.1). For the organophosphate, Bhaktapur (8.44) demonstrated the greatest inhibitory percentage whereas Lalitpur showed the lowest (4.46). Organophosphate continuously exhibited higher average inhibition percentages than Carbamate across all the districts.

CONCLUSION

The study concluded that nearly all the vegetable samples tested from Bagmati province had residue levels of organophosphate and carbamate pesticides that were below the Maximum Residue Limits (MRL), while a few commodities specifically spinach, sword beans, and potatoes were consistently found to have pesticide level higher than the acceptance level. One of Spinach sample exceeded the 45% limit, make it unsafe for consumption. A main drawback of this study is that it was limit of only carbamate and organophosphate pesticide groups through the RBPR technique. Given the wide range use of other pesticide classes such as synthetic fungicides, pyrethroids, and neonicotinoids, further research should aim to widen the scope of pesticide residue analysis using more systematically multi-residue detection technique.

In countries with scant laboratory resources RBPR approach is crucial as it is cost effective and efficient, is essential for rapid screening approaches. But to cover farmers throughout the nation, broader implementation is needed. This can be accomplished by educating people on the proper use of pesticides, waiting periods, and testing options. This will reduce health risks and improve food safety, which should worry lawmakers. Along with referencing agriculture and public health, this reinforces the growing need for a more integrated strategy to pesticide usage.

ACKNOWLEDGEMENTS

Authors are grateful to Rapid Bioassay of Pesticide Residue Analysis Lab Unit situated in Kalimati, Kathmandu, Central Agricultural Laboratory, Ministry of Agriculture and Livestock Development for procurement of the laboratory equipment and required supplies. There was no involvement of any outside fundings; the researchers themselves covered all the expenses required for the study.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Determinants of Output and Profitability among Lowland Rice Producers in North West, Nigeria

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ABSTRACT

This work is centered on determinants of output and profitability analysis among lowland rice producers in North West, Nigeria. A multi-stage sampling design was utilized, at the fourth-stage, a random sampling approach was utilized to select 200 lowland rice producers. Primary data of cross-sectional sources were utilized for this research, the data were estimated utilizing descriptive statistics, farm budgetary method, and stochastic production frontier version. The result shows that approximately 78% of lowland rice producers were male with mean age of 42 years. They are small-scale producers with an average farm size of 1.27 hectares. The lowland rice production is profitable with an evaluated gross margin (GM) and net farm incomes of 916219.39 and 868078.35 Naira per hectare. The fertilizer usage, seed, farm size, agrochemicals, and labour were significant and positively affect the quantity of rice produced. The investigation recommends that credit at single interest rate should be giving to rice producers.

Keywords: Agrochemicals, lowland rice producers, farm budgetary technique, Nigeria, Stochastic production frontier model,

INTRODUCTION

Rice (*Oryza sativa*) is one of the significant and importance cereal crops grown and eaten worldwide (Ojo et al., 2020). Rice rated third coming next to wheat and maize with regard to world output (Imolehin and Wada, 2000). Nigeria is one of the major rice consumers in the world and one of the major growers of rice in Africa (FAO, 2015). Nigeria has numerous abilities for enhanced output as the country is endowed with sufficient rice farming conditions (Alabi and Anekwe, 2022). Rice has retained its rank as one of the hopeful commercial crop for enhancing food security, increasing economic growth, and alleviating poverty (Houngue and Nonvide, 2020). Rice plays a significant part in household foodstuffs in developing countries and constitute the main produce in the wage against poverty, food insecurity in Africa (Seck et al., 2013). Rice productivity in sub-Saharan countries such as Nigeria is low, income of farmers is low, profitability is low, this is due to traditional methods of farming, land fragmentation, poor irrigation facilities, lack of modern farm technologies, lack of credit, and the impact of climate change (Chandio et al., 2017). Approximately, 90% of domestic rice output in Nigeria comes from feeble planned, resource poor, peasant, small-scale growers (USAID, 2009). The resource poor farmers use low input requirements, use low-input strategy, and has low productivity (IFAD, 2012). The smallholder farmers in Africa such as Nigeria are not so much productive when equate to global levels arising in lower outputs, and lower profitability (FAO, 2014). Africa has the lowest cereal crops output per hectare when compared to any other parts of the world, in some instances there has been reducing output per unit area. According to Obih and Baiyegunhi (2017) and USDA (2016) the yearly quantity of rice supplied in Nigeria was 2.7 million metric tons, the annual consumption of rice was 5 million metric tons, with the demand-supply gap of 2.3 million metric tons. Nigeria has approximately 4.6 million ha of land appropriate for rice farming, but approximately 1.8 million ha of land accounting for 39% is under rice farming (Danbata et al., 2013). Five main rice farming systems have been recognized in Nigeria, they include: upland rain-fed, deep water, inland shallow swamp, floating lowland, and irrigation farming systems. Akpokodge at al. (2001) reported that approximately 46% of the total area devoted to rice farming in Nigeria is for irrigated and rain-fed upland rice production systems. Table 1 shows the output of rice in Nigeria and the world. Nigeria in 2021 and 2022 produced approximately 1.06 % and 1.09% of the world rice output, respectively. Similarly, Table 2 shows the rice cultivated area (hectares) in Nigeria and the world for 2021 and 2022, respectively (FAO, 2024). In Africa, rice is listed as one of the speedy emerging food crops, the demand in the area is rising by approximately 6%, but then the gap between the demand and output also continue to rise (Miassi et al.,2023). It is important to evolve agricultural strategies to increase the output of farmers for an advancement on one hand, and the other hand in the provision of rice. Smallholder rice producers in Nigeria are confronted with numerous problems such as low productivity, little-access to farm resources and assets, post-harvest losses, lack of support extension and research services, lack of market and rural infrastructures, and shortage of chance for agricultural value addition (IFAD, 2012).

Table 1. The Output of Rice in Nigeria and the World

Variables	Output of Rice in Nigeria (tons)	World Output of Rice (tons)
Rice Output in 2021	8342000	789045342.64
Rice Output in 2022	8502000	776461456.61

Source: FAO (2022)

Table 2. The Rice Cultivated Area in Nigeria and the World

Variables	Area of Rice in Nigeria (hectares)	World Area of Rice (hectares)
Rice Area in 2021	4320100	166310782
Rice Area in 2022	4580000	165038826

Source: FAO (2022)

MATERIALS AND METHODS

This study was conducted in North West which consists of Kano and Kaduna States, Nigeria. This work utilized the use of a multi-stage sampling design. The sample frame of lowland rice growers was 400 respondents. The total sample number of lowland rice producers was proportionately and randomly selected, which consisted of 200 respondents comprising of 100 smallholder lowland rice producers from each state, respectively. Primary data of cross-sectional sources were used on a well-organized questionnaire that was submitted to test involving validity and reliability. This sample number was calculated based on the established formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{400}{1+400(0.05^2)} = 200 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
n = The representative number
N = The complete number of lowland rice growers
e = 5%
The data obtained were evaluated utilizing both descriptive and inferential statistics:

Farm Budgetary Technique

The farm budgetary technique includes the gross margin (GM) analysis and net farm income. The gross margin analysis can be explained as the distinction between the gross returns (GFI) and total variable cost (TVC):

$$GM = \sum_{i=1}^{n} P_i Q_i - \sum_{i=1}^{n} P_j X_j \qquad (2)$$

$$GM = TR - TVC \qquad (3)$$

Where,
GM = Gross Margin (₦)
TR = Total Revenue (₦)
TVC =Total Variable Cost (₦)

NFI = Gross Margin (GM) – Total Fixed Cost (TFC)

$$NFI = \sum_{i=1}^{n} P_i Q_i - \sum_{i=1}^{n} P_j X_j - K \qquad (4)$$

Where
NFI = Net Farm Income (Naira)
GM= Gross Margin (Naira)
P_i = Price of Rice Output i^{th} ₦/Kg
Q_i = Quantity of Rice Output i^{th} (Kg)
P_j = Price of Input j^{th} (₦/Kg)
X_j = Quantity of Input j^{th} used (Kg)
K = Total Fixed Cost (TFC)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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Depreciation of Assets

The straight line depreciation method is specified as:

$$D = \frac{P - S}{N} \qquad (5)$$

D= Depreciation of Farm Production Assets (Naira)
P= Purchase Cost of Farm Asset (Naira)
S= Salvage Estimate of Farm Asset (Naira)
N= Years of the life span of the Farm Asset (Years)

Financial Analysis

The formula of gross margin ratio (GMR) is stated as:

$$GMR = \frac{Gross\ Margin}{Total\ Revenue} = \frac{GM}{TR} \qquad (6)$$

The operating ratio (OR) is stated thus:

$$OR = \frac{TVC}{GI} \qquad (7)$$

Where, OR= Operating Ratio (Units); TVC= Total Variable Cost (Naira); GI= Gross Income (Naira).

The rate of return invested per naira is stated thus;

$$RORI = \frac{NI}{TC} \qquad (8)$$

Where, RORI is defined as Rate of Return per Naira Invested (Units); NI= Net income from Rice Farming (Naira); TC= Total Cost (Naira).

The SPEFM (Stochastic Production Efficiency Frontier Model)

This follows the work of Alabi et al. (2022), the SPEFM is expressed as:

$$Y_i = f(X_i, \beta_i)e^{v_i - u_i} \ldots\ldots (9)$$

$$Ln\ Y_i = Ln\ \beta_0 + \sum_{j=1}^{5} \beta_i\ LnX_i + (v_i - u_i) \ (10)$$

$$TE_i = \frac{Y_i}{Y_i^*} \ldots\ldots\ldots. (11)$$

$$TE_{ij} = \frac{F(X_i, \beta)\exp\,(v_i - u_i)}{F(X_i, \beta)\exp\,(v_i)} \ldots.. (12)$$

$$TE_{ij} = \exp(-u_{ij}) \ldots.. (13)$$

where,

Y_i = Output of Rice (Kg)
Y_i^* = Unobserved Frontier Output of Rice (Kg)
X_i = Inputs
β_i = Vectors of Estimated Parameters
V_i = Random Variations

U_i= Error Term due to TIE (Technical Inefficiency)
X_1 = Fertilizer Usage (Kg)
X_2 = Seed in Kg
X_3 = Farm Size (Ha)
X_4 = Agrochemicals (Litre)
X_5 = Labour (Mandays)

RESULTS AND DISCUSSION

The farm and farmers characteristics of lowland rice producers

The farm and farmers' characteristics of lowland rice producers was presented in Table 3. Approximately 78% of lowland rice producers were male, while 22% of the growers were female. About 72% of lowland rice producers were married, while 28% of respondents were either single, or divorced. Averagely, the age of lowland rice producers were 42 years. This signifies that the producers are active and resourceful. This means that they can easily adopt ideas, innovations, farm technologies, and research findings. This result is supported with the study of Ojo et al. (2020) who obtained the mean age of household head of 47 years among rice farmers in Southwest, Nigeria. The large household size is a source of unpaid family labour for rice farming activities. The household sizes were large with mean of 12 people per household. The lowland rice producers were smallholder farmers with average farm size of 1.26 hectares of rice farms. They attended formal education and are literate, can read and write with average of 12 years (SD = 2.71) of attending school education. Approximate 81% (SD = 0.38) are members of cooperative organization. The members of cooperative organization afford the rice producers access to credit, share ideas and information, and sell their rice produce in bulk. They had about 13 years' experience in rice farming. This result is in line with outcome of Okello et al. (2019) who obtained that the mean farming experience of rice growers in Northern Uganda was 18 years.

Analysis of profitability in lowland rice farming

The analysis of profitability in lowland rice farming is displayed in Table 4. The different costs attracted and profits realized in lowland rice farming was based on the present market data. The TFC was estimated at 48141.04 Naira per hectare, and this attributed for 12.47% of TC. The total variable cost (TVC) was computed at 337878.61 Naira per hectare and this attributed for 87.53% of TC.

The TC is the sum of TVC and TFC, and this was calculated at 386019.65 Naira per hectare. The GM and NFI were computed at 916219.39 Naira and 868078.35 Naira, respectively. This signifies that lowland rice farming was profitable. The GMR and RORI were computed at 0.730 and 2.25, respectively.

Table 3. The Farm and Farmers Characteristics among Lowland Rice Producers

Variables	Unit of Measurement	$\bar{X}_i$	SD
Sex	1, Male; 0, Otherwise	0.78	0.17
Marital Status	1, Married; 0,Otherwise	0.72	0.23
Household Size	Number	12	4.47
Age	Years	42	7.03
Farm Size	Hectare	1.27	0.42
Member of Cooperatives	1, Member; 0, Otherwise	0.81	0.38
Formal Education	Years	12	2.71
Farming Experience	Years	13	4.07

Source: Field Survey (2024)

The GMR of 0.730 reveals that for each one Naira expended in lowland rice farming, approximately 73 Kobo covered interest, profits, depreciation, and other expenses (marketing and administrative cost). This further means that the lowland rice producers retained 73% after accounting for the production cost. Furthermore, approximately 73% of each Naira earned from lowland rice farming contributes to covering other expenses and generating net profit. The RORI or return per Naira invested in lowland rice farming was computed at 2.25. This designates that for every one Naira invested into lowland rice farming, approximately 2.25 Naira is made as revenue, that is 1.25 Naira is realized as profit. This finding is supported with the outcomes of Sadiq et al. (2021) who obtained the gross margin of 543429.60 Naira among rice growers in Niger State, Nigeria.

The determinants of output of rice among producers

Table 5 presented the ML estimates of the predictors influencing output among lowland rice producers using SPEFM. The values of the estimates in the TE component lies between 0 and 1, this reveals that all marginal values are positive and reducing at the mean of predictors. This aligns with a priori expectations, this is supported by findings of Abdulai and Abdulahi (2016) who reported the significant and positive influence of frontier factors on output of maize producers in Zambia. The mean-TE of 77% indicates that the mean small-scale rice grower in the representative needs about 23% additional inputs to reach the frontier, in other terms, a small-scale rice producers lost on balance of 23% of produce due to technical inefficiency (TIE).

Table 4. The Profitability Evaluation among Lowland Rice Producers per Hectare

Items	Kg	Value (Naira)	Percentage of TC
Quantity (1.15 tons)	1150		
Price per Kg		1090.52	
TR (Total Revenue)		1254098	
TVC (Total Variable Cost)		337878.61	87.53
Depreciated Cost, Total Fixed Cost (TFC)		48141.04	12.47
TC (Total Cost)		386019.65	100.00
GM		916219.39	
NFI		868078.35	
GMR		0.730	
OR		0.269	
RORI		2.25	

Source: Field Survey (2024) USD = 1,040 Naira

The partial derivatives are called the marginal product or the partial elasticity. The sum of first order partial differentials of the output stimulus which is termed the return to scale or scale efficiency reveals the decreasing return to scale in the frontier model summing up to 0.9208. This designates that increasing all predictors by a certain percentage will lead to a less than comparable rise in quantity of the small-scale rice produced. The value of farm size as measured in hectares is positive (0.2902) and statistically different from zero in enhancing the output of rice at 1% alpha level. This reveals that as farm size rises by 1% while holding all other predictors constant will lead to 29.02% rise in quantity of rice produced. This is highlighted by Adenuga et al. (2013) who achieved 66.70% rise in output of tomato from 1% rise of farm size in Kwar state, Nigeria.

The values of labour as measured in man-days is positive (0.1637) and significant different from zero in enhancing the quantity of rice at 5% alpha level. This signifies that as labour rise by 1%, while holding all other predictors constant will lead to 16.37% rise in quantity of rice.

This is similar with the study of Ojo et al. (2020) who noted a 5% rise in quantity of rice from a 1% rise in labour in Southwest, Nigeria. In the diagnostic information section, the measure of variance ratio(γ) also termed gamma is 0.7021, this reveals that 70.21% of changes in the quantity of rice were as a result of differences in TE.

Table 5. The Determinants of Output of Rice among Producers using SPEFM

Variables	Coefficient	Std. Error.	*P*-value
Fertilizer Usage	0.2341**	0.0975	0.021
Seed	0.1009**	0.0458	0.028
Farm Size	0.2902***	0.0784	0.000
Agrochemicals	0.1319***	0.0366	0.000
Labour	0.1637**	0.0711	0.043
Constant	2.319***	0.5946	0.000
RTS	**0.9208**		
Diagnostic Statistics			
δ^2	2.3461***		
Gamma	0.7021		
Log-Likelihood Function	-527.46		
Mean Efficiency Score	0.77		

Source: Field Survey (2024)

*Significant at ($P < 0.10$)., **Significant at ($P < 0.05$), ***Significant at ($P < 0.01$).

In addition, this signifies that 70.21% of random differences in the quantity of the rice produced were as a result of the growers' inefficiency. Therefore, decreasing the action of gamma or variance ratio will raise the quantity of rice and greatly boost the TE of the growers. The values of total variance (σ^2) also called the sigma square is 2.3461, which is statistically different from zero at 1% alpha level. This reveals that the model utilized and data gotten were well specified. The LLF (Log-Likelihood function) is -527.46. The study is supported with results of Adenuga et al. (2013) who noted that farm size, seeds, labour, and herbicides had positive values and were significant predictors affecting the quantity of tomato produced in Nigeria. This study is in line with the work of Okello et al. (2019) who noted that rice seeds, land area, were significant predictors influencing quantity of rice in Northern Uganda.

CONCLUSION

The average age of rice growers was 42 years. This signifies that they are young, active, and energetic. They can easily adopt research findings, innovations, and new technologies. The number expressing central value of farm size was 1.27 ha of rice farms. This means that they are smallholder farmers because they had less than 5 hectares of rice farms. This result is supported with the study of Okello et al. (2019) who noted an average age of 37 years for rice growers in Uganda. Also, this work is similar to the findings of Ogundari (2008) who documented an average farm size of 1.23 hectares among rain-fed rice farmers in Nigeria.

The lowland rice farming is profitable. The gross margin and net farm income was computed at 916219.39 and 868078.35 Naira per hectare. This result is in conformity with the findings of Yusuf (2022) who observed that rice production was a profitable enterprise in Kwara State, Nigeria. This study is in line with the outcomes of Alabi et al. (2023) and Nwahia (2021) who reported that rice production is a profitable enterprise and could enhance the livelihood of resource poor farmers.

The fertilizer usage, seeds, farm size, agrochemicals, and labour were significant and positively affect the quantity of rice among growers. The partial elasticities or marginal products were computed at 0.2341, 0.1009, 0.2902, 0.1319, and 0.1637 for fertilizer usage, seed, farm size, agrochemicals, and labour. The sum of the partial elasticities gives a return to scale of approximately 0.9208. This designates a decrease return to scale, this signifies that a rise in the variable inputs by a certain percentage will lead to less than increase in output or rice. According to Onuk et al. (2012) who reported that to achieve optimal resource output of variable inputs, policies and programmes should be directed to rice producers in order to increase the level of use of these inputs.

SUGGESTIONS

(i)The fertilizers, seeds, agrochemicals, and other farm inputs should be made available to rice farmers to increase output.
(ii)Government and private organizations should provide credit at single digit interest rates to rice producers devoid of cumbersome administrative procedures. That will enable the rice producers to procure farm inputs at appropriate time and required quantity.
(iii)Land policy should be amended to provide easy access to land for rice farming by both male and female farmers.
(iv) Extension service delivery should be strengthened to disseminate research results, innovations, new farm technologies to rice growers.

(v) Farm technologies, machines, and labour saving machines should be made available to rice producers to increase output.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Assessment of Technical Efficiency and Its Determinants in Maize (*Zea Mays*) Farming System of Chitwan, Nepal

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ABSTRACT

Maize is the second major staple crop of Nepal which is commonly used for human consumption and animal feed. This study analyzed technical efficiency and its determinants in Chitwan's maize farming system. Two villages, Shaktikhor and Fulbari, were purposively selected for this study. In total, 120 maize-growing farmers were selected using simple random sampling, with 60 respondents from each site. Primary data were collected using a set of well-structured pretested questionnaire. The data obtained were analyzed using the stochastic production frontier and Tobit regression. The analysis revealed that the average maize productivity at the site was 1261.21 kg ha^{-1} and was significantly affected by tractor time, farmyard manure, and labor. Technical efficiency was found to vary from 16.7% to 89.7%, with an average of 64.5%. Household head's age, household head's education, access to credit, and extension/training were positive significant determinants of technical efficiency, and every unit increase in each of these variables found to increase technical efficiency by 0.002, 0.001, 0.126, and 0.071 unit, respectively. There is sufficient scope to increase technical efficiency with the same amount of inputs. The local and national governments should emphasize enhancing loans and credit facilities. Furthermore, more educated people should be motivated to be involved in maize farming, and extension or training programs should be boosted to expand maize production efficiency.

Key words: Credit facilities, extension, manure, Stochastic production frontier, Tobit regression,

INTRODUCTION

Nepal, a small country dwelling in the lap of Himalayas, is predominantly an agrarian nation with 51.1% active population relying on agriculture. Agriculture itself contributes 24% of nation's Gross Domestic Product (GDP) (CBS, 2021). Nepal has a wide variation in climate, ranging from hot tropical Terai to cold alpine in the high Himalayas, engendering favorable conditions for the growth of varieties of crops. Maize (*Zea mays*) is second most important cereal crop in Nepal, occupying 985,653 ha with a production of 106,397 mt (MOALD, 2021/22). It serves as one of the major sources of staple food and animal feed, along with making a significant contribution to Nepalese rural household income. In 2022, Nepal had imported maize worth NPR 16.5 billion (MOF, 2022/23). Maize imports have increased to USD 134.5 thousand in 2022, growing at an average annual rate of 320.78% (Knoema, 2023). Since 2015-2021, the maize area and production have increased, but production has still failed to meet the increasing demand (Dhakal et al., 2022). Chitwan ranks third in Nepal's maize production, producing 105,239 mt, after Ilam and Jhapa. Chitwan has 28,055 hectares of land dedicated to maize farming, yielding 3.75 metric tons per hectare (MOALD, 2021/22). It has diverse agroecological conditions, various farming hurdles, resource constraints, and climatic obstacles, leading to lower productivity. Under such circumstances, enhancing technical efficiency is indispensable for sustainable agriculture and poverty elimination.

Technical efficiency, a rooted concept in production economics, refers to the ratio of observed output to the maximum possible output that can be achieved from a constant amount of inputs (Porcelli, 2009). Technical efficiency represents the transformation of input into output without resource wastage to engender a particular amount of output (Charnes et al., 1978). Technical efficiency assessment offers knowledge about production processes, production inefficiencies, and strategies for upgrading resource utilization and production. Agricultural efficiency is influenced by factors such as social capital, access to credit, distance from road, and extension services (Binam et al., 2004). In coupled with these age of household head, soil quality and sources for investments can also affect the technical efficiency of agricultural production (Nowak et al., 2015). In Nepal, age and education of household head, area of cultivation, livestock holding, and availability of extension services have major influences on technical efficiency of maize (Sapkota & Joshi, 2021). In eastern Terai, technical efficiency is influenced by the age of head of household, land holdings, and number of family members (Adhikari et al., 2018).

This study aims to assess the technical efficiency of the maize farming system in Chitwan using various econometric and empirical methods. By evaluating technical efficiency, this study aims to provide valuable insights for policymakers, extension service providers, and farmers to improve maize productivity and profitability.

MATERIALS AND METHODS

Sampling method and sample size

Chitwan is a major maize-growing district in Nepal. Favorable climatic and weather conditions in the district enable farmers to grow maize throughout the year. Two villages in Chitwan district, Shaktikhor (27.73 °N,84.59 °E) and Fulbari (27.64 °N, 84.37 °E), were purposively selected for the study. Simple random sampling was used to choose maize growing farmers for the study, and a total of 120 respondents were included, 60 of whom came from Saktikhor and 60 from Fulbari.

Data Collection

The majority of the primary data were gathered at the study site, and every ethical guideline was rigorously adhered while creating the questionnaire, conducting the survey, and analyzing the data. A semi-structured questionnaire was created thorough desk reviews, expert opinions, and site visits. Ten percent of the sample size was used for pre-testing before the actual survey. In addition, the questionnaire was improved based on the pre-testing results.

Data analysis

The data gathered from the survey were coded and entered into a computer. Microsoft Excle, STATA, and Statistical Package for Social Science (SPSS) were computer software packages used for data analysis. The local unit of measurement was converted into a scientific unit. The data analysis techniques included both descriptive and analytical methods. Basic descriptive statistics, such as percentage, mean, frequency count, standard deviation, maximum, minimum, etc. of socioeconomic and farm characteristics of the respondents were described. The bulk of the empirical analysis was conducted using STATA. A stochastic frontier function was used to estimate technical efficiency, and the factors influencing technical efficiency were identified using Tobit model.

Technical efficiency analysis

The Cobb-Douglas production function is used to estimate the Stochastic Frontier Production (SFP) model. The SFP analysis was performed as described by Aigner et al. (1977). Cobb-Douglas is preferred over other forms because of its connivance on estimation and interpretation (Coelli et al., 2005). The general form of the Cobb- Doglas production function is

Yi = f (Xi; β) expVi – Ui

Where Yi is the output and Xi inputs of firm. Vi represent independent and identically distributed random error with normal distribution N (0, ζ2y) and independent of Ui. Ui represent technical inefficiency effects of half-normal distribution N (μ, ζ2i). Stochastic Frontier Production model is used to estimate input output relationship (Battese, 1992). Stochastic Frontier Production function is represented as-

$$lnY = \beta_0+\beta_1 lnN_1+ \beta_2 lnN_2+ \beta_3 lnN_3 + \beta_4 lnN_4+ \beta_5 lnN_5 +(V_i-U_i)$$

where,

ln= natural logarithm, Y = Maize yield (kg/ha), N_1 = Area under maize production (ha), N_2 = Tractor time (hr/ha), N_3= Farm Yard Manure (FYM)(kg/ha), N_4 = Seed used (kg/ha), N_5 = Labor (man days/ha), β_0 = Constant term to be estimated, β_1 - β_5 = Coefficient of independent variables, and V_i-U_i = error term

Technical efficiency refers to the capacity of particular farmer relative to a maximum output using given input and technology (Kitila and Alemu, 2014). It is the ratio of current production to corresponding frontier production. General formula for technical efficiency is:

$$T.Ei= yit/exp(xit,\beta) * expVit) = f \exp(xit,\beta) * expvit * \frac{\exp(-uit)}{expf(xit,\beta)*expvit}$$

$$TE = \frac{Yi}{Yi*} = \exp(-Ui)$$

Where,

Yi= Maize production of ith farm, Yi*= minimum output and represent frontier output, F (Xi) = suitable function of vector Xi of inputs for ith farm, and Vi= symmetric component of error term

Tobit Regression

Socioeconomic and demographic factors affecting technical efficiency of maize production were identified by using Tobit regression. In this model dependent variable technical efficiency score is censored distribution and its value varies from 0 to 1 (Tobin, 1958). Same method was found to be followed by Adhikari et al. (2018) and Ghimire et al. (2023).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

$Ei^* = \beta 0 + \beta_1 M_{1i} + \beta_2 M_{2i} + \beta_3 M_{3i} + \ldots\ldots\ldots\ldots\ldots \beta_n M_{ni} + u_i$

$E_i = E_i^*$ if $E_{i^*} = > 0$

Where,

E_i = technical efficiency of ith farm, E_{i^*} = latent variable, M_i = explanatory variable in model, β_0 = intercept, β_j (j=1,….n) = coefficient of independent variables, i= (1, 2, 3…..n) = numbers of observations, and u_i= error

Table 2. Description of variables used in Tobit model.

Name of variables	Type of variables	Description	Expected sign
Technical Efficiency(E_i)	Dependent	Technical efficiency of individual maize growing farmers.	
Age of household head (M_1)	Continuous	Age of maize growing household head in years.	+/-
Gender of household head (M_2)	Dummy	1 if household head is male and otherwise, 0.	-
Education of household head (M_3)	Continuous	Years of schooling of household head.	+
Marital status of respondent (M_4)	Dummy	1 if married and 0, otherwise	+
Economically active family members (M_5)	Continuous	Numbers of family members aged between 15 to 59 years	+/-
Location of farmer (M_6)	Dummy	1 if location is Shaktikhor and 0 for Fulbari	+/-
Involvement in organization (M_7)	Dummy	1 if farmer is involved in certain organization and 0, otherwise	+
Access to credit (M_7)	Dummy	1 if famer has access to credit and 0, otherwise.	+
Extension and training (M_8)	Dummy	1 if farmer has involved extension and training program related to maize farming and 0, otherwise.	+

RESULTS AND DISCUSSION

Socio- economic characteristics

The data obtained from the research revealed that majority of the households in the study were male headed. Only 9.2% of households were found to be head by females. Household heads are the major decision-makers in every operation of the house. The average age of household head was found to be 46.92 years. Households in Fulbari were found to be headed by older people than those in Shaktikhor. The education status of the household head was found to be low on the site, with an average of 3.80 years. Economically active populations can contribute significantly to farming practices and lead to greater output, both in the form of yield and revenue. Economically active population was found to be 630. The economically active population was higher in Fulbari than in Shaktikhor.

Most respondents involved in the survey were married (90.8%). The results revealed that farmers' involvement in organizations and access to formal or informal credit were quite impressive. A total of 73.3% of farmers were involved in the organization, and 80.8% had access to credit facilities. The values of both variables were found to be superior in Fulbari than in Shaktokhor. Extension or training facilities were disappointing, with only 21.7% farmers gaining training or extension facilities. Detailed information is presented in Tables 3 and 4.

Table 3. Description of continuous variables

Variables	Mean	Shaktikhor	Fulbari
Age of household head(yr)	46.92	41.08	52.75
Education of household head	3.80	1.20	6.41
Economically active population (15-59 years)	630	215	415

Inputs

The study was conducted on small landholder farmers at the study site. Thus, mean maize growing area of site was 0.23 ha with highest value 0.83 hector to lowest 0.03 hector. Farm yard manure (FYM) was the predominant manure used to improve soil quality. The average FYM used per hector was discovered to be 7109.36 kg/ha. 2.16 hour per hectare was the mean time used by the tractor for overall activities in maize production. The average seed requirement was 20.25 kg/ha. The average number of man-days required for maize production, from land preparation to harvesting was 46.31 in average. Its value varied from 13.13 to 103 man days.

Table 4. Description of continuous variables

Variables		Shaktikhor (n=60)	Fulbari (n=60)	Total (N=120)
Gender of household head	Female	4 (6.7)	7 (11.7)	11 (9.2)
	Male	56 (93.3)	53 (88.3)	109 (90.8)
Marital status of respondent	Unmarried	3 (5)	0 (0.0)	3 (2.5)
	Married	57 (95.0)	60 (100.0)	117 (97.5)
Involvement in organization	No	31 (51.7)	1 (1.7)	32 (26.7)
	Yes	29 (48.3)	59 (98.3)	88 (73.3)
Access to formal or informal credit	No	17 (28.3)	6 (10.0)	23 (19.2)
	Yes	43 (71.7)	54 (90.0)	97 (80.8)
Participation in extension/training	No	54 (90.0)	40 (66.7)	94 (78.3)
	Yes	6 (10.0)	20 (33.3)	26 (21.7)

Table 5. Descriptive statistics of inputs used in maize production in study area

Variables	Mean	Standard deviation	Minimum	Maximum
Total land (ha)	0.23	0.15	0.03	0.83
FYM (kg/ha)	7109.36	3285.52	1575	25200
Tector(h/ha)	2.16	2.23	0.63	10
Seed (kg/ha)	20.25	11.69	10	75
Labor(mandays/ha)	46.31	16.42	13.13	103

Production and productivity

The study asserted that the production and productivity of the study site were lower than the national average for the surveyed year. The average production was 282.67 kg with a higher production in Fulbari. The minimum production was 15 kg, whereas the highest amount produced by the farmers at the survey site was 1800 kg. The finding on productivity was also in line with the findings on production. This value was higher in Fulbari. Mean productivity was 1261.12 kg/ha varying from 281.25 kg/ha to 3750 kg/ ha. This indicated that the majority of farmers in the study site were smallholders and productivity was notably lower than the national average which is 3.11 mt/ha (MOALD, 2021/22). This indicates that farmers in the study site had a significant probability of enhancing their production with the proper inclusion of techniques and technologies and upgrading their skills.

Table 6. Descriptive statistics of production and productivity

Production(kg)	**Average**	**SD**	**Min**	**max**
Shaktikhor	210.08	192.16	15	1200
Fulbari	355.25	297.59	40	1800
Total	282.67		15	1800
Productivity(Kg/ha)				
Shaktikhor	1086.47	547.07	300	3000
Fulbari	1435.77	746.62	281.25	3750
Total	1261.12		281.25	3750

Econometric models

A proper model is crucial for attaining scientific results from any analysis. A good model should be free of multicollinearity, heteroscedasticity, and omitted variables. Thus, to avoid these three factors, different model specification tests were conducted. Variance inflation factor (VIF) was calculated for multicollinearity, the Breush-Pagan/Cook-Weisberg test for heteroscedasticity, and the Ramsey reset test was performed for omitted variables. The VIF analysis disclosed a mean value of 1.60 with the highest value of 1.79, which was lower than 5, suggesting that there was no multicollinearity in the model. Furthermore, the Breush-Pagan/Cook-Weisberg test showed a Chi^2 value of 0.01 and Pro> chi^2 of 0.9061 ($P > 0.05$), suggesting no heteroscedasticity in the model. In combination, the Ramsey reset test was done and Prob>F was 0.1817 ($P>0.05$), indicating the absence of omitted variables in the model.

Stochastic Production Frontier

Stochastic frontier analysis revealed that area, quantity of farm yard manure (FYM), quantity of seed, tractor time, and labor had a positive relationship with the quantity of maize produced. Among others, tractor time, FYM, and labor were found to have a significant effect on maize production. These three variables were found to be significant at the 5% level. An increase in tractor time by 1% found to increase maize production by 0.095%. This is in line with the findings of Subedi et al. (2020) and Khan et al. (2020), who found a positive and significant relationship between the tractor time and the amount of crop produced. Similarly, a 1% increase in the amount of FYM resulted in a 0.29% increase in production. Similar results were reported by Bajracharya and Sapkota (2017) and Sapkota and Joshi (2021), where a 1% increase in FYM increased maize production by 3.8 and 4%, respectively.

Table 7. Stochastic production frontier of maize production

Variables	Coefficient	Standard Error	p > z	Test of Multicollinearity	
				VIF	1/VIF
Log Area per hector	0.104	0.092	0.262	1.78	0.561
Log tractor time(hour/ha)	0.095**	0.045	0.034	1.76	0.567
Log FYM (kg/ha)	0.290**	0.115	0.012	1.13	0.884
Log Seed (kg/ha)	0.101	0.133	0.939	1.52	0.658
Log labor(man days/ha)	0.554**	0.173	0.001	1.79	0.558
Constant	3.003	1.306	0.021		
Sigma_v		**0.327**	**0.063**		
Sigma_u		0.638	0.113		
Sigma 2		0.5133	0.117		
Lambda		1.952	0.165		

** represent significant at 5% level of significance

Summary Statistics	
Log likelihood	-86.138
Number of observations	120
Wald chi2 (5)	22.10, Prob> chi 2 = 0.0005
Likelihood-ratio test of sigma u =0: chibar2 (01)	4.47 prob>= chibar2 = 0.017

A percent increase in the number of man-days of labor seems to increase maize production by 0.554%. This can be supported by research conducted in Ghana by Bempomaa and Acquah (2014) and another study conducted in Switzerland by Dlamini et al. (2012). In essence, farmers need to focus on increasing tractor time, FYM, and man-days to increase maize productivity. The lambda value of the model was 1.95 (>1), which indicated that the model was well fitted (Ghimire et al., 2023). The model was found to be significant at the 1% level of significance, indicating that the included independent variables can properly explain the variation in the dependent variable.

Test of Statistics

Variance Influence Factor (VIF)	Mean VIF(1.6) Maximum VIF(1.79)
Breush-Pagan/Cook-Weisberg test	Chi2 (1) = 0.01 Pro> chi2 = 0.9061 (Constant variance)
Ramsey reset test	F(3,110) = 1.65 Prob>F = 0.1817 (model has no omitted variables)

Technical efficiency

Technical efficiency calculated from stochastic frontier analysis showed that technical efficiency at study sites were found to fluctuate from 16.7% to 89.7%.Average efficiency was found to be 64.5%, and most repeated value of efficiency among farmers was 48.2%. This indicates that if proper techniques and technologies are followed than in average 35.4% more output can be gained by the use of same amount of inputs. 58.33% of farmers in the area of study found to have efficiency between 70 to 79%. 47(39.17%) sampled farmers had efficiency below mean level, whereas 73(60.83%) farmers were working above mean level. A study conducted in mid hill of Nepal discovered mean 71% of technical efficiency of maize production (Sapkota and Joshi, 2021), whereas in Switzerland, its value was found to be 80% (Dlamini et al., 2012).Meanwhile technical efficiency of 79% was found in eastern terai of Nepal (Adhikari et al., 2018). A study conducted in hills of Nepal in 2004 reported lower efficiency than this study, which was 58% for local maize and 63% for improved varieties (Paudyal and Ransom, 2004). Mean productivity for different efficiency level 0.1 -0.19, 0.2-0.29, 0.3-0.39, 0.4-0.49, 0.5-0.59, 0.6-0.69, 0.7-0.79 and 0.8-0.89 are 281.25, 337.5, 445.71, 656.67, 822, 1148.23, 1517.64 and 2332.77 kg per hector, respectively.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Table 8. Technical efficiency and mean productivity of study area

Efficiency	percent	Mean
0.3-0.39	0.83	75
0.4-0.49	0	0
0.5-0.59	7.5	48.33
0.6-0.69	17.5	182.38
0.7-0.79	58.33	319.71
0.8-0.89	15	388.89
0.9-0.99	0.83	2000
Total	**100**	**297.67**

Mean +- SD	0.645 +- 0.157
Mode	0.482
Minimum	0.167
Maximum	0.897

Determinants of technical efficiency – Tobit analysis

a) **Based on different literature review:** Eight different socioeconomic variables were selected for the Tobit analysis. The research finding showed that the technical efficiency of maize at the area of study was significantly affected by the age of the household head, education of the household head, marital status, access to credit, and extension or training. All variables except marital status had positive influence on technical efficiency of maize production. Gender of household head, location of farmer, and involvement in the organization were non-significant variables in the model, whereas involvement in the organization was found to be negatively related to the technical efficiency of maize. This indicates that the government and other sectors should emphasize these variables in order to make maize production efficient in Chitwan.

b) **Age of the household head:** Respondents' age had a positive and significant impact on the efficiency of maize farms. If the age of the household head rises by a year, the technical efficiency of the maize farm will expand by 0.002 units. As age increases, farming experiences will also increase, which will aid in conducting farm activities efficiently, leading to an increase in technical efficiency. This might be a reason for the positive relationship between the age of the household head and technical efficiency of maize production. This finding was inconsistent with the results of different studies conducted worldwide. Belete (2020) reported a negative relationship between

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

age and technical inefficiency of maize production. Research proclaimed that a year increase in the age of head of household the technical inefficiency of the farmers get deducted by 0.02 units. Moreover, even in Nepal, a positive and significant relationship between age and the efficiency of maize production had been reported (Sapkota and Joshi, 2021). In agriculture sites, every increase in year makes farmers well experienced in farming activities along with galvanizing their marketing and socialization skills, which might lead to enhanced production.

Table 9. Determinant of technical efficiency of maize production

Variables	Coefficient	Standard Error	P(z)	dy/dx
Age of household heads	0.002*	0.001	0.093	0.002*
Gender of household heads	0.018	0.048	0.706	0.018
Education of household heads	0.010***	0.004	0.007	0.010***
Marital status	-0.220**	0.086	0.011	-0.220**
Location	0.047	0.041	0.256	0.047
Access to credit	0.126***	0.038	0.001	0.126***
Involvement in organization	-0.053	0.040	0.178	-0.053
Extension or training	0.071**	0.032	0.029	0.071**
Constant	0.610	0.107		
Summary Statistics				
Numbers of observations	120			
LR chi2 (8)	30.96			
Prob > chi2	0.000			
Log likelihood	64.960			
Pseudo R2	-0.313			

*, ** and *** represents 1%, 5% and 10% level of significance respectively.

In contrast to these findings Adhikari et al. (2018) observed that compared to older maize farmers, younger farmers were more technically efficient.

c) **Education of household head**: Education of the household head was found to be positively and significantly related to technical efficiency of maize production at 1% level of significance. Technical efficiency will increase by 0.01 units with every year of increase in the level of education of the household head. Education is a major source of knowledge in all sectors. Educated people have more knowledge and information related to production, improved technologies and techniques, and plans and policies of the country. Furthermore, they are innovative and have an enhanced capacity to deal with people. All these qualifications might led to a surge in the efficiency of maize farms. Addai and Owusu (2014) and Asante et al. (2013) also found similar findings. A research in Ghana and Ghimire et al. (2023) also reported an advantageous link between education and the technical efficiency of farms. In contrast to this findings, Abdulai et al. (2018) reported an inverse relationship between education and the technical efficiency of maize production. Educated persons are supposed to have better accumulation of farming knowledge, better exposure to technologies, and better decision-making capacities, leading to more production per hectare. In contrast, uneducated farmers are reluctant to adopt new technologies and take proper decisions during disease outbreaks and natural calamities, subsequently leading to lower efficiency (Khanal and Maharjan, 2013).

d) **Marital status:** The study disclosed that if a farmer is married, the farmer had a negative and significant impact on the technical efficiency of maize production. If the farmer is married, technical efficiency will lower by 0.22 units. The reason for this might be an increase in the responsibilities of married farmers compared to unmarried ones. A married person may have to spend more time on household chores, which may reduce the chances of gathering farm-related information, ultimately leading to lower farm efficiency.

e) **Access to credit:** As expected, access to credit had a positive and significant impact on the technical efficiency of maize farming. Compared to farmers without access to credit, farmers with credit will have possibility to enhance their technical efficiency by 0.126 units. This might be because most of the inputs used are associated with money, and if the farmers have access to credit, their possibilities to use improved technologies, tools, and equipment will extend, which will ultimately aid in increasing farm efficiency. In maize production, technical inefficiency was 0.012% lower for farmers with credit availability than for those without (Belete, 2020). Similar findings were reported by Kibaara (2005) and Beyan et al. (2013).

f) **Extension or training:** In line with previous expectations, extension and training had a positive influence on technical efficiency. Involvement in extension or training was found to be significant at 1% level. With involved in extension and training, the technical efficiency of maize production will increase by 0.071 units. Farmers gaining extension or training facilities will gain information about cultivation practices, new and effective technologies, input supplies, and market status, which might aid in uplifting the technical efficiency of farms. This was in line with the findings of Sapkota and Joshi (2021) and Abdulai et al. (2018). Extension and training engender informal farming-related education for farmers. It increases farmers' qualifications for the proper selection of seeds, cultivation techniques, better dealing with diseases, weeds, risks and uncertainties, and marketing obstacles, ultimately ameliorating maize production and productivity. Gautam (2000) also reported that an effective agricultural extension service is crucial to enhance the productivity of stable crops and thus eradicate poverty.

CONCLUSION

This study elucidated that maize production at the study site was not efficient, with the majority of farmers cultivating below-average efficiency. There is room for increasing technical efficiency of maize production using the same amount of inputs. Maize production was significantly influenced by tractor time, FYM and Labor. This implies that to produce more, tractors, FYM and labor need to be used. Age of the household head, education of the household head, marital status, access to credit, and extension or training were determinants of technical efficiency of maize production at the site. This suggests that encouraging more educated people in maize farming would boost the efficiency of maize production. Access to credit had a significantly positive impact. Thus, priorities must be prioritized to enhance banking and financing facilities at the site with an effective interest rate for farmers. Furthermore, extension and training activities need to be increased by focusing on technology dissemination, cultivation techniques, weed and pest management, and cost management. This will aid in surging maize production and productivity in Chitwan, leading to efficient production and prosperous farmers.

ACKNOWLEDGEMENTS

The author express her gratitude to all respondent farmers and other supporting participants for granting their time and sharing their information for this research.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

REVIEW ARTICLES

Indigenous Pest Management: Scientific Validity or Folklore?

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ABSTRACT

Traditional pest management practices, deeply rooted in Nepal's indigenous knowledge and cultural heritage, have played a significant role in the country's agricultural systems for generations. While many of these methods are based on oral traditions and anecdotal evidence, a number have been scientifically validated and align well with the principles of sustainable agriculture. This review critically explores various native pest control techniques, evaluating their effectiveness and relevance in the modern context. It underscores the potential of integrating traditional wisdom with scientific innovation to develop environmentally sound and culturally respectful pest management strategies. The findings emphasize the importance of further research and supportive policies to incorporate proven traditional methods into contemporary agricultural frameworks.

Keywords: Botanical pesticides, Ecological resilience, Folk practices, Indigenous Pest Management, Nepalese farming

NEPALESE AGRICULTURE

The past ten years have seen a number of notable changes in Nepal's agricultural industry, including the adoption of new technology, the transition from subsistence to commercial farming, and the support of government policies. Nepal's economy heavily depends on the country's agricultural sector. In 1975, agriculture constituted 65% of Nepal's GDP. As global attention transitioned from agriculture to industry, Nepal's economy saw structural changes, resulting in a diminished contribution of the agricultural sector to GDP. By 2000, the agriculture sector's proportion had diminished to roughly 40%, whilst the manufacturing sector expanded from 4% in 1975 to 9% by 2000. In 2022, the agriculture industry provided 23.95% to GDP, and the manufacturing sector represented 14.3%. Preliminary data for 2023 predicts a modest increase in the agriculture sector's contribution to 24.1% (Mishra, 2023; World Bank Open Data, 2023). Approximately 75% of Nepal's population made their living from agriculture in 2000. By 2022, this percentage had dropped to 66%, with 57.3% of the population working in agriculture, according to data from the 12th census (Mishra, 2023; Nepal Statistics Office, 2025).

Nepal is a multicultural, multireligious, and multiethnic country. Its distinctive and noteworthy characteristics include diversity and pluralism. The traditional farming methods used by Nepalese farmers are one topic of continuous debate. These customs, which have been carried down through the generations, demonstrate a strong bond with biodiversity, ecological balance, and local culture. While some could claim that these approaches are unscientific and ineffective in comparison to more contemporary alternatives, others might see them as having their roots in sustainable traditions and cultural heritage. They might also be seen as creative by some, using their indigenous knowledge and inventiveness to address regional agricultural problems. The diversity of opinions on conventional techniques creates new study and exploration opportunities for the next generation of agricultural scientists and policymakers. Investigating these approaches can shed light on their environmental impact, economic viability, and potential integration with modern technologies. This combination of tradition and innovation provides a chance to create long-term agricultural systems that respect cultural heritage while increasing productivity and resilience. As Nepal's agriculture sector changes, a balanced strategy that recognizes both traditional wisdom and scientific innovation will be critical for long-term prosperity and sustainability.

INDIGENOUS/TRADITIONAL KNOWLEDGE – MYTH OR REALITY?

Indigenous knowledge reflects the knowledge and methods that communities have evolved over many generations of intimate engagement with the natural world. It offers workable answers for environmental stewardship and land management and is based on necessity, careful observation, and trial-and-error learning (Kumar et al., 2009). According to Berkes et al. (2000), this knowledge, which is frequently transmitted orally or through experience, provides important insights to support contemporary science and influences decisions about the use of resources and agricultural practices.

Indigenous Technical Knowledge (ITK) is localized, traditional knowledge molded by environmental and cultural factors. Crop production, animal management, pest control, food processing, healthcare, and the preservation of natural resources are just a few of the many diverse disciplines it covers. ITK is a combination of traditional knowledge and technological adaptation (Warren et al., 1995). Indigenous Agricultural Practices (IAPs) are mainly undocumented and exist in the thoughts, languages, and experiences of various groups. The lack of systematic records makes it difficult to recognize and adapt them for larger applications, despite their promise to improve sustainable agriculture and environmental resilience (Atteh, 1989). Preserving and integrating these practices is critical for connecting traditional wisdom with scientific advances.

TRADITIONAL BELIEFS

As a nation with a strong agricultural heritage, Nepal has historically depended on traditional ideas and methods to direct farming operations. Many of these age-old methods have been handed down through the generations, frequently impacted by Nepal's close cultural and spiritual ties to China and India, its neighbors. Some of these customs have their roots in myths and rituals that still influence agricultural choices, while others are based on ecological observations and indigenous knowledge. These historic ideas continue to have cultural value and are extensively followed by farmers nationwide, even in the face of contemporary scientific discoveries.

Table 1. Techniques and the methods of their uses

Techniques	How is it used	References
Myth-Based Practices	Observing lunar phases (e.g., new moon sowing) to prevent pest attacks.	(Kumar *et al.*, 2009).
Fallowing	In order to disrupt insect cycles and restore soil fertility, land should be left fallow in between planting seasons.	(Kumar *et al.*, 2009).
Ritualistic Offerings	Farmers perform rituals and offerings to deities before planting or harvesting to ensure good yields.	(Singh, 2012)
Sacred Groves	Maintaining undisturbed forest patches near farms to attract beneficial insects and birds that control pests.	(Ramakrishnan, 2001)

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Existing literature on traditional plant protection measures

Farmers' reliance on locally accessible and natural resources to protect their crops, traditional plant protection techniques have long been an essential component of Nepalese agriculture. These methods, which are based on indigenous knowledge, place an emphasis on economically and environmentally beneficial approaches to managing diseases and pests.

Table 2. Techniques and the methods of their uses

Technique	How It Is Used	References
Use of Wooden Ash	The common practice of using raw ash to control pests like aphids and stem-cutting insects involves spreading ash in powder form on pest-affected plants every 2-4 days, which also improves soil nutrient status	(Verma, 1998).
Use of Fresh Cow Urine	**Composition:** Fresh cow urine, a pest of onion, garlic, mugwort, chili, *Ageratina adenophora*, and *Adhatoda vasica* mixed with water. **Usage:** Filtered and applied to repel sap-sucking insects and disease-causing pests.	(Gahukar, 2013).
Use of Papaya Leaf Paste	**Composition:** Papaya leaf paste mixed with water. **Usage:** Filtered with a clean cloth and applied to control fungal diseases in crops	(Arvind *et al.*, 2013).
Use of Mugwort (*Artemisia vulgaris*) Solution	**Composition:** 2-3 liters of water mixed with half a kilogram of dry mugwort powder. **Usage:** Protect plants from leaf-eating hairy caterpillars	(Tobyn *et al.*, 2011).
Use of Chili Powder	Chilli powder can be used to control aphids and other sap-sucking insects. It is usually applied in powder form, generally on sunny days when the wind flow is stable	(Patil *et al.*, 2018).
Use of Turmeric Powder Mixture	**Composition:** 1kg turmeric powder, 3-4 liters of cow urine, and 15-20 liters of soap water. **Usage:** Applied on paddy fields to control the leaf roller	(Poudel, 2020).

Despite the increasing use of contemporary chemical pesticides, many of these methods—such as the application of wooden ash, cow urine, and botanical extracts—have been handed down through the centuries and are still commonly

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

used today. Some of these techniques have received scientific validation, but more study is needed to fully evaluate their potential in integrated pest management.

Table 3. Techniques and the methods of their uses

Technique	**How It Is Used**	**Stage of Crop Development**
Mixture of Kerosene and Ash	2-3 spoonful of kerosene mixed with 1 kg of raw ash; applied twice a week (morning/evening) by broadcasting.	Applied in all development stages of every type of plant.
Solution of Fresh Cow Urine, Onion, Garlic, Mugwort, Chilli, *Ageratina adenophora*, and *Adhatoda vasica*	4-5 liters of cow urine mixed with onion (5-6), garlic (100 g), mugwort, chilli, *Ageratina adenophora*, and *Adhatoda vasica*; diluted with 4-5 liters of water, filtered, and applied by foliar spray.	Used throughout the crop cycle for sap-sucking insects and disease prevention.
Peppermint, Bari, and Mugwort Solution	The mixture of peppermint, bari, and mugwort is applied by foliar spray to control hairy caterpillars.	Applied in all growth stages for caterpillar control.
Chili Powder	Applied in powder form, usually on sunny days when wind flow is stable, to control aphids.	Used during active pest infestation, particularly in the vegetative and reproductive stages.
Fresh Dung Solution	1-2 kg of fresh dung mixed with 4-5 liters of water, filtered, and applied by foliar spray.	Applied at every stage of crop development for pest repellence.
Papaya Leaf Extract	Papaya leaves are crushed into a paste, mixed with 1-2 liters of water, filtered, and applied by foliar spray.	Apply during any crop stage for fungal disease control.
Holy Basil Extract	Crushed basil leaves mixed with 2-3 liters of water, applied by foliar spray, to control leaf-eating insects in citrus fruits.	Applied particularly during fruiting stages to prevent insect damage.
Bovine Urine Solution	Mixed with water in a 2:1 ratio, applied by foliar spray to control mealybugs and sap-sucking insects. Lower concentrations are used before harvest to prevent odor.	Apply in all stages, with caution before harvest.
Mugwort Solution	2-3 liters of water mixed with 0.5 kg of mugwort, applied by foliar spray to control hairy caterpillars.	Used throughout the crop cycle for caterpillar prevention.

Source : Gyawali *et al*., (2021)

A study by Asmita Bhattarai and Narayan Datta Bastakoti on *Plant-Based Traditional Knowledge for Pest and Disease Management in Pokhara*

Metropolitan City Ward No. 32, Kaski, identified several indigenous techniques. These practices highlight the community's dependence on locally available plant resources and traditional wisdom for sustainable agricultural pest and disease control.

Table 4. Plant species used for various pest / diseases and methods of application

Plant Used	Pest/Disease Targeted	Method of Application
Neem (*Azadirachta indica*)	Various insect pests	Leaves are boiled in water; the cooled extract is sprayed on crops.
Titepati (*Artemisia vulgaris*)	Aphids, caterpillars	The leaves are soaked in water overnight; the solution is sprayed on affected plants.
Marigold (*Tagetes erecta*)	Nematodes, aphids	Planted as a companion crop to repel pests through its root exudates and scent.
Garlic (*Allium sativum)*	Fungal infections, insects	Cloves are crushed and mixed with water; the mixture is sprayed on crops.
Chili (*Capsicum annuum*)	Insect pests	Fruits are crushed and mixed with water; the solution is applied to deter pests.
Bakaino (*Melia azedarach*)	Caterpillars, beetles	Leaves and fruits are ground into a paste, mixed with water, and sprayed on crops.
Ash	Stored grain pests	A thin layer is sprinkled over stored grains to protect against insect infestation.
Cow Urine	Fungal diseases, insects	Diluted with water and sprayed on crops as a preventive measure.
Bojo (*Acorus calamus*)	Stored grain pests	Rhizomes are powdered and mixed with stored grains to repel insects.
Khaira (*Senegalia catechu*)	Rice brown spot disease	Leaves were placed in water channels to manage the disease.

Source: Bhattarai & Bastakoti, (2023)

The study *Indigenous Technical Knowledge in Plant Disease Management* by Hari Prasanna Sahul and Rakesh Roshan Satapathy highlights various traditional plant disease management practices. Their findings reflect the strong agricultural ties between Nepal and India, showcasing how both countries share similar indigenous techniques and knowledge systems in pest and disease control.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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CHALLENGES IN ADOPTING TRADITIONAL AGRICULTURAL PRACTICES

The adoption of traditional agricultural methods confronts numerous problems, including a lack of documentation, awareness, and proper implementation. Farmers' perspectives and the insufficient integration of ecological theories impede their effectiveness. Furthermore, poor collaboration between farmers and agricultural scientists undermines support for indigenous knowledge. Addressing these challenges is critical for long-term plant conservation while also presenting a challenge to modern solutions, as deeply ingrained cultural traditions frequently hinder adoption rates.

Table 5. Techniques and the methods of their uses

Techniques	How is it used
Ash and Liquid Waste Spraying	A little dusting of ash and spraying of liquid waste from tanned leather in tribal areas to manage bunchy top illness in chilies.
Cow Dung for Fungal Disease	Fresh cow dung is sprayed in the collar region of chili plants to treat damping-off and dieback.
Cow Dung Slurry for Seed Treatment	Fresh cow dung slurry (1 kg of cow dung in 5 L of water) is used to treat ginger and turmeric seeds for disease management and improved germination.
Organic Soil-Borne Disease Control	Farmers use sesame, mustard, and neem cake in betel vine-growing areas to manage soil-borne diseases.
Chickpea Wilt Management	Farmers mix 30 kg of chickpea seeds with 0.5 mg Heeng, 200 g salt, and 1 L of buttermilk to control wilt disease.
Cow Urine for Pulse Seeds	Pulse seeds are sprayed with cow urine to protect against soil-borne fungi and improve development.
Root and Collar Rot Control	Castor cake, Karanja cake, and neem cake are used to control root rot and collar rot caused by soil-borne pathogens.
Casuarina Leaf Extract for Infections	20 kg of *Casuarina equisetifolia* leaves are boiled, filtered, and diluted with water to treat bacterial and fungal infections.
Papaya Leaf Extract for Rice Brown Spot	A solution of 2 kg fresh papaya leaves in 3-4 L water is soaked overnight, filtered, diluted with 50-60 L water, and 250 mL soap solution added to control rice brown spot disease.
Marigold for Bacterial Infections	Marigold cultivation followed by solanaceous vegetable crops helps control bacterial infections.
Khair Leaves for Brown Spots in Rice	Placing khair (*Acacia catechu*) leaves in a water canal helps manage brown spot disease of rice.

Source : Sahu & Satapathy, (2021)

Validating traditional agricultural practices: a collaborative approach

A multidimensional, multi-stakeholder approach is required to validate, adopt, safeguard, certify, and advance traditional agricultural techniques. A solid beginning point could be the next Census 2031/32, which will include questions to systematically document indigenous knowledge. The focus of subsequent research should be on incorporating ancient farming approaches into modern plant disease management. Field demonstrations with farmers can highlight practical applications while ensuring that scientifically established procedures are promoted. Ineffective practices should be publicized via media campaigns, conferences, and house visits. Cultural and social sensitivities must be considered throughout the process. Although time-consuming, this technique promotes research, teaching, and extension, which contributes to agricultural development.

LEVERAGING MULTI-STAKEHOLDER COLLABORATION FOR INDIGENOUS AGRICULTURAL INNOVATIONS

The usage of 'jholmal,' a locally made bio-fertilizer and bio-pesticide, is one example of how cooperative efforts among various stakeholders have aided in the development and implementation of indigenous agricultural practices in Nepal. Jholmal is a traditional, home-made liquid bio-fertilizer and insecticide manufactured by combining water, locally accessible botanical plants with repellent qualities, farmyard manure (FYM), and animal urine in certain amounts. In agricultural settings, cow urine and certain botanicals have long been used to control pests and diseases.(Jandaik *et al*., 2015). Building on this traditional knowledge, CEAPRED and ICIMOD refined the practice by developing three distinct jholmal formulations—Jholmal-1, Jholmal-2, and Jholmal-3. This innovation integrates traditional practices with scientific research, leading to improved crop yields and reduced pest infestations. Field trials demonstrated that applying jholmal resulted in a significant increase in bitter gourd yields—30.5% and 31.1% at foothill sites and 26.6% and 28.7% at hilltop sites over two consecutive years—while also decreasing fruit infestations (Bhusal *et al.,* 2022). Such initiatives highlight the effectiveness of ecosystem-based adaptation measures that utilize local resources and knowledge, offering simple, affordable, and climate-friendly solutions to enhance agroecosystem health and build resilience among smallholder farmers (Bhusal *et al.,* 2022).

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Profitability of Mechanical Transplanting of Rice Farming in Nepal

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ABSTRACT

Most farmers in Nepal practice manual transplanting, which is labor-intensive and costly as well. Rice farming has considerable challenges due to labor scarcity and growing labor costs. Manual transplantation also creates delays owing to labor constraints, as well as the difficulty of handling younger seedlings during transplanting, causing older seedlings to be used, resulting in a lower yield. In such circumstances, mechanical transplanting may be the best alternative to manual transplanting since it ensures timely transplanting, involves fewer labors, maintains appropriate plant population, lowers production costs, contributes to higher yield, and is a more cost-effective technique of rice production. Despite its numerous benefits, the adoption of mechanical rice transplanting technique among Nepalese farmers is sluggish due to the majority of small-holder farmers, expensive starting costs, and a lack of knowledge about the technology related mat-type nursery growth. So, to enhance farmers' acceptance of mechanical transplanting, providing technical knowledge of raising mat type or tray nursery, as well as capacity building for custom hiring, could be a solution. This review examines the impact of mechanical transplanter on the growth, yield, and economics of rice production.

Key words: Grain yield, production cost, growth, transplanter, cost effective

INTRODUCTION

Rice is recognized as the global grain since it is the primary staple food for more than half of the world's population. It was grown across an area of 166.3 million hectares in over a hundred countries, with an annual yield of over 789 tons in 2021 (FAO, 2022). Rice is the principal food for most of the Nepalese population. Rice has a significant role in agriculture and the economy of Nepal as it contributes 13.6 % to agriculture GDP and 7% to national GDP (MOALD, 2023). It is grown in an area of 14,77,378 ha, with a yield of 5,130,625 tons in the fiscal year 2021/22 (MOALD, 2023). The rice productivity of Nepal is 3.9 tons/ha (MOALD, 2023)) which is comparatively lower than neighboring countries China and India.

Most farmers in Nepal follow traditional methods of rice cultivation, which are labor- and capital-intensive. Human labor costs account for 59.4% of the overall production costs (Acharya et al., 2020). Similarly, rice transplantation done manually alone costs 19.9% of the total labor requirement for rice cultivation (Acharya et al., 2020). It requires 30-35 men a day's labor to transplant manually one hectare of paddy land (Bhandari et al., 2022). The scarcity of labor and rising labor expenses are significant issues in rice farming. Manual transplanting causes transplantation delays due to labor constraints, which force older seedlings to be used, resulting in a low yield. Under these conditions, the use of a mechanical transplanter is essential for lowering production costs, enabling transplants at the right time, and addressing labor shortages.

Comparing mechanical transplanting of rice to the prevalent hand transplanting method, it ensures timely transplanting, requires less labor, maintains an optimal plant population, contributes a higher yield, and is a more economical way of producing rice. According to Goswami et al. (2020), rice transplanting with mechanical transplanting is three times cheaper than rice transplanting by hand. Significantly higher yield was observed in mechanical transplanting systems than in manual transplanting systems (Regmi et al., 2020, Kumar et al., 2012). Nadga et al. (2021) also reported a higher benefit-cost ratio in the MTR system than in the manual transplanting system.

The most important factor among all the agro-techniques used to increase grain production is the age of the seedling. The age of the seedling greatly affects the rice's growth and development, tiller production, grain formation, and other traits that affect yield (Manir et al., 2022). Younger seedlings that are less than 20 days old can be transplanted mechanically; however, hand transplanting makes it more difficult to transplant younger seedlings. Therefore, mechanical transplanting can result in a higher grain yield since younger seedlings can be transplanted.

In Nepal, agricultural mechanization dates back to the 1970s, when two- and four-wheeled tractors from Japan were introduced (Biggs and Justice, 2015). Since then, different agricultural machines have been used to reduce human labor and production cost. The government of Nepal has been promoting agricultural mechanization to increase farming's profitability. Four-wheeled rice transplanters, walking behind rice transplanters, and self-propelled riding rice transplanters are the three types of rice transplanters that are most used in Nepal. Among these, four-wheeled riding machines are growing in popularity in the Terai region due to their durability and speed of operation. The adoption of mechanical rice transplanters is sluggish because of small-holder farmers, high initial costs, and a lack of technical knowledge regarding mat-type nursery growth (Bhat et al., 2023; Poudel et al., 2021). This review examines the impact of mechanical transplanter on the growth, yield, and economics of rice production.

NURSERY MANAGEMENT

Tray nursery or mat nursery are prerequisites for mechanical transplanting. In mat-type nursery, rice seedlings are raised on about 2.5 cm thin layer of soil and farmyard manure (FYM) or compost mixture placed on a perforated polythene sheet (Rickman et al., 2015). In tray nursery, rice seedlings are raised on a tray that vary in size according to the types of rice transplanter being used. Sieved soil is mixed with farmyard manure in a 4:1 ratio, with approximately 4 m^3 of soil mixture required (Rickman et al., 2015). A 70:30 mix of soil and vermicompost is recommended as a media for tray nursery growing (Reddy et al., 2020). For each hectare of transplanting, a 100 m^2 nursery area and 20 kg of seed are adequate. Zohaib et al., (2022) found that a seed rate of 90 g per tray of 60cm * 30 cm increased productivity in fine basmati rice. Then, the pre-germinated seeds are evenly spread with the help of manual seeder to achieve a uniform density and seeds are covered with about 0.5 cm soil layer (Bhandari et al., 2022). Currently, a semi-automatic stationary rice nursery sowing equipment is available that can perform various activities at the same time, such as tray moving, soil spreading, seed sowing, watering, and topsoil covering, and three people can prepare 600-700 nursery trays per hour. Keep the bed moist for the first 3-4 days by sprinkling water from the top using a watering can. After that, irrigate the nursery using floods. Use a foliar application of 0.5% urea (5 g urea per liter water) or 3-5 g/ml NPK (19:19:19) per liter water if there are nutritional deficiencies (yellowing). Foliar spraying of 0.5% urea at 10 days after sowing is recommended for tray nurseries due to its better growth results compared to other foliar applications tested (Reddy et al., 2020). Seedlings of 18-20 cm height (2-3 leaves) are produced in 14-18 days. Hossain et al. (2017) observed 14 cm-tall seedlings with 3-4 leaves in 12 days that were grown in plastic trays filled with mixture of sandy loam soil and organic fertilizer.

PLANT POPULATION

Optimal plant population is critical for achieving optimal production. Manual transplantation involves transplanting seedlings that are more than 25 days old, and seedlings are transplanted with root eroded seedling. The root washed seedlings get shocked before establishment in puddled soil. On the other hand, mat type nursery or tray nursery is required for mechanical transplanting and seedlings with soil attached within root net are transplanted, reducing transplanting tremor and preventing floating. Mechanical transplanting also allows for the transplantation of younger seedlings (12-18 days old seedling). It was found that transplanting younger seedlings resulted in significantly higher tillers number per hill than transplanting older seedlings (Mupeta et al., 2022; Manir et. al, 2022). Therefore, plant populations per m^2 are therefore greater in mechanical transplanting than in hand transplanting because of all the aforementioned factors. Same results were reported by Basir et al., (2020) and Regmi et al., (2020).

PLANTS GROWTH AND YIELD ATTRIBUTES

No significant difference in plant height was observed between mechanical transplanting and manual transplanting (Islam et al (2020) and Kang et al., 2019). Similarly, Kang et al. (2019) reported that there was no significant effect on leaf area index and dry matter accumulation at harvesting between mechanical transplanting and manual transplanting practices. However, significantly higher plant height was observed by Regmi et al., (2020) and Munnaf et al. (2014). It might be due to the fact that transplanting at proper time, depth and spacing by mechanical transplanter helped in quick establishment and thereby enhanced cell division and enlargement, ultimately leading to higher plant height.

Different yield attributing characters, such as 1000 grain weight, number of grains per panicle, and number of effective tillers/m^2 determine the variety's final grain yield. Regmi et al., (2020) reported that the number of effective tillers/m^2, panicle length and number of grains/panicles were significantly higher in mechanically rice transplanter than manually transplanting, use of drum seeder and seed drill machine. Similarly, Vijay et al. (2020) recorded higher number of tillers/hills, number of grains/panicle and panicle length in mechanical rice transplanting than manual transplanting. Munnaf et al. (2014) also reported higher numbers of panicle/m^2, number of tillers/hill and panicle length in mechanically transplanting method in comparison to manual transplanting. Elsoragaby et al. (2018) recorded mechanical transplanting resulted in a 25.18% increase in planting density (522 versus 417 stems/m^2), 20% increase in panicles (480 versus 400 panicles/m^2), 23.5% increase in grain weight/panicle (4.1 versus 3.4 g/panicle), and 7.3% less weedy rice population (4.89% versus 12.16%) compared to the control field. In contrast, Kumar et al. (2014) and Kang et al. (2019) reported no significant difference in number of effective tillers/m^2, panicle length and number of grains/panicles between manually transplanting and mechanical transplanting. A higher number of effective tillers in mechanical transplanting methods is due to the use of younger seedling, optimum spacing, quick establishment, and less seedling root injury (Regmi et al., 2020; Munnaf et al., 2014).

GRAIN YIELD

Grain yield is one of the crucial and complex attributes of rice. Number of grains/panicles, number of effective tillers per unit area, 1000 grain weight determine grain yield. Islam et al. (2016) reported significantly higher grain yield in mechanical transplanting than manual transplanting and recorded 14-23% higher grain yield in mechanical transplanting than manual transplanting. According to Elsoragaby et al. (2018), there was a 24.3% increase in grain yield in the mechanical transplanting plot while comparing the plots broadcasted by the Hary mist duster and transplanted by the riding type four-wheeled rice transplanter. Similarly, Regmi et al., (2020) conducted the experiment on comparison of different establishment practices of rice and observed significantly higher grain yield in mechanical transplanting than manual transplanting, drum seeder sowing and seed drill sowing. Similarly, Vijay et al., (2020); Munnaf et al., (2014); Basir et al., (2019) and Kumar et al., (2012) also reported that mechanized transplanting recorded higher yield than manual transplanting. Mechanical transplanting results in higher grain yield than hand transplanting because of transplanting younger seedlings with optimal spacing. This caused better photosynthate translocation from source to sink, resulting in a higher number of productive tillers per hill, more filled grains per panicle, and, ultimately, increased grain yield. However, Kumar et al. (2014) and Kang et al. (2019) observed no significant differences in grain yield between mechanical transplanting and manual transplanting.

ECONOMIC INDICATORS

Mechanical transplanting practice has lower production cost compared to manual transplanting, mainly due to low seed rate and a smaller number of labors required in transplanting operation. The seed rate required in mechanized transplanting varies with size of seed and ranges from 20 to 30 kg/ha (Rajaiah et al., 2019). However, about 50 kg of seed sown in 500 m^2 of seedbed area is required to transplant manually one hectare of main field (Kega et al., 2015). The recommended seed rate is 100-120 kg/ha for broadcasting or dry direct seeding practice and 50-60 kg/ha in seed drill machine used (Zaman, 2018). The labor requirement for transplanting operation in mechanical rice transplanter is only 2-man day/ha (Vasantgouda et al., (2014) and Elsoragaby et al. (2018). Similarly, Samal et al. (2020) observed the requirement of 6 man-hour/ha in 8 rows mechanical rice transplanter and 250 man-hours in manual transplanting. Dixit & Khan (2011) also reported number of man-hour/ha required in manual transplanting and mechanical transplanting were 238 and 32, respectively. The number of man-hour/ha required for transplanting decreased to 25 from 220 while using a self-propelled walking behind type rice transplanter (Kumar et al., 2012).

Table 1. Comparison of Benefit Cost ratio between manual transplanting and mechanical rice transplanting.

S.No.	Benefit Cost ratio		Authors
	Manual transplanting	Mechanical rice transplanting	
1.	2.82	3.63	Nadga et al., (2021)
2.	2.51	3.21	Goswami et al. (2020)
3.	2.53	3.87	Deshmukh et al., (2017)
4.	1.32	1.62	Islam et al. (2016)
5.	1.66	3.00	Raj et al. (2014)

According to Munnaf et al. (2014), the cost of seedling raising in mechanical transplanting was 22.2% higher than in manual transplanting, whereas the cost of transplanting in mechanical transplanting was 65.3% lower than in manual transplanting, resulting in an 8.03% reduction in total cost. Similarly, Goswami et al. (2020) recorded 2.4 times increase in cost of raising seedling in mechanical

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

transplanting practice than manual transplanting practice, but 3.2 times decrease in cost of transplanting, resulting in an 18.5% reduction in total cost of production. In addition, Raj et al. (2014) found that mechanical transplanting had higher net returns than hand transplanting, drum seeding, and broadcasting techniques. Reddy et al., (2018) reported that the breakeven point and payback period of Kuboto and Yanmar transplanters were observed as 43.45%, 2.3 years and 48.34%, 2.6 years, respectively. The benefit-cost ratio of the mechanical transplantation was more than that of manual transplantation in the various studies done, as indicated in Table 1.

CONCLUSION

Mechanical transplanting is more efficient but requires significant capital investment, making it suitable for larger-scale operations. Manual transplanting, while more labor-intensive, is cheaper and more adaptable, making it ideal for small-scale farmers or regions with low mechanization. Manual transplanting is often seen as more environmentally friendly due to lower fuel consumption, but mechanical transplanting offers faster and more consistent outcomes, which can lead to higher yields. As manual transplanting is labor and capital intensive. Mechanical rice transplanting can be used successfully as a substitute to manual transplanting to increase grain production, reduce cultivation costs, and eventually attain a better benefit-cost ratio.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Government Intervention in Agriculture Market Management

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ABSTRACT

This review critically examines government intervention in agriculture through policies and bilateral agreements, focusing on mechanisms such as the Minimum Support Price (MSP), input subsidies, crop insurance, extension services, and market regulations. A review of existing literature reveals that although these interventions aim to support farmers and stabilize the agricultural economy, their implementation is often flawed. Key findings highlight systemic gaps: M SP programs face delays and insufficient procurement; input subsidies suffer from targeting inefficiencies and elite capture; crop insurance adoption remains limited due to accessibility barriers; and the federalization of extension services has led to institutional fragmentation. The study has deduced that, despite considerable effort by the government, its efficacy and accessibility to common farmers remain far-fetched, and it is confronted with several technical and infrastructure shortcomings.

Keywords: Crop Insurance, Government Intervention, Input Subsidies, Minimum Support Price (MSP)

INTRODUCTION

In a winter morning in rural Nepal, a poor farmer stands alongside a load of freshly harvested cauliflower, his hand hardened through years of fieldwork, yet a look on his face is not one of pride, but of worry. Despite a good harvest, farmers in Nepal are frequently left vulnerable to price fluctuations and unfair trading practices. With a lack of proper cold storage facilities and no transport to reach bigger markets across the country, he is compelled to sell his crops at a loss, or in extreme cases, as seen in Kalimati, farmers were forced to throw their harvest onto the roads, unable to secure a fair price.

This is not a story of a single farmer, but rather a reflection of the broader challenges faced, especially by smallholder farmers across Nepal and many developing nations. While agriculture continues to be the pillar of the economy, the markets where the farmers of our country rely are often ineffective and unregulated. In such a fragile ecosystem, the government needs to step out and intervene to support these issues. Although, Nepalese government has suggested various kinds of solutions to address these issues through Minimum Support Price (MSP), input subsidies, cooperative structure, online marketplaces, supply chain efficiency, more market transparency, and bring out favorable policies, its efficacy is frequently questioned.

Farming in Nepal has always been a gamble; it is a profession of uncertainty. A single hailstorm can wipe out months of labor, a delayed monsoon can leave fields thirsty, and unpredictable market prices can turn a season's earning into losses overnight. In Nepal, where agriculture is a backbone of the country's economy, these types of risks not only pose a threat to the livelihood of individuals but also to overall national food security. While government intervention is intended to stabilize agricultural markets and support farmers, does it truly serve its purpose, or are farmers trapped?

GOVERNMENT INTERVENTION IN NEPAL'S AGRICULTURE MARKET

The debate over government involvement in regulating the agricultural market has persisted for many years. Given that Nepal is a primarily agrarian country, its agricultural and food security system highly depends upon effective price policies. The need for government intervention in the price policy of agricultural commodities was realized long ago, and some of the mechanisms are in place (Bhattarai & GC, 2020). The government of Nepal historically played an active role in agricultural markets by implementing policies and programs aimed at price stabilization and farmer support.

Minimum support price

Minimum Support Price (MSP) is one of the most commonly used tools by governments to ensure income security for farmers despite the loss caused by several external effects. It aims to provide farmers with assured support prices and ensures the accessibility to get the commodities at a reasonable rate (Parikh & Singh, 2007). In the context of Nepal, the introduction of MSP came in 1975, it was introduced during the fifth five-year plan (1975-1980), when agriculture was put as top priority to enhance the productivity and creation of diversified products from the point of view of industrial demands and usage (Joshi & Chaulagai, 2024). Since then, the MSP has served as a crucial approach to stabilize prices and incentivize agricultural production and encourage farmers to produce.

In the global scenario, this approach has been applied in order to control the agricultural market and to enhance the agricultural market (Lyu & Li, 2019; Guda et al., 2019; Marcus & Modest, 1986; Rasmussen & Baker, 1979). In the context of Nepal, the MSP policy was introduced during the Seventh Five-Year Plan**,** initially covering key crops such as paddy, wheat, and sugarcane**.** The primary objectives are:

1. Protection of farmers from market fluctuation that is very common in countries like Nepal.
2. Procurement of food grains for buffer stocks and public distribution.
3. Reduction of middle-men interference from price setting view point, middlemen are highly active players in the market channel of Nepalese agricultural scenario, causing high price levels of the agricultural commodities compared to the field level prices which distorts the agricultural market; thus, MSP was imposed to combat this issue (Jha & Srinivasan, 2006).

Despite these objectives, the MSP policy has been highly criticized by both farmers and free trade supporters. Farmers consistently call for a significant hike in the Minimum Support Price (MSP), while supporters of free agricultural trade argue that MSP often does not align with global market prices or the domestic supply and demand conditions. These differences lead to distortions and inefficiencies in production patterns (Singh et al., 1986). The policy was stopped in the fiscal year 1997/98. Although MSP was occasionally announced until 1999, it had little impact due to inconsistent declarations and unclear vision. Proposals to reinstate MSP were previously rejected by the Finance Ministry, but in 2012, the government decided to resume the policy following concerns about middlemen controlling market prices. In 2016, MSP was reintroduced, setting the price of common paddy at Rs. 2,230 per quintal and "Mota Dhan" at Rs. 2,070, with a government guarantee to purchase at these rates.

According to the MoALD (Government of Nepal, 2024), the Minimum Support Prices (MSP) for key crops in Fiscal Year 2024/25 have been increased, with common paddy set at NPR 3580.62 and Mota Dhan (Coarse Paddy) at NPR 3410.51–both reflecting an increment of up to 6.5% from the previous year.

Similarly, sugarcane received a moderate price increase, now fixed at NPR 585. These revisions indicate the government's continued commitment to stabilizing farm incomes and incentivizing crop production. Singh et al. (1986) argued that agricultural price policies like MSP have worsened farm income inequalities and that MSP has become more of a political instrument than an economic tool. Therefore, it is crucial to assess MSP's effectiveness across Nepal's diverse regions and evaluate its contribution to agricultural growth. For instance, research in Kanchanpur district found that poor implementation and inadequate procurement under MSP left many paddy farmers vulnerable to market fluctuations, limiting the policy's intended benefits (Joshi & Chaulagai, 2024). This example clearly highlights the scenario of Nepal from MSP view point.

Input subsidies

Government intervention in agricultural market management often includes input subsidies aimed at reducing production costs and boosting productivity. Recognizing the critical role of agriculture in improving rural livelihoods and driving national economic growth, the Government of Nepal has placed high priority on agricultural development (Chaudhary, 2018). Hence, it has formulated different agricultural policies and implemented them as farmer support programs. Despite the global arguments and criticism on the efficiency of subsidy program, Nepal's agriculture policies have prioritized subsidy programs (Paudel & Crago, 2017). Minister for Agriculture and Livestock Development, Ramnath Adhikari, stated that Rs 107.66 billion has been provided in agricultural subsidies over the past five years. The subsidies were distributed to cooperatives, groups, and firms from fiscal year 2019/20 to 2024/25. Despite the amount spent, many literatures have claimed of being inefficient, corrupt and unmanaged. Presently, there has been a drastic increase in the agricultural budget that support farmers through the provision of providing production inputs, extension services and financial assistance through grants and subsidized bank loans. Farmers are directly benefited from these subsidized inputs such as chemical fertilizers, improved seeds, machinery, and equipment, along with technical assistance provided. Moreover, the low interest agricultural loans and insurance premium subsidies are also handy tools for the farmers (MoF, 2023). As per Proceedings of the National Symposium on Major Agricultural Inputs Supply and Subsidy Mechanism in Nepal fertilizer has been increased tremendously which hindered the import of fertilizer in Nepal in spite of increasing the fertilizer subsidy budget during recent years. The inputs like Fertilizers, Seed and Irrigation are fundamental inputs for agricultural production. Thapa et al. (2024) conducted research in Makwanpur and Dhading districts, found that the accessibility of the agricultural subsidies is influenced by social factors like ethnicity, membership level in the cooperative or farmer group. It pinpoints the disparity among the various farmers due to these factors. The study highlights that farmers who are actively engaged in such networks and services are more likely to benefit from subsidy programs. It recommends strengthening cooperative participation and improving extension services to enhance farmer's access to subsidies effectively. A study conducted by Bharati et al. (2024) in Kavrepalanchowk District revealed that 72% of households received less than NPR 15,000 annually in agricultural subsidies. Some common inputs are enlisted below:

Extension services

Agricultural extension plays a pivotal role in bridging the scientific wisdom in the brains of a farmer and vice versa. Extension services are directly responsible for providing valuable information to the farmers that have been proven by science and research. It is responsible for disseminating farmers with knowledge about improved technologies, input use, and market opportunities. Agricultural extension generally refers to the process of applying new knowledge and scientific research to farming practices by educating and informing farmers (Hossain et al., 2014). Agricultural development relies heavily on an effective agriculture extension system. According to the Constitution of Nepal (2015), the country is composed of three tiers of government: one federal government, seven provincial governments, and 753 local governments. Federalization has paved opportunities to formulate and enhance efficacies of agricultural policies at the provincial and local levels, promoting a bottom-up approach to development (Kyle & Resnick, 2016). Under the new federal system, many extension functions previously managed by the Ministry of Agriculture Development (MoAD) and its central and district-level units have been devolved to provincial and local governments. With the implementation of federal system, most of the extension functions that were previously under the MoAD and its central and district level units have been now placed in the provincial and local levels.

Crop insurance and risk management

Agriculture Insurance is a tool designed to mitigate risk; it provides cushions for the shock of crop loss by assuring the farmers protection against various risks that are beyond the control of a farmer (Dandekar, 1976; Benami & Carter, 2021; Karki et al., 2024). It can be taken as an equitable transfer of risk from one entity to the other to prevent large devastating loss (Iturrioz, 2009). The entity that provides insurance is known as an insurer and the entity that buys is termed as the insured (Bhattarai, 2024). In recent times, the Government of Nepal has focused greatly in the development and extension of agriculture insurance services to the farmers to reduce vulnerability. In the context of Nepal, agricultural insurance was formally introduced on 14 January 2013 (Insurance board, 2017). The government has prioritized agriculture insurance in its national policies, plans, programs, and budgets. During 2014-2022, the government allotted almost Rs 4 billion as a subsidy to agriculture insurance (MoF, 2022).

Public- Private Partnerships (PPP)

The concept of PPP in Nepal began to flourish in the early 2000s, as it was the outcome of government recognition that the private sector had to be made part for the countries holistic development specially from the point of view of infrastructure development. Initially, the focus of PPP concept was based around sectors like Transportation, telecommunication, and energy (Rai, 2021). The relevancy of the PPP model in agriculture is relatively new as pinpointed by Rai, 2021. The model began to be the subject of discussion during the late 2000s. In response to greater agricultural inefficiencies such as low productivity, poor market access and lack of post-harvest facilities in the country (Ghimire, 2017). Major policy framework such as Agribusiness Promotion Policy (2006) and ADS (2015-2035) laid foundation for integration of PPPs specially in the agricultural scenario. These policies focused the importance of collaboration among various private sectors to improve agricultural commercialization, strengthen value chains, and support the development of agro-processing industries (MOAD, 2015). One of the major examples of PPP model in agriculture is the collaboration between Nepal Agricultural Research Council (NARC), Non- governmental organizations (NGOs), and Private seed companies for the production of hybrid tomato seeds. This collaboration involved direct interaction of NARC with the farmers cooperative along with the private companies supplying the inbred lines, this collaboration proved to be holistic and well thought as all of the concerned stakeholders were under a common umbrella that was to produce hybrid seed for tomato (Nepal Horticulture Society, 2016).

Market regulations

Market regulation plays an important role in maintaining the productivity and fair pricing systems for the farmers, if we talk in the context of agriculture. However, market regulation is a far-fetched reality due to various technical inefficiencies in our country. Most of the causative factors include poor governance, fragmented institution and weak enforcement. Several government bodies are responsible for the regulation of agricultural market, the Agricultural Marketing Promotion Development Directorate (AMPDD) plays a crucial role in enhancing market infrastructure, providing market information, and bonding links between the farmers and the market. The Food Management and Trading Company (FMTC) is given responsibility to buy essential food items and managing their prices to ensure food security and to maintain an equilibrium in the market. The agricultural supply chain of Nepal is hindered by multiple inefficiencies, including inadequate infrastructure, limitation in storage capacities and the lacking of cold chain services. These constraints collectively contribute to significant losses in post-harvest, and reduced market inefficiencies (FAO, 2020). The export performance of Nepal during the first five month of the fiscal year of 2024/25 present a mixed scene, some of the commodities showed a steady spike while some are confronted with strong setbacks demanding urgent fixing. Nepal lacks the standardized quality controls and certification and thus we struggle to compete with other globally produced products and our commodities don't get enough recognition and importance from an export point of view (IFPRI, 2021). By implementing targeted strategies, the country can work toward achieving a more stable and diversified export portfolio in the coming years.

POLICIES STRATEGIES FOR AGRICULTURE DEVELOPMENT

Although Nepal in its early phase towards strengthening trade policies, aims to enhance economic growth, ensure food security and expand domestic product outside of country. In order to reduce trade deficit, Government of Nepal has diligently worked towards establishment of numerous strategies and international agreements, which also contributes towards supporting farmers and the modernization of agriculture sector. Through the establishment of trade policies, it further plays a pivotal role which helps in regulation of import and export of agricultural products, stabilize country's made product, meaning to keep local economy protected, take care of local farmers and ensure overall food security. On the other hand, international trade has its own role in shaping the country's development towards economic growth. Import and export are two key indices when it comes to international trade (Breinlich and Criscuolo, 2011). In past decades, Tibet and India were the only countries Nepal traded goods with. After 1951, Nepal further expanded mutual trade with many other countries that included the likes of Japan, Germany, the USA, and Malaysia. Despite these trade relationships, country continuously faces trade deficits, due to higher number of imports and lesser exports, which limits economic growth of our country. Below is Nepal's Trade Policy 2015, which aimed to stabilize country's economy via multilateral and bilateral mechanisms.

International trade agreements and Nepal

Nepal obtained observer status in the General Agreement on Tariffs and Trade (GATT) in 1989, marking the beginning of its gradual integration into the global trading system and laying the foundation for its eventual accession to the World Trade Organization (WTO). GATT, which aimed to reduce tariffs and trade barriers, served as a preparatory platform for Nepal to engage in multilateral trade diplomacy and begin aligning its domestic trade policies with international norms (Shrestha, 2013). However, as a developing country with structural economic constraints, Nepal struggled to fully benefit from GATT during this period. The transition to WTO membership highlighted these challenges, as Nepal encountered difficulties in aligning its trade commitments with national development objectives due to limited negotiation capacity and technical expertise (Adhikari & Yamamoto, 2006). These institutional limitations became especially evident during its WTO accession process, which formally concluded in 2004 when Nepal became the first Least Developed Country (LDC) to join the WTO through full working party negotiations, an effort rooted in the groundwork laid during its GATT involvement.

The Agreement on Agriculture (AoA), part of the WTO since 1995, aims to make agricultural trade fairer through three pillars: market access, domestic support, and export subsidies. For Nepal, a least Developed Country, the AoA offers special treatment but with limited benefits. Nepal's market access gains remain minimal due to poor infrastructure and low export capacity (Shrestha, 2010). Although allowed to provide subsidies up to 10% of its agricultural output, Nepal lacks the financial resources to do so, it doesn't offer export subsidies, so that pillar has little effect. Critics argue the AoA favors rich nations that continue supporting their farmers under permitted "green box" subsidies, leaving countries like Nepal at a disadvantage despite formal equal rules (Adhikari & Dahal, 2006). World Trade Organization (WTO) Agreements on Agriculture are as follows:

1. **Market Access**: Although global markets opened, Nepal's exports remain low due to weak infrastructure, low productivity, and non-tariff barriers (Shrestha, 2010).

2. **Domestic Support**: Nepal can legally offer subsidies up to 10% of its agricultural output, but provides far less due to budget constraints, limiting support to farmers (Adhikari & Dahal, 2006).
3. **Export Subsidies**: Nepal doesn't use export subsidies. Though developed countries' subsidy cuts were expected to help, Nepal saw little benefit due to trade imbalances and logistical issues.

WTO membership gives Nepal chances to grow its exports and join global markets, but it also limits some domestic policies. Nepal needs to modernize its agriculture, follow international standards, reduce trade barriers, and build stronger trade institutions. Complex WTO rules are hard for small farmers to follow. Although Nepal has aligned many policies with WTO and GATT, trade deficits and weak capacity remain problems.

Regional and bilateral trade agreements

Nepal became a member of the **Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC)** in February 2004. This regional organization aims to foster deeper economic cooperation by establishing a comprehensive free trade area covering trade in goods, services, and investment, thereby strengthening ties between South and Southeast Asia. Nepal is also a member of the **South Asian Free Trade Area (SAFTA)**, which was established in 2006 with the goal of reducing customs duties and enhancing trade among South Asian countries. However, Nepal has not fully liberalized its tariffs under SAFTA, limiting its ability to fully benefit from the agreement (Kharel et al., 2021).

Nepal Trade Integration Strategy (NTIS)

The first trade strategy created by the Nepali government was called NTIS 2010. Nineteen priority export goods and services were identified. It featured six services and thirteen goods with the goal of bringing Nepal into the international market and using trade to combat poverty. Additionally, the strategy identifies high-growth potential priority export sectors, including manufacturing and craft goods, tourism, BPO, IT, and forest and agricultural products. The Nepal Trade Integration Strategy (NTIS) 2016 recognized agriculture as a critical industry for increasing export potential and promoting inclusive economic growth, according to the FNCCI (2016). Four main agricultural products were the focus of the strategy:

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

- **Large Cardamom**: Aimed to increase production from 5,750 metric tons in 2012/13 to 6,500 metric tons by 2020. The goal was also to raise the export price to 75% of India's by enhancing value addition.

Table 1. NTIS and Agricultural Commodities at a glance

Category	NTIS 2010	NTIS 2016	NTIS 2023
Agricultural Product	• Ginger • Cardamom • Tea • MAPs • Fruits and Vegetables	• Cardamom • Ginger • Tea • MAPs	• Lentils • Jute • Vegetables • Fruits • Spices • Coffee
Industry Category	• Wool Products • Instant Noodles • Readymade Garments • Silver Jewelry	• All Fabrics, Textiles, Yarn, and rope • Leather goods • Footwear • Chyangra Pashmina • Knotted Carpets	• Jewelry • Pasta • Himalayan Spring water • Honey • Dog chew products • Felt
Services	• Tourism Services • Information Technology services • Business processing Outsourcing	• Skilled and Semi-skilled professionals • Information Technology and Business Process Outsourcing • Tourism Services (leisure, business, education, medical)	• Electricity
Forestry			• Handmade lokta paper • Rosin and turpentine • Fragrant oil • Textiles made from long fiber

Source: NTIS, 2023

- **Ginger**: Targeted a production increase to at least 300,000 metric tons, with 70% exported. The strategy aimed to increase the export price to 75% of China's by enhancing processing and value addition.

- **Tea (Orthodox)**: Set a goal to boost exports from approximately US$2.7 million in 2013 to US$6 million by 2020, with production rising from 3,000 to 4,500 metric tons.
- **Medicinal and Aromatic Plants (MAPs)**: Focused on increasing export value from US$14 million in 2013 to US$20 million by 2020. This included establishing modern processing industries to enhance value addition.

Through the creation of a master plan for the construction and improvement of trade infrastructure, the Nepal Trade Integration Strategy (NTIS) 2023 presents a thorough policy framework intended to increase the nation's trade capacity. The strategy places a strong emphasis on establishing standards for the expansion of trade infrastructure, enhancing digital trade through the training of logistics service providers, and developing both physical and IT transportation infrastructure to enable more seamless cross-border trade. Acknowledging the revolutionary potential of new technologies, NTIS 2023 promotes the use of tools from the fourth and fifth industrial revolutions to increase global trade, emphasizing the use of digital platforms like B2B, B2C, C2C, and C2B models to increase productivity and cost-effectiveness. Additionally, social inclusion is given top priority in the strategy, with an emphasis on boosting women's involvement in the trade labor force. In addition to suggesting research projects to address the difficulties faced by women in trade, it calls for the creation of a Women Empowerment and Social Inclusion Unit within the NTIS department, which will be backed by the gathering of gender-disaggregated data. Furthermore, NTIS 2023 broadens the scope of export priorities by including industrial goods like iron and steel, cement, and ready-made clothing alongside products like lentils, jute, fruits, spices, coffee, handmade paper, rosin, turpentine, aromatic oils, and long fiber textiles.

Agriculture development strategy

Nepal’s agriculture sector has played a crucial role in shaping overall country’s national economy, providing helping hand to local farmers (training, subsidies, extension services, etc.), employment facilities, and enhancing rural livelihoods. Despite its economic significance, challenges such as climate vulnerability, farming at subsistence level, limited market reach, low outputs persist (MOAD, 2015). To solve these ongoing issues, Government of Nepal introduced long term agricultural plan called Agriculture Development Strategy (ADS) 2015–2035. This plan was introduced just after Agricultural Perspective Plan (APP) 1995–

2015 commenced, which fell short to achieve many of its desired goals (MOAD, 2015; ACIAR, 2022).

The ADS was formulated as a long term (20 Years) strategic plan to bring out significant changes into Nepal's Agriculture Sector and make it more competitive. Its main role is to enhance food and nutrition security, provide employment, and support local economic growth, assist local farmers (MOALD, 2015). ADS further brings out themes related to gender equity, social inclusion, environmental sustainability, and climate resilience (LEAP, 2015; ACIAR, 2022).

CONCLUSION

In Nepal government intervention in agricultural market management is not only a matter of policy but also a necessity. To stabilize markets and safeguard farmers, Nepal has implemented a number of policies over the years, including the Minimum Support Price (MSP), subsidies, and cooperative structures. Many farmers continue to struggle against unstable markets, unjust pricing, and restricted access to adequate storage or transportation, even with government efforts. These efforts have frequently failed due to a lack of access to trustworthy market systems, limited crop coverage, and delays in the implementation of policies. Many farmers continue to bear the burden of a system that does not adequately support them, as this review has demonstrated. Government policies can contribute to the development of a more stable and just agricultural market—one in which farmers not only survive but flourish—with improved planning, prompt action, and local adaptation. The way forward is to ensure that no farmer is left behind in the marketplace and to pay attention to those who work the land. In order to transform the agricultural market into a just and sustainable system, Nepal will need to take a comprehensive, farmer-centric strategy that incorporates infrastructure development, policy reform, and market transparency.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Food Systems Transformation in Nepal: Commitments and Challenges in Boosting Nature-Positive Food Production

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ABSTRACT

Nepal stands at a pivotal moment in its development trajectory as it prepares to graduate from least developed country status by 2026. Despite this milestone, food insecurity, malnutrition, and unsustainable agricultural practices persist, exacerbated by climate change, demographic shifts, and global geopolitical trade dynamics. The current food systems fail to deliver sufficient, nutritious, and safe food for a growing population without damaging natural resources and the environment. In response, Nepal developed the 2021 Food Systems Transformation Strategy, aligning with global pathways to build sustainable, resilient, and equitable food systems. Translating these commitments into tangible action requires alignment with policy, planning, and fiscal investment. However, achieving Action Track 3, which focuses on boosting nature-positive food production at scale, remains a significant challenge due to entrenched policy practices, low public investment, knowledge and capacity gaps, and limited implementation of sustainable agriculture initiatives. The concept of food systems is not new to Nepal; however, there is limited literature examining the evolving shifts and dynamics of food systems and their transformation pathways toward achieving triple outcomes, beyond food security and economic growth. The main objectives of this paper are to identify barriers to implementing nature-positive food systems at the scale in Nepal and to offer insights and lessons that should be prioritized to effectively advance the goals outlined in Nepal's Food Systems Transformation Strategy 2021. This paper analyzes Nepal's policy landscape, agricultural performance, and gaps in sustainable agriculture implementation to examine their alignment with nature-positive food systems goals. Drawing on national and international experiences, it identifies systemic barriers, including policy incoherence, insufficient local capacity, limited research and innovation, and lack of empirical evidence, that hinder the adoption and scaling of sustainable practices. A "one-size-fits-all" approach to transform the systems is inadequate for Nepal's diverse agroecological zones, marked by significant provincial variation and increased demographic and socio-economic changes. The paper advocates for a transformative mindset, governance, investment, and multi-stakeholder coordination shifts to foster nature-positive food systems tailored to Nepal's diverse context. Key actions include enhancing local capacities, reorienting subsidies, improving governance and monitoring systems, and strengthening private sector engagement. Ultimately, a systems-oriented and context-specific approach is essential to accelerate the transition toward environmentally sustainable and inclusive food systems in Nepal.

Key words: Subsidy, food systems transformation, nature-positive, sustainable agriculture, policy

INTRODUCTION

Nepal, one of the least developed countries, is set to graduate to developing country status in 2026, a milestone that indicates both emerging opportunities and impending challenges (NPC, 2024). Food insecurity remains a persistent challenge in Nepal, with significant regional disparities, affecting an average of 13% of households, ranging from 8% in Gandaki Province to 32% in Karnali Province (NDHS, 2022). This persists despite the country's longstanding efforts to drive economic growth through agricultural development and its recent legal commitment to the right to food. Several studies evidence that current food systems fail to deliver sufficient, nutritious, and safe food for a growing population without damaging natural resources and the environment. Nepal's food systems are highly vulnerable and unsustainable due to the impacts of climate change, demographic shifts, and evolving geopolitical trade dynamics. Declining agricultural productivity and increasing pressure on soil, water, and forests (Shrestha et al., 2021) have contributed to Nepal's slow agricultural growth rate of 0.06%, the lowest among India, Bangladesh, and Pakistan (Sharma & Pudasaini, 2020). Nepal's food imports have been rising rapidly, with a 65% increase in key agricultural product imports between 2015 and 2020, signaling alarming trade dependency (Adhikari et al., 2021). Despite some improvements in maternal and child dietary diversity, only less than half of children aged 6-23 months and women of reproductive age consume foods that meet minimum nutritional standards. Marginalized groups face persistent disparities in accessing adequate and quality food, compounded by the high costs of a healthy diet. More than half of the population in the mountainous regions cannot afford a nutritious diet (FNG, 2021). Meanwhile, the consumption of unhealthy foods characterized by high sugar, high salt, and unhealthy fats is increasing at an alarming rate across both rural and urban areas in all provinces of Nepal, with rates ranging from 57% in Karnali Province to 78% in Koshi Province (NDHS, 2022).

To address these issues within the current food system, the National Planning Commission, working in collaboration with the Ministry of Agriculture and Livestock Development, other relevant ministries, and development partners, developed Nepal's Food Systems Transformation Strategy in 2021. This strategy, framed around six action tracks aligned with UN Food Systems Transformation Pathways, aims to transform the food systems towards sustainability, resilience, and equity. It calls on all development stakeholders, civil society, and the private sector to contribute to accelerating the momentum in this process. However, achieving the goals of the strategy, particularly Action Track 3, which focuses on “boosting nature-positive food production systems at scale”, by 2030 remains a significant challenge, considering the limited historical progress on sustainable agriculture development initiatives in Nepal. Despite clear priorities and the urgent need for action around food systems transformation, the national budget for the recent fiscal years has with no significant changes in allocations. Public sector investment in agriculture remains very low. According to last year’s annual budget 2024, agriculture accounted for only 3.17% of the total federal budget, 8% of provincial budgets, and just 1.4% of local government budgets. Furthermore, a substantial portion continues to support chemical fertilizer subsidies, reflecting entrenched policy practices.

The concept of food systems is not new to Nepal; however, there is limited literature examining the evolving shifts and dynamics of food systems and challenges of their transformation pathways toward achieving triple outcomes, beyond food security and economic growth. This paper provides an overview of sustainable food system pathways, with a particular focus on Action Track 3, boosting nature-positive food systems at scale. The food systems approach is complex and multisectoral, extending beyond the agriculture sector, however, agriculture remains a central component that shapes food systems. This paper, hence, highlights key agricultural indicators and some country contexts to discuss their potential linkages to sustainable food systems within the broader development landscape. Although policy frameworks increasingly advocate for sustainable agricultural systems, there remains a significant gap between policy design and effective implementation (Atreya et al., 2020). Drawing on Nepal's initiatives to promote sustainable agricultural intensification, alongside international experiences with nature-positive food systems, the paper discusses key implementation challenges and proposes potential ways forward for the policy coherence and strategic investment pathways to support the transition toward environmentally sustainable and productive food systems in Nepal.

The main objectives of this paper are to identify barriers to implementing nature-positive food systems at the scale in Nepal and to offer insights that should be prioritized to effectively advance the goals of food systems transformation. The paper is structured into four sections. The first section outlines the national context, presenting key agricultural performance indicators data to provide a foundation for understanding, which is crucial while designing and implementing any programs. The second section offers an overview of Action Track 3, boosting nature-positive food systems, as articulated in Nepal's Food Systems Transformation Strategy, reflecting the Government of Nepal's commitment to sustainable food system pathways. The third section reviews the status and challenges of ongoing sustainable agriculture initiatives in Nepal, drawing on national and international experiences and lessons learned. The last section synthesizes key barriers to the effective implementation of nature-positive food production systems, along with proposing some potential ways forward to accelerate the food systems transition towards sustainability and greater resilience.

1. Some agricultural performance indicators and country context for food systems transformation

Nepal's agriculture sector is at a crossroads, facing the dual challenge of advancing agricultural modernization and intensification, while also urgently transforming toward more sustainable and resilient systems to adapt to changing global dynamics. Historically, Nepal has been an agrarian country, with agriculture serving as the primary source of livelihood for over 80 percent of households, was self-sufficient in food and a net exporter of agricultural products until the early 1980 (Baral, et al., 2020) and has been a cornerstone of the country's economy. However, over the past two and a half decades, the sector has undergone significant changes, as illustrated in Table 1, based on findings from the most recent National Living Standards Survey (NLSS III-2022/23). The agriculture sector's contribution to Nepal's gross domestic product (GDP) has declined significantly from 39% in 2001 to 24.1% in 2023, while the service sector's share has increased, reflecting a broader structural transformation of the Nepali economy over the past two decades (NPC, 2024).

Table 1. Selected agricultural indicators, 1995/96-2022/23

(Source, NLSS-III, 2024)

Description	Nepal Living Standards Survey			
	1995/96	2003/04	2010/11	2022/23
Agricultural households (percentage of total households)	83.1	77.5	73.9	60.3
Average size of agricultural land (in hectares)	1.1	0.8	0.7	0.4
Average number of parcels	3.8	3.1	2.9	2.8
Holdings operating less than 0.5 hectares (percentage of total holdings)	40.1	44.8	52.7	88.5
Percentage of holdings operating on rent-in-land only	4.8	7.3	5.4	18.4
Percentage of holding growing main paddy	76	76.1	72.3	64.3
Percentage of holdings growing summer vegetables	35.6	60.8	68.8	39.3
Percentage of holdings with cattle	73.5	66.6	64.2	37.8
Percentage of holdings with poultry birds	49.9	52.7	53.6	43.9

With the continued decline in agricultural households, the national average now stands at 60.3%, varying significantly across provinces from 82% in Karnali to 42% in Bagmati, indicating that a shift away from agriculture as the primary source of livelihood is high. Households classified as poor are more likely to be engaged in agriculture (73.9%) compared to non-poor households (57.6%). Agricultural land covers 28% of the total land, and only 21% of it is cultivable. Additionally, the average size of agricultural landholdings is decreasing, and the proportion of holdings operating on less than 0.5 hectares is rising along with provincial variation, an indication of increasing land fragmentation at different rates. This fragmentation poses significant challenges for efficient agricultural practices and limits the ability to achieve economies of scale (NPC, 2024). According to the 2021/22 Agriculture Census, the area under paddy, wheat, and maize cultivation has declined, along with a reduction in the number of households owning large livestock compared to the previous census. The adoption of modern farming techniques in Nepal remains low compared to other South Asian countries, despite being a key priority in the agriculture sector since the Agriculture Perspective Plan of 1995. This trend is driven by urbanization, land fragmentation, land use changes, labor shortages, and shifting market dynamics.

In reviewing the various facts and trends related to agriculture, it becomes evident that current food systems changes are not in a positive direction of sustainable and resilient development. A "one-size-fits-all" approach to transform the systems is inadequate for Nepal’s diverse agroecological zones, marked by significant provincial variation and an increased trend of rural-to-urban and Hill/Mountain to Terai migration. However, most agricultural programs continue to emphasize commercially oriented farming systems, often under the premise of improving the subsistence conditions of smallholders. These initiatives frequently overlook the root causes and structural barriers to transformation, ultimately benefiting only a small number of large-scale commercial farmers. Transforming food systems is a critical challenge that requires a deep, holistic understanding of the complex and multifaceted barriers to achieving sustainability, with political economy barriers at the core, often serving as foundational system-level obstacles to meaningful change (Even B., 2024). In this context, it is important to examine Nepal’s food systems transformation pathways, particularly how the nature-positive food systems are being envisioned and to what extent they are achievable. Without such a nuanced approach, efforts toward sustainable and inclusive transformation risk falling short despite Nepal's progress in developing policies, plans, and programs aligned with international guidelines and national commitments.

2. Unfolding Action Track 3 “Boosting Nature Positive Food Production Systems”

Approaches to addressing food-related challenges and priorities have evolved over time from a narrow focus on increasing calorie production to a broader systems approach that incorporates health, inequality, and environmental sustainability (Farmery et al., 2025). Like many other developing countries, Nepal has historically prioritized increasing agricultural productivity and food access through agricultural modernization and market development to drive food security and economic growth. However, with a growing sense of urgency to address current food systems issues in Table 2, Nepal has prioritized the six food systems transformation Action Tracks, building on the existing policies, plans, and programs. The action tracks are: 1. ensuring access to safe and nutritious food for all, 2. shifting to sustainable consumption patterns, 3. boosting nature-positive production at scale, 4. advancing equitable livelihoods and value distribution, 5. building resilience to vulnerabilities, shocks, and stresses, and 6. Right to food and food sovereignty. These interrelated action tracks involve trade-offs and synergies, and policy coherence and strong governance across sectors, health, nutrition, education, agriculture, forestry, environment, and land management are crucial for successful implementation.

Table 2. Issues of current food production systems in Nepal

Food Production Trends	Drivers
Highly climate-sensitive food production systems, with only 27% of agricultural land irrigated, and smallholders disproportionately affected by droughts and other climate-induced disasters, 90% crop losses and damages due to climate-induced disasters	Environmental impacts, limited technologies, and investment in infrastructure for diverse ecosystems
Heavy reliance on agricultural commodities (eg, chemical fertilizers, pesticides, feed, farming tools) and food imports—80% of grains, a 62% rise in import spending, and declining exports, reflecting a growing trade deficit and a vulnerable food system	Trade globalization, socio-economic (increased income, migration), demographic changes (changing food habit and life style, urbanization, out-migration), Geopolitics
38% of forest land, 37% of pasture/rangeland, and 10% of agricultural land have been affected by the land degradation process, feminization in agriculture, with 70% women workforce, declining soil fertility, and crop productivity	Socio-economic-Poverty and demographic shifts-urbanization, male migration, Physical-infrastructure, market constraints, Policies for agriculture intensification, and politics of modernization in agriculture (chemical fertilizer subsidy schemes)
Land use changes such as about 65,000 ha of premium land suitable for cereal cultivation, has been converted into urban areas, shrinking agricultural cultivable land	Socio-economic (increased income), demographic (such as urbanization, migration),
On average 37% of arable land is abandoned in Nepal with almost 21% of *bari* land (upland) and 5% of *khet* (paddy) land in hills and underperformance of agriculture	Socio-economic (increased income), demographic (such as urbanization, migration), and Technological (poor agriculture growth and underperformance)
Loss of biodiversity is rapid, with 50% traditional crops varieties in the past six decades of agricultural development	Socioeconomic-changes in food habit based on few calories, animal protein and processed food and life style, technological-limited research and development on traditional crops, Policies for agriculture intensification and politics of modernization
Environmental pollution (water, soil, air); Greenhouse gas emissions- values for Nepal equals about 23% of total national gross GHGs emission per annum in terms of CO2	Agriculture intensification, misuse of agrochemicals- Technological-poor management practices, and limited innovation and research on climate smart animal husbandry

Source: NPC & WFP, 2021

The Ministry of Agriculture and Livestock Development plays a leading role in driving the transformation of Nepal's food systems, particularly the Action Track-3 "Boosting Nature Positive Food Production" to meet the fundamental human right to healthy and nutritious food while operating within plenary boundaries. Nature-positive food production systems are characterized by a regenerative, nondepleting, and non-destructive use of natural resources in food production systems. It focuses on environment-friendly food and feed production systems that ensure biodiversity, conserve soils and water, reduce pollution, and enhance climate resilience and social responsibility. The framework for nature-positive food systems is presented diagrammatically in Figure 1.Nature-positive food systems are built on three pillars: protecting, sustainably managing, and restoring (agro) ecosystems (E. Hodson de Jaramillo et al., 2023). Nepal's 2021 food systems transformation strategy outlines action areas for each pillar within the national context, with implementation, and assessing the success of actions underway.

Action area 1: Protect natural systems from new deforestation and conversion for food and feed production: Some proposed actions under this pillar are: enforcement of Land Use Act (2019) and Land Use Policy (2015), Land use planning enforcement through land pooling, unused fallow land, land bank etc., Subsidies and safety nets to resource poor to prevent forest encroachments.

Action area 2: Manage sustainably existing food production systems: Some proposed actions under this pillar are: Agroecosystem and landscape based planning focusing on comparative and competitive advantage; regenerative agriculture production system with focus on ecological, organic and conservation agriculture, sustainable use of agrobiodiversity including value chain development of local crops, promotion of climate-resilient food systems and animal husbandry technologies; intensification of Good Agricultural Practices

Action area 3: Restore degraded ecosystems and rehabilitate soil functions for sustainable food production: Some proposed actions under this pillar are: convert degraded riverbeds to gardens, watershed conversion, improvement of soil fertility through legume rotation, integrated farming, agroforestry promotion and green manuring; revitalization of local indigenous food systems, removal of subsidies for unhealthy/agrochemical intensive food production system. Political will and sustained commitment are essential to reduce land conversion and degradation, prevent biodiversity loss, safeguard indigenous knowledge, restore ecosystem services, and ensure the sustainable management of natural resources, all critical to achieving nature-positive food systems outcomes. Several existing policies, acts, and regulations in Nepal provide an enabling policy environment to support and scale up nature-positive food production initiatives. Key among them are presented in table 3.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Table 3. Policy Environment for Nature-Positive Food Production Systems

S.N.	Policies/Strategies/Plans	Key highlights
1	Environment Protection Act and Regulation (2019	Provides the legal foundation for environmental conservation and regulation
2	National Adaptation Plan (2021–2050)	Outlines long-term climate adaptation strategies
3	Nature Conservation National Strategic Framework for Sustainable Development (2015–2030	Guides integrated approaches to conservation and development
4	National Climate Change Policy (2019)	Promotes climate-resilient development across sectors
5	National Agroforestry Policy (2019)	Supports sustainable land use through integrated agriculture and forestry practices

Additionally, several other agriculture sector development policies, strategies, and plans, particularly related to sustainable agriculture, underscore the implementation of nature-positive food production actions. The promotion of sustainable agriculture with several approaches has long been part of Nepal's policy discourse, often positioned as a pathway toward long-term environmental sustainability and to minimize the negative impacts of agricultural intensification in the context of climate change. However, the systematic evolution of policies and programs explicitly supporting sustainable agriculture is relatively recent. While sustainability principles have been embedded within the broader frameworks of conventional or modern farming systems, they have not always been central or consistently prioritized. Since the 10th Five-Year Plan (2002-2007), there has been a growing emphasis on mainstreaming sustainable agriculture approaches, particularly organic agriculture, into national development strategies and plans. Yet, despite this recognition, the organic agriculture movement has remained slow and not encouraging (Atreya, et al. 2015, Gauchan et al, 2020, and Acharya, et al, 2020).

3. Landscape of sustainable agriculture development programs

Different sustainable agriculture approaches versus organic agriculture

Traditional and industrial agriculture both fall short of meeting the demands of a growing population sustainably. While traditional practices cannot support large-scale production, modern industrial agriculture, heavily dependent on chemical inputs, has led to serious environmental and health concerns. In response, sustainable agriculture has emerged as a vital alternative, aiming to balance environmental health, economic viability, and social equity in the production of crops, livestock, and fisheries. To address global sustainability challenges, various alternative farming systems have evolved, including integrated farming, conservation agriculture, agroforestry, regenerative agriculture, organic farming, and more (Atreya et al., 2020). Recently, nutrition-sensitive agriculture and nature-positive food production have also gained attention. Among these, organic agriculture has received significant recognition, especially in Nepal. However, organic farming alone is not sufficient to achieve the broader goals of agricultural sustainability (Tal, 2018).

In Nepal, efforts toward promoting sustainable agriculture remain limited, and most initiatives disproportionately focus on organic farming. A more tailored approach, considering socio-economic conditions, demographic shifts, and ecological potential, is needed. Rather than treating sustainable practices as competing models, they should be viewed as complementary tools grounded in agroecological principles. Clear definitions, distinct goals, and innovation pathways for each approach are essential to avoid confusion and ensure wider adoption beyond small pilot initiatives.

Policy setbacks for sustainable agriculture

Most agriculture sector development policies, plans, and strategies in Nepal are in favor of conventional agriculture, particularly emphasizing enhanced productivity using synthetic fertilizers, chemical pesticides, and irrigation, despite the organic agriculture movement starting in 1987. There are limited separate sectoral policies that support different sustainable agriculture systems, and they are often found mainstreamed within the broader frameworks of conventional or modern farming systems.

- Agriculture Perspective Plan 1995, National Fertilizer Policy 2002, the 9th Five Year Plan: Emphasizing integrated pest management
- National Coffee Policy 2003, National Agricultural Policy 2004, Agribusiness Policy 2006:Promotes organic agriculture with focus on export (organic coffee)
- Agricultural Biodiversity Policy 2006- Regulates GMO and promotes organic agriculture
- National Standards of Organic Agriculture Production and Processing 2007-Sets standards for organic production and processing

- Trade Policy 2009, Nepal Trade Integration Strategy 2010-Supports organic certification, and promote organic tea, coffee, honey, and vegetables for export
- Agricultural Development Strategy 2015-Emphasizes organic branding for export, promotes bio-fertilizers, good agricultural practices
- The 10th, 11th, 12th , 13th 14th, 15th and 16th Five Years Plans-Promotes organic agriculture as the part of sustainable, competitive and prosperous agricultural economy with food and nutrition security, food sovereignty
- District level organic fertilizer subsidy guideline 2015:Promotes the use of and increased access to organic manures, fertilizers for organic agriculture
- Karnali Province's Policy and Development Program 2018:Outlines gradual transformation into a fully organic province, Endorsed the Organic Agriculture Bill, Prioritizes for organic fertilizer plants, agro mechanization and organic pesticides plants, One local level one model organic farm, One cooperative one model agriculture, livestock and fisheries farm

While reviewing existing sustainable agriculture-related policies in Nepal, it becomes evident that most emphasize organic agriculture, with only a few other sustainable intensification approaches such as integrated pest management, integrated soil nutrient management, climate-smart agriculture, and agroforestry. Notably, there is a lack of explicit policy support for conservation agriculture, ecological agriculture, regenerative agriculture, and climate-smart animal husbandry. Since the 10th Five-Year Plan, organic agriculture has received increasing policy attention at the federal, provincial, and local levels, an important acknowledgment of the progress made in Nepal's organic movement. However, most of these policies remain fragmented and piecemeal, with a predominant focus on market development, export promotion, and income generation. This focus often diverges from the foundational agroecological principles of organic agriculture. Consequently, current approaches tend to exclude smallholder and subsistence farmers, favoring large-scale producers instead of ensuring inclusivity and broader food system transformation.

Emerging issues and insights in advancing sustainable agriculture

While the literature widely highlights the benefits of sustainable agriculture, such as reduced input costs, biodiversity conservation, lower environmental degradation, and improved food quality, there is limited data-driven evidence in the context of evolving agricultural systems. From a global perspective, including Nepal's experience, the drawbacks of sustainable agriculture include inefficient land use, labor intensiveness, lower crop yields and income, and time-consuming practices (Shrestha et al, 2021). The limited application of science-based practices in promoting sustainable agriculture is largely due to a lack of action research, which hinders farmers from adopting and scaling these approaches. For instance, while composting is widely practiced, many farmers perceive it simply as collecting organic waste and dumping it into a pit. This improper practice leads to significant nitrogen loss through leaching and runoff, especially during the rainy season. As a result, it fails to enhance soil fertility, leading to low agricultural productivity and poor economic returns (Amagain et al., 2017). Moreover, inefficient composting not only undermines soil and crop productivity but also contributes to groundwater pollution and increases the carbon footprint (Tal, 2018).

Organic amendments alone are unlikely to be sufficient to maintain high levels of productivity, and imbalanced fertilizer use poses major fiscal and environmental challenges in South Asia, and high labor demands and costs of organic inputs limit their use, despite their benefits, making farmers favor synthetic alternatives. (Kishore, et al., 2020). The comprehensive reviews found that organic agriculture has a 34% lower yield than conventional; the transition to a fully organic system would require 30% more land usage than conventional (Tal, 2018). Due to the ban on agrochemicals in Jumla to declare an organically certified district in Nepal, several cultivation, technical, and operational challenges have emerged, resulting in only apples being certified. This reflects a gap between the ambitious goals and the necessary investments in infrastructure, technological research, and innovation to provide viable alternatives to agrochemicals (Baral, et al., 2020). Farmers practicing large-scale organic agriculture face challenges due to limited technical and extension support for meeting organic standards, poor access to affordable inputs, and a lack of effective technological innovations. (Acharya, et al, 2020).

Although organic agriculture is fundamentally intended to promote agrobiodiversity, current policies and programs, centered on export promotion and income generation, primarily support a limited range of cash crops such as coffee, tea, ginger, honey, walnut, apple, and certain vegetables. These efforts often overlook underutilized crops, with a lack of organic certification standards that would otherwise support the conservation and use of local crop diversity.

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July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Moreover, the organic certification process remains complex, costly, and not easily accessible. As a result, most smallholder farmers, producers, and traders are either unaware of the process or unable to navigate it effectively (Gauchan, et al. 2020). The organic fertilizer promotion subsidy programs were not found to be effective, as the subsidy distribution data did not show the increased consumption of organic fertilizers. Organic fertilizers are bulky in nature, with transportation challenging and a lack of quality assurance discouraging farmers from purchasing fertilizers even at a subsidized rate. (Amagain, et al, 2017). There are many issues and challenges while accelerating organic agriculture at scale due to the ambiguity of the roles of the three tiers of government, along with a lack of effective coordination. Limited capacity of local government, both in terms of technical, human resources, and financial resulting in lower service and support delivery to farming communities who are interested in organic agriculture (Baral, et al., 2020).

Scaling up climate-smart agriculture practices such as solar irrigation, rainwater harvesting, resilient crop varieties, ICT-based advisory services, insurance, and gender-friendly tools remains limited to pilot projects due to poor access to technology, high costs, inadequate extension services, and weak institutional support (Gurung, et al., 2016). Conservation Agriculture-based Sustainable Intensification (CASI) has gained academic and policy attention in South Asia; however, despite growing awareness and farmer interest, the adoption of zero tillage remains stagnant. Beyond issues of low yields and weed infestation, key barriers for farmers include unsuitable land, limited access to CASI machinery, a shortage of skilled operators, and inadequate financial support (Karki, et al., 2024). Regenerative agriculture is considered the key to improving soil health, biodiversity, and the climate crisis, however, no-till farming with the use of heavy herbicides to manage weeds in U.S harm the soil life (Food tank, 2025)
Beyond policy gaps, sustainable agriculture faces implementation challenges rooted in farmers' motivation. Although farmers recognize their role in environmental sustainability, they are primarily driven by economic gains and improved livelihoods. Accelerating food systems transformation requires responsible investments that address these barriers by building physical, human, and intangible capital to enhance productivity, food security, nutrition, and sustainable development (Shrestha and Shrestha, 2023).

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

4. Challenges of and Call for Actions to Nature-positive food systems

The transition to nature-positive food systems is hindered by various agronomic, economic, and social challenges, further intensified by gaps in knowledge and capacity (Hodson de Jaramillo et al., 2023).

1. Agronomic and technological performance challenges

Yield reductions- Nepal's food systems vary across its three agroecological zones: Terai, Hill, and Mountain. In the Terai, food production is heavily reliant on high external inputs. Transitioning to nature-positive systems through normative sustainable approaches such as conservation agriculture, organic farming, ecological, and regenerative agriculture often leads to reduced yields and income. As discussed in Section 3, the limited application of science-based practices in promoting sustainable agriculture has made it difficult for these approaches to compete with conventional or commercial farming methods. Additionally, demographic shifts, particularly rising urbanization and increased male migration, have led to a decline in households rearing large livestock in Nepal. This trend poses a challenge for sustainable soil nutrient management, as livestock are a primary source of organic manure. Sustainable agriculture that prioritizes quality production and environmental benefits, but overlooks yield and economic returns, poses challenges, especially in the context of ensuring food security for a growing population. The strategy of sustainable intensification, hence, has recently gained considerable attention to increase yield potential and productivity from the same amount of land while reducing negative environmental impacts (Tal, 2018).

2. Economic Challenges

High labor and land demand-Nature-positive food systems tend to be labor-intensive, as highlighted by several studies discussed in Section 3. This presents a significant challenge in Nepal's evolving context, where high rates of male and youth migration have left approximately 70% of the agricultural workforce composed of women. While mechanization could reduce the labor burden, it is often not feasible in Nepal's diverse and rugged terrain. Moreover, the high cost of mechanization remains prohibitive for many smallholder farmers, further limiting its adoption. Land use inefficiency poses a significant challenge to promoting nature-positive food systems, especially in the current context of Nepal, where land fragmentation is increasing and average landholding size is declining, as shown in Table 1. However, the trend of fallow land shows opportunity to better utilize through nature positive production systems.

Higher transaction cost- Nature-positive food systems, due to their diversity, often produce a wider range of crops or livestock in smaller volumes, limiting market and processing opportunities. They also demand greater knowledge, experimentation, and risk-taking. Farmers may bear the financial and technical burden of sourcing and applying alternative inputs. Additionally, many practices require collective action across landscapes, involving multiple stakeholders, which increases coordination demands and transaction cost (Hodson de Jaramillo et al., 2023).

Limited value chain support for sustainable practices- The consumption of unhealthy, ultra-processed foods high in sugar, salt, and fat is rising among women and children in both rural and urban areas across all provinces of Nepal (NDHS, 2022). These foods are often cheap, easily available, convenient, and appealing, making them strong competitors to healthier alternatives. In contrast, nutritious foods produced through nature-positive value chains tend to be more expensive and often remain unaffordable for marginalized communities. A key challenge lies in the dominance of mono-cropping of calorie-dense staples through industrial agriculture, which benefits from economies of scale and lower unit costs, unlike the diverse crop systems required to support healthy and sustainable diets.

3. Political Challenges

Policy incoherence- One of the key game-changing solutions proposed in Nepal's Food Systems Transformation Strategy to restore degraded ecosystems and rehabilitate soil functions for sustainable food production is the removal or redirection of subsidies that support unhealthy or agrochemical-intensive production systems. Notably, following CoP28, Germany revised its Nationally Determined Contributions (NDC) to include concrete steps toward phasing out harmful subsidies; an important precedent that could help accelerate food systems transformation (e.g., R. and J. Xu, 2025). Despite clear priorities and the urgent need for action around food systems transformation in Nepal, the national budget for the recent fiscal years has with no significant changes in allocations. According to last year's annual budget 2024, a substantial portion continues to support chemical fertilizer subsidy programs, reflecting entrenched policy practices that pose a significant challenge to reorienting programs toward more ecological and sustainable goals aligned with nature-positive food systems. The relationship between fertilizer subsidies and the promotion of nature-positive

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
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e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
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agriculture is complex and multifaceted. Evidence from previous research indicates that such subsidies may undermine nature-positive food systems in three key ways

- High Opportunity Costs- Subsidy budgets have a high opportunity cost, and empirical evidence on their effectiveness remains limited (Gautam, 2015). A significant portion of public agricultural budgets is allocated to subsidizing chemical fertilizers, particularly urea. This diverts scarce financial resources away from more strategic and transformative investments, such as research and development of nature-positive technology advancement, agroecological practices, and sustainable land management innovations. Redirecting subsidy funds from urea, which no longer requires promotional support could encourage farmers to adopt a more balanced use of NPK fertilizers (Shrestha, 2010).
- Overdependence and Soil Degradation-Continued fertilizer subsidies have increased farmers' reliance on synthetic inputs, often without proper soil testing or awareness of nutrient requirements. This practice, especially the excessive use of urea, contributes to nutrient imbalances and long-term soil degradation, undermining the ecological foundation of sustainable food production.
- Environmental and Climate Impacts-The use of nitrogen-based fertilizers is a major source of greenhouse gas emissions, particularly nitrous oxide, which contributes significantly to agriculture’s carbon footprint. This trend directly contradicts the goals of climate-smart agriculture and undermines efforts to promote nature-positive food systems that emphasize environmental sustainability and climate resilience.

4. Agricultural knowledge systems gaps

Poor knowledge and limited advisory systems capacity- Public and private investment in research on nature-positive food systems remains significantly lower compared to other innovative agricultural approaches, leading to persistent and substantial knowledge gaps. There is a clear lack of systems-oriented, trans-disciplinary, and long-term field research, resulting in a disconnect between knowledge generation, advisory services, and the capacity needed to support nature-positive food systems (Hodson de Jaramillo et al., 2023). Accelerating the promotion of nature-positive food systems in Nepal may face several challenges, primarily due to unclear roles and responsibilities across the three tiers of government and a lack of effective coordination. Local governments, which serve as the primary implementing bodies, often have limited technical, human, and financial capacity. This results in inadequate service delivery and support for farming communities interested in pursuing nature-positive food systems in Nepal. Additionally, the lack of data and empirical evidence on the effectiveness of nature-positive food system implementation hinders the delivery of need-based, context-specific technical and advisory services, limiting efforts to accelerate adoption and scale-up.

Call for actions

Numerous structural lock-ins continue to reinforce the unsustainability of current food production systems. Achieving a transition to nature-positive food systems requires a fundamental shift in mindset and silo approach, and actions across the entire food value chain, from policymakers and researchers to practitioners, local extension services, private sector entities and communities. This also calls for a realignment and strengthening of collaboration among all stakeholders, minimizing power imbalances, vested interests, and conflicts (Even et al, 2024). Based on national and international experience and insights, some actions are proposed to advance a nature-positive food system.

- Increase policy coherence and strengthen governance across all three tiers of government by establishing effective coordination mechanisms across multi-sectors including forestry, land management, nutrition, health, and education, with clearly defined roles, responsibilities, and accountability. To minimize policy and practice gaps, committed actions should be integrated into periodic agricultural plans, backed by adequate funding and strong institutional frameworks.
- Enhance local government capacity in terms of technical, human, and financial resources to advance nature-positive food systems. Challenges ranging from limited awareness and financing to land access and sociocultural barriers must be addressed through local government's leadership in collaboration with province, federal government and other stakeholders such as private sector actors, and development partners, with a focus on policy support, technical assistance, and farmer capacity building.
- Prioritize responsible investment in boosting knowledge and technological innovation for nature-positive food systems, with a focus on addressing challenges such as land use inefficiency, low yields, labor intensity, and high time and cost requirements

- Develop a clear vision and understanding for a comprehensive sustainable intensification agriculture as a pathway for transitioning to nature-positive food systems, rather than applying a one-size-fits-all approach focused on organic agriculture.
- Establish a robust monitoring and learning mechanism to generate data and evidence on the effectiveness of various nature-positive food system approaches such as conservation agriculture based sustainable intensification, regenerative agriculture, climate resilient agriculture, climate smart animal husbandry practices, nutrition sensitive agriculture, agroforestry, polyculture and ecosystem based commercial agriculture. This should include evaluating local community people's perception on what works, what does not, and why, along with identifying opportunities for improvement and strategies to accelerate adoption and scale-up in achieving policy objectives.
- Engage private sector entities for capacity strengthening and infrastructure development including market linkages for nature-positive food systems since public sector investment alone may not be adequate.

CONCLUSION

Transforming food systems toward sustainability is an urgent and complex global challenge, vital for improving human health, securing livelihoods, and safeguarding the environment. Current food systems characterized by unsustainable practices are major contributors to malnutrition, biodiversity loss, land and water degradation, and greenhouse gas emissions, ultimately undermining the productivity, resilience, and long-term sustainability of food production. Existing program interventions continue to serve as the primary vehicles for implementing food systems transformation efforts, but these programs lack innovation and targeted budget allocations to operationalize key action tracks. Furthermore, advancing transformation through nature-positive food production pathways requires a comprehensive understanding of the complex and multifaceted barriers that impede progress. This transition demands not only innovation in technologies and practices but also fundamental shifts in food system governance. Such shifts must include bold reforms in policies, investments, and incentives, particularly in response to evolving socio-economic, political, demographic, and global dynamics, which currently do not adequately support sustainable and equitable practices.

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NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Approaches and Features of Biologically Intensive Farming system

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ABSTRACT

In order to substantially reduce the negative impact of conventional petro-chemical farming and to address the issues of poverty, agri-production, environment conservation and food security, it is high time to adopt biologically intensive farming (BIF) system around the globe. It plays pivotal role in conserving natural resources and improves soil health and agri-production. This article addresses the importance, approaches and features of biologically intensive farming system.

INTRODUCTION

Oue planet- the Earth- has a tremendous wealth of plant species and water that can sustain human life besides other living beings. Human beings have been suffering from hunger, malnutrition, depletion of natural resources and other natural and man-made problems. We have narrowed down the biodiversity of plant species which were used as food crops and limited to rice, wheat and maize as major crops that provide 50 percent of the plant-based calories we eat, and occupy 40 percent of the world's arable land. It's no more secret that our global reliance on such a limited set of food crops has wide implications. While these crops have had an invaluable role in reducing world hunger, they alone cannot provide the full range of nutrients people need to flourish. For this, a far more diverse diet is required, one that many of the world's poorest people are unable to access. This degradation of agricultural diversity also has severe consequences on global biodiversity and the natural environment including soil health. In this context the Food and Agriculture Organization (FAO) of the United Nations has pointed out why it's time to turn to some of the other approximately 5,000 potential food crops estimated to exist around the world (FAO, 2024). These are collectively known as "neglected and underutilized species" (NUS) – plants, animals and fungi whose contributions to sustainable food systems are under-valued due to a general lack of awareness and information. The NUS are typically native to the environments in which they are grown. As such, they have adapted to local conditions, and require fewer external and economic inputs than conventional crops. Many NUS can also thrive in marginal areas, in arid soil or on land considered unsuitable for other purposes. This makes them an important part of climate-change adaptation strategies, and economically viable for small-holder producers. Moreover, many NUS are highly nutritious and rich in micronutrients and bioactive compounds. While the world at large has overlooked these species in research and policymaking, and ignored their vast potential contributions to sustainable agriculture, rural livelihoods and affordable and nutritious diets, the same is not true of the communities that know and use them. Because most plant NUS are grown at home, often in kitchen gardens, or harvested from forests, they are usually tended by rural women and indigenous peoples, both for household consumption and to sell at local markets. As NUS enter markets, whether local, national or international, they have the potential to create earnings for the communities who hold the keys to understanding how to cultivate, use and process these plants. It should ne noted that NUS crops cultivations are confined to traditional subsistence farming within a broader framework of the biologically intensive cropping with the use of intercropping, use of organic manure and pest management practices. However, this understanding is disappearing fast, so it is essential to ensure that this traditional knowledge on NUS is preserved and transferred to the next generations. Traditional foods are an intrinsic part of human knowledge and are embedded in our ceremonies and how we understand ourselves and our communities. This is particularly true for indigenous peoples, whose foodways rely heavily on NUS but are often under-valued in their wider societies. Protecting NUS enables peoples to become ambassadors of their cultures and identities. By cultivating these foods, indigenous and rural producers are able to share their valuable traditional foodways, and build their rural livelihoods.

Small-scale producers constitute another sector or category of the entrepreneurs who provide over 70 percent of the world’s food needs. Often they are known as small farmers. In Nepal and India around 70 percent of these farm households belong to this category. Obviously in such developing countries of Asia and Africa promotion of biologically intensive farming system in a broader sense is utmost important. Indeed this is the key to address hunger, food insecurity, rural livelihoods, environment conservation and strengthening human capital simultaneously.

Governments should support small farmers, small and medium agribusinesses and civil society to promote inclusive and efficient food production and marketing systems that better integrate smallholder farmers and small and medium agribusinesses into food value chains. This will improve their access to markets, generate decent employment opportunities, and make nutritious food available (FAO, 2024). In another word, investing in small-scale agriculture and local food systems is one of the most impactful ways of tackling malnutrition and food insecurity, bringing lasting benefits to national economies (IFAID, 2025). Obviously, our need today is to transform the existing food production, marketing and consumption systems. Various researches have clearly noted that the transformation of agrifood systems can only be achieved through the collective action of a broad range of public and private actors, each of whom brings distinctive interests, needs, resources, influence and capacities. These are the aspects that the inclusive and organic biologically intensive farming (BIF) systems address for achieving few sustainable development goals.

APPROACHES OF BIF SYSTEM

BIF system employs three approaches, viz. participatory, holistic and self-reliance building (Rajbhandari, 2004). A brief description about these approaches is presented below.

Participatory approach

A farm system is not just a collection or gathering of crops and animals to which one can apply an input and expect immediate results. It is a complex of soils, plants, animals, fishes, insects/micro-organisms, water, tools/technologies, workers, other inputs and environment having synergistic interactions among themselves. It is the farmer who attempts to understand this synergistic interaction; and based on personal preferences, experiences and aspirations, manipulates the available inputs and interaction to produce output. In order to sustainably and efficiently use the available resources and technologies, all the adult members of the farm households must participate in the decision-making processes in regard to acquiring/using inputs/technologies, production practices and trade/marketing. BIF system pays special attention to this issue and puts the real growers at the focal point of a given agro-ecosystem. It starts and ends with the growers and the integrated farming system in a given agro-eco system.

Bio-intensive farming system is implemented at local levels (ecosystem) with the active and direct participation of local growers/ entrepreneurs. Local growers are also engaged in conducting participatory research in their own field in the technical assistance of the Technicians coming from development agencies (GOs and I/NGOs). They are also engaged in participatory extension activities at local level. Participatory research and extension activities are conducted jointly by the farmers and research/extension workers utilizing the Model Demonstration Farm (MDF) managed by the concerned grower(s) in his/their land. The MDF is also used as farmer's field school (FFS) to facilitate farmer-to-farmer extension and communication as well as farmer’s marketing school (FMS) to facilitate marketing of their produce. “Farmer Field Schools (FFS) are an extension approach built upon principles of adult education and experiential participatory learning processes (FAO 2013). FFS provide a forum for farmers to meet and discuss real issues and experiment together on possible solutions that they can implement themselves. A typical FFS involves practical hands-on oriented learning processes in which groups of farmers (20-30) with a common interest within a given micro-catchment get together on a regular basis (ranging between weekly to biweekly depending on the specific needs of the group) to study the “how and why” of a situation in a given context under the guidance of a facilitator. The approach is particularly adapted to field learning activities that require unpacking the underlying basic science to enhance the farmers’ conceptual understanding of relations and interactions. The farmers under the guidance of a facilitator make regular field observations, relate their observations to the ecosystem and combine their local experience with ‘new’ information before making appropriate management decisions” (FAO, 2013).

Holistic system approach or experiential learning and knowledge generation

Bio-intensive farming system promotes learning and knowledge generation by the growers’ own actions, observation, and sharing of experiences. The systems approach was first developed and applied in biology and is probably most associated with ecology. An agricultural farm is part of an ecosystem and consists of the location specific system of the rural area (ecosystem) and, various sub-systems (crop/livestock /fishery/agro-forestry) which are inter-related. This concept of a series of interacting sub-systems within broader systems provides the integrating framework within which individual units are studied. In other words, the hierarchical level is conceptualized as a system composed of a set of subsystems (crop/livestock /fishery/agro-forestry). By applying this concept and approach to agricultural production processes, a set of hierarchically related agricultural systems can be identified. A typical farm household system (farm system) is bound to larger, higher agricultural systems in many ways. It is influenced by them and can influence them. A farm's crop production activities for example determine its cropping system. A system may be composed of several cropping patterns and involve the production of several crops. All components required to produce a particular crop and their environmental relationships are part of a cropping system. Individual crop (crop 1, crop 2, crop N) within a crop sub-system comprises a lower level of subsystems; and these subsystems comprise eco-physiological systems. Similarly, livestock production is another major subsystem in the agro-ecosystem. Socio-economic aspect comprises a subsystem in the farm system. Thus farms or farm households are the goal-oriented complex systems. Farmers have many goals and usually seek to increase income, avoid risks, and increase long-term benefits of resources/inputs. Bio-intensive farming system addresses all of these and other issues with an overall goal of increasing food and income security of the farm households, simultaneously managing local resources/ technologies in a sustainable way, i.e. without any detrimental impact on environment and health (Rajbhandari, 2001).

BIF system is thus a holistic system approach. It is based on experiential learning and knowledge generation system. BIF system is about sustainable management of natural resources in a given agro-ecosystem with specific cultural and knowledge base. It is therefore a development approach as well. Effective learning occurs when development of a conceptual framework is inextricably linked with development of effective traditional practice. In this approach learning is a developmental spiral of theory-informed practice being tested in real situations. In the context of a group, BIF system incorporates an appreciation of group dynamics and stages in group development. It is based on the concept of experiential learning as a continuous process of "identifying" the context of a problematic/ poor life-situation, "making sense" of this and "taking action" to improve the situation of livelihood, production, marketing, etc. Consistent with this is a systemic approach to facilitating learning. Experiential learning or knowledge generation system is constructed as a purposeful flux between experiencing, finding-out, making sense (conceptualizing) and taking action. The extent to which the learners understand this process or concerned growers (in case of operating BIF model demonstration farm) determine their capability to consciously guide the process. BIF system prefers participatory knowledge generation system, concept development and planning and taking action to effectively influence the productive synergistic interaction among the dimensions of livelihoods. The methodology emphasizes participation and calls for open and active patterns of communication based on interdependent relationships (Rajbhandari, 2015).

Much less as a problem of total food availability than problem of who produces the food and who has the income to buy it. A high priority is therefore needed to enable the tens of millions of resource-poor farm families to increase their production and improve its stability. Most of the governments in developing countries have been following the normal 'transfer-of-technology' (TOT) model for agricultural research and development. It has built-in biases which favor resource-rich farmers whose conditions are more or less similar to those of governmental research stations. TOT approaches have been modified through on-farm trials and demonstrations but the basic model and approach have remained the same. A second emerging model is 'farmer-first-and-last' (FFL). In bio-intensive farming system concept and approach developed by Rajbhandari (2001), Model Demonstration Farm (MDF) is based on FFL approach. It should also be regarded as a model for Field Laboratory (FL) of sustainable agriculture and rural development. This starts and ends with the farm family and the farming system in a given agro-ecosystem. It begins with holistic and interdisciplinary appraisal of farm families' resources, needs and problems, and continues with on-farm farmer's action research and extension, in consultation with the scientists, experiment stations and laboratories in a consultancy.

Self-reliance building and collective empowerment

Economic globalization and dependence of LDCs like Nepal on exotic inputs like synthetic fertilizers, pesticides, and crop varieties has simultaneously put the small farmers at the risk of experiencing external techno-economic shocks. Bio-intensive farming system's approach is to minimize the potential of external economic and technological shocks and build the self-reliance of the growers in various agricultural inputs/ technologies and finance. It is based on the approach of collective empowerment and social mobilization.

FEATURES OF BIF SYSTEM

Characteristic features of BIF system within the framework of its principles are as follows (Rajbhandari, 2004):

- Empowerment of people's organizations

- Conservation and utilization of biodiversity (plant, animal, microorganism, landscapes)
- Eco- and health-friendly production systems (biologically intensive mixed farming; intensive crop rotation/cropping; optimum organic recycling; use of bio- or organic-fertilizers and bio-pesticides; integration of crop/ livestock/ agro-forestry components)
- Equal access to natural productive resources (land, seed, water, forest) and public services (education/skill training, health service, information)
- Use of sustainable technologies (technologies that promote the use of: indigenous knowledge system (IKS), traditional technologies/practices, locally well adapted and average yielding varieties/seeds; local livestock breeds; etc.)

Empowerment of people's organizations

Enhancing people's organization's identities as social capital through empowerment of local farmers' or women's groups and advocating for the rights of farming communities and women on natural productive resources like land, plant genetic resources and seeds, water, forest is an important feature of the BIF system. It is a demand driven problem-solving approach directly related to the needs of the rural marginalized population groups including women and the landless and their socio-economic environment. This approach places the small landholders and women at the center of the innovation. It is a promising alternative to traditional methods and the intensive chemical farming, which is based on commercialization of food production resources and process, greed market economy, and which is in control of a few rich people, landlords or corporations. Bio-intensive farming system flourishes when the rights of farming communities to natural resources, work/employment, food, education, health, information and skill development are translated into reality. This approach intends to make the farming communities aware of the fact that food security is a human rights issue, which includes a number of other human rights. And these rights are inter-linked with various dimensions of food security. Empowerment of the people's organizations is a primary work for advocacy on food security issues from the perspective of human rights (Rajbhandari, 1999).

Conservation and utilization of biodiversity

The integrated animation and bio-intensive farming system approach envisages that in-situ conservation, authorized utilization, and free exchange of plant genetic resources (PGRs) among the farming communities and researchers comprise an essential component of sustainable livelihoods. It encourages cooperation between farming communities and researchers for proper identification, documentation, conservation and utilization of biological diversity for the benefit of local farming communities, in particular, and for human beings, in general. Documentation, conservation and utilization of biodiversity (plants, animals and soil microorganisms) and the farming communities' control over plant and animal genetic resources are critical for preventing further degradation of the productive resource base, economic opportunities, poverty and the food insecurity situations as well as to make the livelihood of the rural population sustainable both in terms of space and time.

Eco- and health-friendly production systems

“Due to lack of ecological regulation mechanisms, monocultures are heavily dependent on pesticides. In the past 50 years the use of pesticides has increased dramatically worldwide and now amounts to some 2,6 million tons of pesticides per year with an annual value in the global market of more than US$ 25 billion. In the US alone, 324 million kg of 600 different types of pesticides are used annually with indirect environmental (impacts on wildlife, pollinators, natural enemies, fisheries, water quality, etc.) and social costs (human poisoning and illnesses) reaching about $8 billion each year. On top of this, 540 species of arthropods have developed resistance against more than 1000 different types of pesticides, which have been rendered useless to control such pests chemically” (Altieri et al. 2012b). These facts and figures clearly indicate the need of promoting / up-scaling eco- and health- friendly comprehensive alternative production systems to address hunger, poverty and livelihoods of the small farmers and marginalized population groups in the tropics and sub-tropics.

“Solid waste management has become one of the vital issues to protect health and public safety. Preparation of organic manures like vermi-compost, Farm Yard Manure (FYM) etc. from various organic wastes (agricultural wastes) will save our environment from pollution as well as application of these manures in agricultural land prevent those lands from the harmful effect of chemical fertilizers. It has been found that the vermi-compost treated soil showed better result in comparison to that demonstrated by the chemical fertilizers in terms of soil physical and chemical properties as well as productivity of soil” (Karmakar, Brahmachari, and Gangopadhyay 2013).

The bio-intensive farming system is a biologically intensive mixed farming system, which relies on intensive engagement of farmers, organic recycling optimization through intensive crop rotations, integrated plant nutrient management (IPNM), integrated pest management (IPM). The IPNM favors a very limited use of synthetic fertilizers in the field crops to complement organic or bio-fertilizers and IPM is about the limited use of less hazardous pesticides/fungicides integrated with/without plant-based or biological agents in emergency cases. Neupane (2000) has pointed out that integrated pest management (IPM) is the only eco- and health-friendly option available today for the management of insect pests in agriculture. Integrated pest management (IPM) is one of the techno-environmental components within the conceptual framework of bio-intensive farming system. The bio-intensive farming system relies on appropriate spatial management of field crops, vegetable crops, fruits and fodder trees as well as livestock and poultry for rational and ecologically non-destructive utilization of lands in the hills and mountains. Furthermore, it increases the soil fertility, revitalizes the degraded soil, decreases environmental pollution and prevents health hazards to humans and livestock as well as reduces further degradation of the environment, which otherwise might lead to desertification of the globe. It is, therefore, not only eco-friendly but also friendly to human and animal health (Rajbhandari, 2015).

Equal access to natural productive resources and public service

Equitable access to natural productive resources like land, community pasture/forest, medicinal plants, water sources and community irrigation water, and equal respect to the diversity of farming community (ethnicity, gender, sex, religion) at the local level are the essential prerequisites for attaining food security and sustainable livelihood. The community forestry, community pasture, community irrigation system, community food banks (*Dharam Bhakari*), community herbal garden, community-based women's health resource center, community-based health clinic, community-based information and communication center, and community-based agriculture service center are some of the local infrastructures or social capital, which would prove to be a sustainable way of ensuring community members' equitable access to common resources and public services.

Agro-ecotourism can be an important alternative enterprise for small farmers. Such an enterprise typically involves charging fees for access to public or private property for wildlife-related recreational activities such as hiking, canoeing, camping, and photography, or from the sale of items associated with these activities such as maps, food, canoe rentals, etc.

NEPALESE JOURNAL OF AGRICULTURAL SCIENCES,
July, 2025, volume 29
e-ISSN: 2091-0428; p-ISSN 2091-041X; esjindex ID =6279
Published by HICAST, Purbanchal University, Kathmandu

Sustainable technologies

The learning process in agro-ecological innovation is systematic and guided by situation specific curricula that follow natural cycles of the subject which could be crop, animal, natural resource, or a community problem that requires collective action. A typical module of the curriculum may follow a "seed to seed" or "egg to egg" approach where the concept starts with the planting of a crop, through the seasons and is completed when the following season's crop is planted (Gallagher, 2003). Key livelihood issues that affect the community are blended into the curriculum as special topics based on farmers' priorities. This responsiveness to farmers' needs is phenomenally fundamental in developing the farmers' confidence in determining their destiny (Okoth et al., 2002). The BIF system as a kind of sustainable agriculture focuses on the community in terms of resources (human resources, animal power, seed, manure/fertilizers, bio-pesticides, agricultural implements, and finance), perfect social marketing and extension of technical skills and information through the local farmers' scholars and leaders, both male and female employing farmer-to-farmer (F-t-F) extension approach. The importance of indigenous knowledge and traditional technology (IKTT) has called attention to the necessity of understanding and respecting the different "realities", ethno-cultural diversity and experiences of native people. The BIF system approach relies on the utilization of indigenous knowledge, realities, resources and experiences, which have a history of hundreds of thousands of years, and, on the modern agro-ecological principles and scientific techniques that offer the potential to conserve and regenerate resources. It is close to the beneficiaries and low in cost with minimum reliance on external expertise, capital, resources and equipment, which has been shown to result in the over–dependence of farming communities.

Technological aspects of BIF include promotion of organic recycling, inter- or mixed- cropping, crop diversification and scientific crop rotations to increase the cropping / rotational intensity as well as to minimize the incidences of diseases and pests. In addition, it emphasizes the promotion of agro-forestry, renewable energy like solar energy, bio-gas, and improved cooking stoves aimed at conserving the forest, reducing the work burden on women in regard to collection of fuel wood and cooking food at the cost of their health (2010, 2011). The by-product of biogas plant is applied in the crop field for improving the soil fertility and structure. Furthermore, the time saved by infrequent movement to the jungle or forest is utilized for extra–income generation for livelihood. This approach facilitates farmer-to-farmer (F-t-F) communication and extension. The farmer managed model demonstration farms (MDF); maintenance of seed purity and improvement of local crop varieties with high food values in the farms by the farmers themselves; seed storage at household level and farmer-to-farmer information, education, communication and extension are the essential components of this technology (Rajbhandari 2001; 2004).

The model demonstration farms (MDFs) are the nodal points, which serve to be the field laboratory (FL) of the farmers or "Farmer's Field School". It is a model of the farmer-first-and-last (FFL) concept. It is managed by the farmers and used for demonstration, dissemination or extension of technology to the members of the local farming communities in cooperation with the researchers, scientists, or extension workers.

These farms are also used for participatory action research. MDFs serve to bridge the gaps between participatory action research, extension and capacity building (training, field visit) of neighbor farmers for higher stable production and income. MDF is not a replica of the conventional “transfer of technology” (TOT) for development model. It is rather an alternative to that model and intends to bring the growers in the center (Rajbhandari, 2015).

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