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RESEARCH ARTICLES

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RESEARCH ARTICLES

EFFECT OF RATES OF COW DUNG AND NPK ON THE GROWTH AND YIELD OF CUCUMBER (*CUCUMIS SATIVUS*) IN SOUTHERN GUINEA SAVANNA, NIGERIA

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ABSTRACT

This study evaluates the effects of various application rates of cow dung and NPK fertilizer on the growth and yield of cucumber (*Cucumis sativus*) in the Southern Guinea Savanna region. The experiment was laid in a Randomized Complete Block Design (RCBD), the experimental treatment included five levels of cow dung (control, 3, 6, 9 and 12tons/ha) and five levels of NPK fertilizer (control, 50, 100, 150 and 200 kg/ha) with three replications. Data were collected on growth attributes such as vine length, leaf area, number of branches, and on fruit characteristics such as number for fruits, fruit length, fruit diameter and fruit yield. Results indicated that the application of NPK at 200 kg/ha significantly enhanced most growth parameters, including vine length, leaf area, and fruit yield, owing to the immediate nutrient availability it provides. Cow dung, particularly at 12 tons/ha, also positively influenced growth and yield, though its effects were more gradual due to its slower nutrient release. The study concludes that while NPK fertilizer offers rapid growth and yield improvements, cow dung presents a sustainable alternative by enhancing soil fertility and supporting long-term productivity. Recommendations suggest a balanced application of both NPK and cow dung to optimize cucumber growth while maintaining soil health.

Keywords:, Cow Dung, Cucumber, Growth, NPK, Yield

INTRODUCTION

Cucumber (*Cucumis sativus*), a member, of cucurbitaceous family, is native of Asia, and Africa, where it has been consumed by people for 3,000 years, may be one of our oldest crops. Cucumber was being grown in North Africa, Italy, Greece, Asia minor and other areas at the beginning of the Christian era (USDA, 1999). Today Cucumber is grown all over the world for pickling, (pickles) and fresh market (slicers) Cucumber is a creeping tender warm season vegetable plant that produces well when grown under proper management. It is a creeping vine that roots in the ground and grown-up trellising on other supporting frames, wrapping around ribbing with thin, spiraling tendrils (Widders and Price, 2018). The plant has large leaves that forms canopy over the fruit. The fruit roughly cylindrical elongated with tapered ends (Legard, 2000) and may be as large as 60cm long and 10cm diameter. Fruits are rich in vitamin A and calcium, calories, small amount of beta carotene which is found in the green peel, dietary fiber carbohydrate, some trace of iron and 95% water which call for its lowest nutritional content in the cucurbit family (Firbank, 2019). Cucumber grown to be eaten fresh (Slickers) and those intended for pickling (pickers) are similar Cucumber are mainly eaten in the unripe green form (Rao *et al*., 2020).

Despite its widespread cultivation, cucumber production is frequently hindered by inadequate nutrient management. Insufficient nutrient supply can lead to stunted growth, poor fruit quality, and reduced yields (Bokhtiar & Hossain, 2017). Traditionally, cucumber farmers have relied heavily on synthetic fertilizers, particularly NPK (Nitrogen, Phosphorus, and Potassium), to provide essential nutrients required for optimal plant growth. However, excessive use of these fertilizers poses several environmental challenges, including soil degradation, water contamination, and negative impacts on human health (Blenkinsop *et al*., 2018; Gajewska *et al*., 2021). This over-reliance on chemical fertilizers not only threatens the sustainability of farming practices but also compels the need for alternative nutrient management strategies.

As an organic amendment, cow dung offers a rich source of nutrients, enhances soil structure, and increases microbial activity, which collectively supports better plant growth and development (Ojeniyi, 2020). Previous studies have indicated that organic fertilizers, like cow dung, improve soil fertility and can lead to higher yields in various crops (Adeoye & Agboola, 2015). However, the effectiveness of cow dung is highly dependent on its application rate, which remains under-researched in the context of cucumber production (Abdollahzadeh & Shamsi, 2021). Although some studies have explored the effects of cow dung and NPK

fertilizers separately, there is a distinct lack of comprehensive knowledge regarding their combined application and the optimal rates that would maximize cucumber growth and yield. Understanding how these two nutrient sources interact when applied at different rates is crucial for developing sustainable farming practices. The aim of this study is to study the rates of cow dung and NPK fertilizer on growth and yield of Cucumber (*Cucumis sativus*).

MATERIALS AND METHOD

Study area

The experiment was conducted during the 2024 cropping season in Crop Production, Faculty of Agriculture, Ibrahim Badamasi Babangida University Lapai, Niger State. It has an average monthly temperature of 23°C-34°C with a mean annual rainfall ranging between 1100mm-1600mm. It is located at Latitude of 9.69°N and a Longitude of 6.53°E of the equator. The town is located at the Southern Guinea Savanna zone of Nigeria. The soil is characterized as sandy loam.

Treatments and experimental design

A factorial experiment using a Randomized Complete Block Design (RCBD) is employed to study the differences between cow dung and NPK fertilizer rates. Five levels of cow dung (control, 3tons/ha, 6tons/ha, 9tons/ha, and 12tons/ha). Similarly, five levels of NPK fertilizer (control, 50 kg/ha, 100 kg/ha, 150 kg/ha and 200 kg/ha) with three replications. 50kg of soil was filled into bags. Cow dung was incorporated into the soil two weeks before planting, while NPK is applied in a split form (half at planting, half at four weeks after planting).

Data collection

Growth data should be collected at regular intervals (2, 4, 6 and 8 WAP) to monitor the development of the cucumber plants. Plant Height (cm) measure the height of the plant from the base to the tip of the growing point, this data will be collected at 2, 4, 6, and 8 weeks after planting. Number of Leaves (cm) will be counted by the total number of fully developed leaves per plant. Vine Length (cm), Measure the length of the vine from the base to the farthest point, this parameter is important to assess how well the plant is developing and spreading, it will be collected at 2, 4, 6, and 8 weeks after planting. Weight of Fruits per Plant (g) is weighed be calculating total number of fruits harvested from each plant. And also, the total Number of Fruits harvested per Plant will be counted.

Data analysis

The data collected were subjected to ANOVA (Analysis of Variance) to determine the significant differences between treatments. Duncan Multiple Range Test (DMRT) was used to separate the means at 5% probability level.

RESULTS AND DISCUSSION

Results

Physiochemical properties of experimental soil, cow dung

Table 1 shows the chemical analysis cow dung and physiochemical properties of soil before the experiment. From the result of the physiochemical analysis, the soil particles of the soil sample include: sand (92.08%), clay (6.24%) and silt (1.68), this implies that the experimental soil is sandy hence coarse in texture. However, the experimental soil had a pH of 6.60 which indicates that the soil is neutral while cow dung had a pH of 8.40, which indicates alkalinity.

Effect of NPK and cow dung on the vine length of cucumber

The vine length of cucumber as influenced by NPK and cow dung rates is presented in table 2. The result showed that there were significant ($p<0.05$) differences in the vine length of cucumber as influenced by NPK as application at 200kg/ha significantly produced longer vines at 4 and 8WAP while control had the shorter vines. Similarly, application of cow dung at 12ton/ha significantly supported longer vines at 6WAP but was not significantly different from application at 9ton/ha while control had the least vine length. The result also revealed that there were no significant difference in the vine length at 2, 4 and 8WAP.

Effect of NPK and cow dung on the number of leaves of cucumber

Table 3 presents the effect of NPK and cow dung rates on the number of leaves of Cucumber. The result showed that application of NPK at 200kg/ha significantly had higher number of leaves at 2, 4, 6 and 8WAP but was not significantly different from application at 150kg/ha while control had the least number of leaves throughout the experiment. Moreso, the result revealed that application of cow dung had significant effect on the number of leaves of cucumber at 4WAP as application at 12ton/ha significantly produced higher number of leaves compared to other rates of application but was not significantly different from application at 9ton/ha while control had the least number of leaves at 5% probability level. The

result also showed that there were no significant differences in the number of leaves at 2, 6 and 8WAP.

Effect of NPK and cow dung on the number of branches of cucumber

The number of branches of cucumber as influenced by application rates of NPK and Cow dung is shown in Table 4. The result showed that application of NPK at 2WAP, application at 200kg/ha had the highest number of branches but was not significantly ($p<0.05$) different from application at 150kg/ha, however at 4 and 6WAP application of NPK at 150kg/ha significantly had highest number of branches while control had the least, whereas there were no significant different in number of branches at 8WAP. The result also showed the effect of cow dung on the number of branches of cucumber. The result revealed that cow dung has no significant effect on the number of branches of cucumber.

Table 1. Physiochemical properties of experimental soil and cow dung

Sample	pH	Elec-Cond (ppm)	O.C (g/kg)	O.M (g/kg)	Aval. P (mg/kg)	Total N (g/kg)	Exchangeable Cations				E.A (Cmol/kg)	CEC (Cmol/kg)	Soil Particle Sizes		
							Na (Cmol/kg)	K (Cmol/kg)	Ca (Cmol/kg)	Mg (Cmol/kg)			Sand (%)	Clay (%)	Silt (%)
Soil	6.6	80.0	11.97	20.64	43.25	0.42	1.04	0.39	2.44	12.61	0.0	16.55	92.0	6.24	1.68
		Elec. Cond	O.C	OM	Total P	Total N	Na	K	Ca	Mg					
		PPM	(%)	(%)	(%)	%	(%)	(%)	(%	(%					
Cow dung	8.4	11780	29.88	70.	0.125	0.68	2.35	1.96	0.64	0.174					

Effect of NPK and cow dung on the leaf area of cucumber (*Cucumis sativus*)

Table 5 showed the effect of NPK and Cow dung on the leaf area of cucumber. The result showed that NPK had a significant ($p<0.05$) effect on the leaf area of cucumber, at 4 and 6WAP application of NPK at 200kg/ha had wider leaves of cucumber while control had the least, however, there were no significant differences in the leaf area at 2 and 8WAP. Application of cow dung had a significant effect on the leaf area of cucumber. The result showed that application of cow dung at 12ton/ha significantly had wider leaves at 4, 6 and 8WAP but was not significantly different from application at 6 and 9ton/ha while control had the least leaf area.

Table 2. Effect of NPK and Cow dung on Vine Length (cm) cucumber (*Cucumis sativus*)

Treatment	2WAP	4WAP	6WAP	8WAP
NPK				
Control	15.67	30.33ab	47.20	63.00c
50kg/ha	15.67	30.00b	47.87	67.67b
100kg/ha	16.67	31.67ab	49.00	72.67a
150kg/ha	16.67	32.67ab	50.33	75.33a
200kg/ha	16.00	33.00a	50.67	76.33a
SE±	0.538	0.856	1.041	1.445
Cow dung				
Control	15.67	28.67	41.33c	58.00
3ton/ha	15.67	29.33	42.33bc	62.00
6ton/ha	15.33	29.33	44.00ab	47.33
9ton/ha	16.33	32.00	45.67a	69.00
12ton/ha	16.00	32.27	46.00a	70.00
SE±	0.298	0.741	0.683	8.534

Means with same letters are not significantly different at 5% probability using Duncan Multiple Range Test (DMRT). SE = Standard Error

Effect of NPK and cow dung on the numbers of fruit of cucumber

Table 6 showed the effect of NPK and cow dung on the number of fruits of cucumber. The result revealed that application of NPK significantly influenced the number or leaves of cucumber as application at 200kg/ha produced the highest number of fruits while control had the least number of fruits. Moreso, there were no significant ($p>0.05$) difference between application at 100kg/ha and 150kg/ha.

Furthermore, the result showed that application of cow dung had no significant ($p>0.05$) effect on the number of fruits of cucumber.

Table 3. Effect of NPK and Cow Dung on Number of Leaves of Cucumber (*Cucumis sativus*)

Treatment	2WAP	4WAP	6WAP	8WAP
NPK				
Control	3.67ab	8.67c	13.33b	21.00b
50kg/ha	3.00b	8.00d	13.33b	23.00b
100kg/ha	3.67ab	9.67b	14.67a	23.00b
150kg/ha	4.00a	11.00a	15.67a	25.67a
200kg/ha	4.00a	11.00a	15.67a	26.33a
SE±	0.211	0.211	0.333	0.715
Cow dung				
Control	3.33	8.33c	13.00	20.67
3ton/ha	3.33	8.67bc	13.33	21.67
6ton/ha	3.67	9.33ab	14.00	22.00
9ton/ha	3.67	9.67a	14.33	22.33
12ton/ha	4.00	10.00a	14.00	22.67
SE±	0.298	0.298	0.422	1.075

Means with same letters are not significantly different at 5% probability using Duncan Multiple Range Test (DMRT). SE = Standard Error

Effect of NPK and cow dung on the fruit length of cucumber

Table 6 showed the effect of NPK and cow dung on the fruit length of cucumber. The result showed that application of NPK fertilizer at 200kg/ha significantly had longer cucumber fruits compared to other treatments followed by application at 150kg/ha while control had the least fruit length. The result also revealed that there were no significant ($p>0.05$) between application at 50kg/ha, 100kg/ha and control. The result further show the effect of cow dung on the fruit length of

cucumber, the result revealed that there were no significant ($p>0.05$) difference in the fruit length of cucumber as influenced by cow dung application rate.

Table 4. Effect of NPK and cow dung on number of branches of cucumber

Treatment	2WAP	4WAP	6WAP	8WAP
NPK				
Control	0.33b	2.00b	4.00b	6.00
50kg/ha	0.33b	2.33ab	4.33ab	6.33
100kg/ha	1.00ab	2.33ab	4.33ab	6.00
150kg/ha	1.67a	3.33a	4.00a	6.67
200kg/ha	1.67a	3.00ab	4.67ab	6.33
SE±	0.298	0.365	0.258	0.258
Cow Dung				
Control	0.67	2.00	4.00	6.00
3ton/ha	1.33	2.67	4.67	6.33
6ton/ha	1.00	2.67	4.67	6.33
9ton/ha	1.67	2.67	4.67	6.00
12ton/ha	1.00	2.33	4.33	6.00
SE±	0.365	0.298	0.298	0.211

Means with same letters are not significantly different at 5% probability using Duncan Multiple Range Test (DMRT). SE = Standard Error

Effect of NPK and cow dung on the fruit diameter of cucumber

The fruit diameter of cucumber as influenced by application of NPK and cow dung is presented in table 6. The result showed that application of NPK significantly influence the fruit diameter of cucumber. Application at 200kg/ha had the highest fruit diameter but was not significantly different from application at 150kg/ha followed by application at 100kg/ha while control had the least fruit diameter. Moreso, application of cow dung had a significant effect on the fruit diameter of cucumber as application at 12ton/ha significantly had the highest fruit diameter while control had the least fruit diameter at 5% probability level.

Table 5. Effect of NPK and cow dung on leaf area (cm^2) of cucumber

Treatment	2WAP	4WAP	6WAP	8WAP
NPK				
Control	22.00	36.33d	65.33b	93.67
50kg/ha	22.33	37.00cd	67.00ab	99.00
100kg/ha	22.33	39.00bc	70.33ab	104.67
150kg/ha	22.00	41.33ab	73.67ab	75.67
200kg/ha	22.33	42.00a	74.33a	113.00
SE±	0.856	0.803	2.547	14.989
Cow Dung				
Control	22.67	34.67b	65.00d	91.00b
3ton/ha	22.00	36.00ab	66.67c	98.33ab
6ton/ha	22.00	37.67a	68.00b	99.67a
9ton/ha	21.67	38.33a	71.00a	101.00a
12ton/ha	21.33	38.33a	71.33a	105.00a
SE±	0.633	0.699	0.333	2.391

Means with same letters are not significantly different at 5% probability using Duncan Multiple Range Test (DMRT). SE = Standard Error

Effect of NPK and cow dung on the fruit yield of cucumber

Table 5 showed the effect of NPK and Cow dung on the fruit yield of cucumber. The result revealed that application of NPK had a significant ($p<0.05$) effect on the yield of cucumber.

Application of NPK at 200kg/ha had the highest fruit yield but was not significantly different from the application rate of 150kg/ha followed by application rate of 100kg/ha while control had the least fruit yield of cucumber. Application of cow dung also had a significant ($p<0.05$) effect on the yield of cucumber as application of cow dung at 12ton/ha significantly produced higher

fruit yield compared to other application rates. However, application rate at 9ton/ha and 6ton/ha were not significantly different while control had the least fruit yield at 5% probability level.

Table 6. Effect of NPK and Cow dung on Fruit Characteristics and Yield of Cucumber

Treatment	Number of Fruits	Fruit Length (cm)	Fruit Diameter (cm)	Fruit Yield (kg/pot)
NPK				
Control	2.00b	20.00bc	14.67d	0.286d
50kg/ha	2.00b	19.67c	17.03c	0.337c
100kg/ha	2.33ab	20.20bc	17.83b	0.362b
150kg/ha	2.67ab	21.33ab	19.00a	0.398a
200kg/ha	3.00a	22.00a	19.00a	0.411a
SE±	0.211	0.451	0.107	0.008
Cow Dung				
Control	1.67	18.50	14.50c	0.280d
3ton/ha	1.67	19.03	16.00b	0.307c
6ton/ha	2.00	19.33	17.00ab	0.322bc
9ton/ha	2.33	19.63	17.50a	0.343b
12ton/ha	2.33	20.07	17.87a	0.377a
SE±	0.298	0.532	0.413	0.007

Means with same letters are not significantly different at 5% probability using Duncan Multiple Range Test (DMRT). SE = Standard Error

Discussion

The results of this study revealed notable effects of both NPK and cow dung on various growth and yield parameters of cucumber (*Cucumis sativus*), highlighting their potential as nutrient sources in cucumber cultivation. The study showed that NPK fertilizer, particularly at the 200 kg/ha application rate, significantly

enhanced vine length, number of leaves, branches, and leaf area of cucumber, especially in the later weeks after planting (WAP).

The application of NPK at 200 kg/ha significantly enhanced cucumber vine length, particularly at later growth stages. This improvement is likely due to the balanced nutrient supply provided by NPK, which supports vegetative growth by enhancing cell division and expansion, essential for vine elongation and leaf development. This result aligned with research done by Ayoola and Makinde (2019), who reported that NPK fertilizers, due to their balanced nutrient content, foster substantial vegetative growth by supplying essential elements like nitrogen, which promotes cell division and elongation. Cow dung also improved vine length, especially at 12 tons/ha, although its effect was less immediate compared to NPK. Organic fertilizers such as cow dung gradually release nutrients, improving soil structure and microbial activity over time, which supports vine growth at a steady rate (Moyin-Jesu, 2017). The organic matter in cow dung likely improves soil structure and water retention, thus indirectly supporting growth but at a slower release rate than NPK fertilizer.

Application of NPK at 200 kg/ha resulted in the highest number of leaves and largest leaf area, which is consistent with findings from other studies that emphasize the role of nitrogen in enhancing leaf production and photosynthetic capacity (Adekiya et al., 2020). The broader leaf area observed with higher NPK rates can increase light interception, ultimately improving crop biomass and productivity. Cow dung also positively impacted leaf area, particularly at 12 tons/ha. This effect may be attributed to organic matter improving water retention and nutrient availability in the soil, creating a favorable environment for leaf expansion (Ayeni et al., 2010).

The study also showed that NPK at 200 kg/ha significantly enhanced the number of branches, especially in early growth stages, while cow dung had no significant effect on branching. Branch development is often influenced by nutrient availability, particularly phosphorus, which NPK provides in readily available forms. This finding aligns with previous studies, such as those by Adediran et al. (2014), which highlight the importance of phosphorus in promoting lateral growth and plant robustness.

The result of the study also revealed that application of NPK at 200 kg/ha resulted in the highest fruit yield, number, and size, confirming the role of balanced mineral nutrients in fruiting. This could be attributed to the differences in the nutrient content in the treatments applied. According to Adeoye et al. (2015) inorganic fertilizers enhance fruit development by meeting the high nutrient

demands during the reproductive phase. Although cow dung at 12 tons/ha also improved yield attributes, its effect was comparatively moderate, suggesting that its nutrient release may not be as rapid as NPK. Cow dung, while beneficial in improving fruit diameter and yield, had a less pronounced effect than NPK, possibly due to its slower nutrient release rate, which may not meet the rapid nutrient demands during peak fruiting phases. Nonetheless, cow dung's significant impact on yield suggests its role as a sustainable alternative that could enhance soil fertility over time, benefiting long-term productivity (Mbah et al., 2019).

CONCLUSION AND RECOMMENDATIONS

In conclusion, the result from this study showed that that NPK significantly enhances immediate growth and yield attributes in cucumber cultivation, while cow dung supports sustainable productivity by improving soil conditions. Therefore, in sustainable low input agriculture systems in the Southern Guinea Savanna where nutrient depletion is a serious constraint to crop production and despite cultivation preferences by farmers, the alternative organic manure may not meet up plant nutrient demand due to low nutrient composition and release efficiency and limited availability.

Future research could investigate the effects of integrating these fertilizers to develop a balanced approach to maximize growth, yield, and soil health in cucumber farming.

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PREVALENCE OF GASTROINTESTINAL PARASITES IN GOAT (CAPRA HIRCUS) OF MALARANI RURAL MUNICIPALITY, ARGHAKHANCHI DISTRICT OF NEPAL

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ABSTRACT

Gastrointestinal parasitic infection in goat is one of the causes of low productivity, morbidity and mortality. This study was conducted to determine the prevalence, intensity of infection and farm management system. Faecal samples were collected from 200 goats from Malarani Rural Municipality, Arghakhanchi, Nepal. Samples were collected in the month of February, 2019 and subjected to direct smear, sedimentation and floatation technique for coprological examination. The study revealed that of the 200 samples examined, 132 samples (66%) were found to be positive for gastrointestinal parasites covering seven genera. The most common parasites were found to be *Eimeria sp. (59.5%), Strongyle sp. (33.5%), Trichuris sp. (23%), Haemonchus sp. (14.5%), Strongyloides sp. (13.5%), Trichostrongylus sp.* (9%) and *Fasciola sp.* (4%). Altogether one genera of protozoa and six genera of helminths parasites were found. There was no significance difference between age wise and sex wise prevalence. Single infection was recorded as the highest (54.54%) followed by double (34.09%), triple (7.57%) and multiple (3.78%). From questionnaire survey some common risk factors were recorded during the study period, which were poor farm management system, contaminated food and water, ingestion of contaminated grasses, ingestion of moist aquatic plant near the river and grazing on contaminated field. These factors help to increase the gastrointestinal infections in Goats.

Keywords: Cestodes, Gastrointestinal, Nematodes, Parasites

INTRODUCTION

Livestock is a group of domesticated animals that is reared in an agricultural setting (Azlan *et al.*, 2018). Livestock plays a crucial role in the economy of developing country like Nepal. Goat farming is an additional source of income mostly in the rural area. Goat is one of the important livestock of our country. The

importance of goat farming is that it satisfies the need as a meat product. Meat of goat is rich in protein, the body building constituent of our diet. Excreta of goat is used as manure in the agricultural fields and garden. Goat has a life span of 8-15 years. The weight of goat is approximately 20-100 kg. The gestation period is 145-155 days (Pathak,2011). A parasite is an organism that lives on or within another living organism. Parasites are classified as ectoparasite and endoparasite on the basis of them live on body cavity or inside the body.

General objective of the study was to determine the prevalence of gastrointestinal parasites in goats of Malarani Rural Municipality-1, Arghakhanchi, Nepal. This study has been focused on the gastrointestinal parasites in goats of Malarani Rural Municipality. Goat farming is major source of financial resource of villagers. The infection of gastrointestinal parasite can cause significant economic loss leading to poor health. This study will be helpful to formulate effective control strategies against gastrointestinal parasites in goats for the development of strategic deworming program. In this study an effort has been made to identify the prevalence of gastrointestinal parasites. Moreover, the present study may be helpful for the future researchers and investigators to advance their knowledge.

MATERIALS AND METHODS

Study area

Arghakhanchi district lies in province number five of Nepal with total area of 1,193 sq.km. The altitude of the district varies from 305 to 2,515 meter above the sea level. 68% of the district is in the Mountainous Mahabharat Range and the rest is Siwalik Hills. The district head quarter is Sandhikharkha. The study was conducted in Malarani Rural Municipality-1, Arghakhanchi district.

Stained smear preparation

Preparation of smear is required for many laboratory procedures. The purpose of making smear is to fix the parasitic cysts/ova/eggs onto the slide. It is useful to study the nuclear character and identification of protozoan cysts. A small portion of fecal sample was picked up with a clean bamboo toothpick and emulsified with Lugol's iodine solution on a clean glass slide and covered with a cover slip. The smear was examined under compound microscope at 10X and40X.

Concentration methods

The concentration procedures include floatation and sedimentation techniques for the detection of eggs/cysts/trophozoites/larva of parasites (Soulsby, 1982; Zajac and Conboy, 2012). In case of heavy infection, parasites can be easily seen in smears but in case of light infection it is difficult to detect the parasitic form in

smears or mounts. Hence, in the study, concentration method (Floatation and Sedimentation) were carried out.

Identification of oocysts, eggs and larvae of parasites

Oocysts, eggs and larvae were identified on the basis of morphological characters (shape and size) by using Soulsby (1982), other published and unpublished articles and also from internet sources. Calibration obtained using ocular and stage micrometer was used to measure length and breadth of eggs, oocysts.

Determination of age and sex of goats

Direct observation and questionnaire survey were carried out for identification of sex and age of goats respectively.

Determination of parasitic intensity

Intensity of gastro-intestinal parasites was calculated depending on the number of eggs/oocysts and larvae found per gram.

- Light infection= <2 eggs/oocysts/larvae per gram
- Mild infection= 2-4 eggs/oocysts/larvae per gram
- Moderate infection= 4-6 eggs/oocysts/larvae per gram
- Heavy infection= > 6 eggs/oocysts/larvae per gram

Questionnaire survey

Questioners were prepared for farmers in Malarani Rural Municipality-1, Arghakhanchi which asks them about grazing site; either forest, riverside, field or zero grazing, farm management system; either good (well-managed, clean, separate site for stool collection from loafing shed), medium (separate loafing shed from house but no separate site for stool collection) or poor (Unmanaged farming, direct association with other animals),

Data analysis

Since, the study was focused on identification of different intestinal parasites, the data were analyzed by using MS-Excel 2007 and statistical analysis was performed using "R", version 3.5.2 with chi-squared test. In all cases 95% confidence interval (CI) and $P<0.05$ was considered for statistically significant association

RESULTS AND DISCUSSION

Results

General prevalence of gastrointestinal parasites in goats

Of the 200 dropping samples of goats, 132 (66%) samples were found to be positive for gastrointestinal parasitic infection in goats of Malarani Rural

Municipality-1, Arghakhanchi, Nepal.

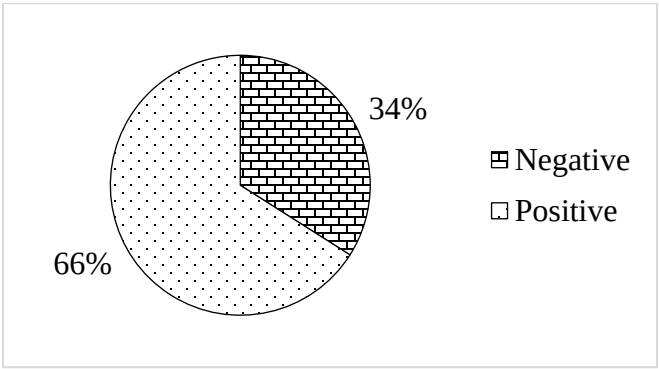

Figure 1. General prevalence of gastrointestinal parasite

Class-wise prevalence of gastrointestinal parasites

Out of the 200 samples examined, seven genera of parasites including one protozoan, one trematode and five nematodes were identified as gastrointestinal parasites. Prevalence of sporozoan was found to be 59.5%, nematode 52.50% and trematode 4%.

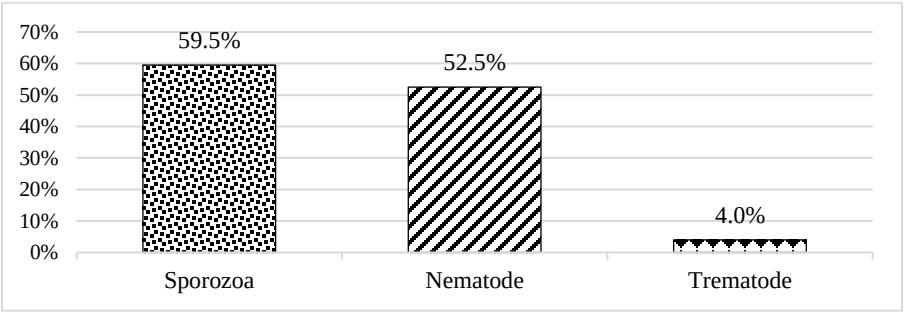

Figure 2. Protozoan and helminth wise prevalence

Genera-wise prevalence of gastrointestinal parasites

Among 200 goat dropping samples examined, 132 (66%) samples were found to be positive with one or more species of parasites. All age groups were affected. The most common parasites found were *Strongyle* sp. (33.5%), *Trichuris* sp. (23%), *Haemonchus* sp. (14.5%), *Strongyloides* sp. (13.5%), *Trichostrongylus* sp.. (9%), *Fasciola* sp. (4%) and also protozoan parasites *Eimeria* sp. (59.5%).

Age-Wise Prevalence of Gastrointestinal Parasites

Age-wise prevalence of protozoan infection

In this study 200 samples were collected, 91 from adults (>8 months), 69 from young(4-8months) and 40 from kids (2-4 months). 52 adults (57.14%), 45 young (65.21%) and kids22 (55%) were infected with one or more parasites. The prevalence of age-wise prevalence of protozoan infection is summarized in table 3 which shows that ($\chi 2$=1.481,df= 2, p-value = 0.476, i.e. p > 0.05), there is no significant difference in age wise prevalence between kids, young and adults in protozoan infection.

Table 1. Genera-wise prevalence of gastrointestinal Parasites

SN	Class	Genera	No. of infected Samples	Prevalence (%)
1	Protozoa	*Eimeria sp.*	119	59.5
2	Trematoda	*Fasciola sp.*	8	4
3	Nematoda	*Strongyle sp.*	67	33.5
		Trichuris sp.	46	23
		Haemonchus sp.	29	14.5
		Strongyloides sp.	27	13.5
		Trichostrongylus sp.	18	9

Table 2. Age-wise prevalence of protozoan infection

Age	**Total sample**	**Total positive**	**Prevalence (%)**
Kids	40	22	55
Young	69	45	65.21
Adults	91	52	57.14
Total	200	119	59.5

Age-wise prevalence of helminths infection

From the table 3, the prevalence of helminths infection in this study did not show any statistical significance ($\chi 2$ =1.727, df = 2, p-value = 0.42, i.e. p > 0.05), in relation to age of the goat's infection.

Table 3. Age-wise prevalence of helminths infection

Age	**Total sample**	**Total positive**	**Prevalence %)**
Kids	40	20	50
Young	69	43	62.32
Adults	91	50	54.94
Total	200	113	56.5

Sex-wise prevalence of protozoan

From the microscopic examination of 200 total samples, 49 males and 70 females

were found to be positive for one or more parasites. The prevalence of protozoan infection in males and females has been summarized in table 5.

Table 4. Sex-wise prevalence of protozoan

Sex	Total sample	Total positive	Prevalence (%)
Male	79	49	62.02
Female	121	70	57.85
Total	200	119	59.50

There is no significant difference in sex wise ($\chi 2 = 0.194$, df = 1, p-value = 0.659, i.e. p >0.05), prevalence in protozoan infection.

Sex wise prevalence of helminths

As per the result of total samples examined, 43 males and 70 females were found infected with one or more parasites. The prevalence of helminths infection in males and females is summarized in table 6 and there is no significant difference in males and females ($\chi 2 = 0.109$, df = 1, p-value = 0.74, i.e. p >0.05), prevalence in helminths infection.

Concurrent parasitic infection in goats

The results revealed that, single infection was found to be higher (n = 52) than double infection, (n = 48), triple infection, (n = 26) and multiple infection (n = 6). Single infection was found highest in *Eimeria* sp., Double infection was found highest in *Eimeria* sp. and *Strongyle* sp.

Table 5. Sex wise prevalence of helminths

Sex	Total Sample	Total positive	Prevalence (%)
Male	79	43	54.43
Female	121	70	57.85
Total	200	113	56.5

Table 6. Concurrent parasitic infection in goats

S. N.	Type of infection	Total 132 (100%)
1.	Single	52 (39.39%)
2.	Double	48 (36.36%)
3.	Triple	26 (19.69%)
4.	Multiple	6 (4.54%)

Intensity of infection

Most of the parasites of goats revealed that light infection with 94.5% while almost six species of parasites revealed mild rate of intensity i.e. 87%, Only four species of parasites were found to be positive for moderate infection i.e. 23% and

two species revealed heavy infection 1.5%.

Table 7. Intensity of infection during study period

Class	Parasites	Light (+)	Mild (++)	Moderate (+++)	Heavy (++++)
Sporozoa	*Eimeria* sp.	60 (30%)	50 (25%)	7 (3.5%)	2 (1%)
Trematode	*Fasciola* sp.	8 (4%)	_	_	_
Nematode	*Strongyle*	20 (10%)	36 (18%)	10 (5%)	1 (0.5%)
	Trichuris sp.	10 (5%)	20 (10%)	16 (8%)	_
	Haemonchus sp.	17 (8.5%)	7 (3.5%)	5 (2.5%)	_
	Strongyloides	8 (4%)	19 (9.5%)	_	_
	Trichostrongylus sp.	11 (5.5%)	7 (3.5%)	_	_

Note: Light infection = <2 eggs/oocysts/larvae per gram Mild infection = 2-4 eggs/oocysts/larvae per gram Moderate infection = 4-6 eggs/oocysts/larvae per gram Heavy infection = > 6 eggs/oocysts/larvae per gram.

Table 8. Assessment of practices and knowledge of farmers on the management of goat

SN	Questionnaires	N=50	Percentage
1.	Grazing site	Zero grazing Forest grazing Riverside grazing Field grazing	_ 50 30 20
2.	Provision of clean water	Yes Sometimes No	30 50 20
3.	Drug availability	Vet. pharmacy Open market Others	90 10
4.	Taking care of side goats	Self Vet. Hospital Traditional healer	10 80 20
5.	Types of drugs used	Allopathic Ayurvedic	80 20
6.	Knowledge about internal parasites in goats	Yes No	30 70
7.	Knowledge on harmful effect of Anthelminthic drug	Yes No	40 60
8.	Drug availability	Vet Pharmacy Open market From others	90 10
9.	Season of infection	Summer Winter All year around	70 20 10
10	Farm management	Good Medium Poor	20 30 50

Discussion

The present study was carried out to determine the prevalence of gastrointestinal parasites of goats. This study was carried out in the month of February/march. The sample was collected from Malarani Rural Municipality-1, Arghakhanchi district. From the present study out of 200 samples 132 (66%) were found positive. It is well known that the intestinal parasites are cosmopolitan in distribution and all animals whether humans, domestic animals or wild animals bear different kinds of parasites. It can be said that the prevalence of any gastrointestinal parasites is influenced by the climatic conditions and geographic factors. Generally, the warm and humid conditions, continuous rainfall throughout the year which prevail in much of South-East Asia, provide good conditions for many gastrointestinal parasites to flourish that means there is no season during which the parasites are not problem (Tiya *et al.*, 2008).

In the present study 66% of the goats from study area were found to be infected with one or more gastrointestinal parasites. One genera of Protozoa, one genera of trematode and five genera of nematode was found. Among protozoa *Eimeria* sp. was found and in trematode *Fasciola* sp. was found. Among nematodes *Strongyle*, *Trichuris*, *Haemonchus*, *Strongyloides* and *Trichostrongylus* were found. The prevalence of protozoan *Eimeria sp*. (59.5%), trematode genera found in goat was *Fasciola* sp. (4%). In the nematode *Strongyle* sp. (33.5%), *Trichuris* sp. (23%), *Haemonchu s*sp. (14.5%), *Strongyloides* (13.5%), and *Trichostrongylus* (9%) were found. The overall prevalence of helminths parasites among goats under traditional husbandry system in South East Nigeria (Opera *et al*., 2005) of which nematode infection revealed 78.4%, trematode13%. The present study was little bit similar to this study i.e. nematode infection 52.5% and trematode 4%.The presence of oocyst of *Eimeria* sp. was observed in goats of different countries (Radavelli*et al*.,2011, Jimenez *et al*., 2007, Idris *et al*.,2011), nine species (Heidari *et al*.,2014) from Iran. In present study since oocyst were not cultured, so species couldn't be identified hence *Eimeria* sp. has been broadly differentiated into two types (*Eimeria* with micropyle and *Eimeria* without micropyle) on the basis of morphological structure. Goats of Malarani were found to be infected with 59.5% out of 132 positive samples which is higher in higher in comparison to 27.1%, 50%, 57.5% and 22.4% revealed by Gupta and Chabra (1990) and Kaur and Kaur (2008), but lower than the 89.54% and 94.7% (Jimenez,2007) and Purja (2015), respectively. The result of present study sample infected with *Eimeria* sp. is 59.5% which is almost similar to 60.83% revealed.

CONCLUSION AND RECOMMENDATIONS

Seven different genera of parasites were observed in the present study which are as follows protozoans; *Eimeria* sp. (59.5%and among trematodes *Fasciola* sp. (4%) and among nematodes *Strongyle* sp. (33.5%), *Trichuris* sp. (23%), *Haemonchus* sp. (14.5%), *Strongyloides* sp. (13.5%), *Trichostrongylus sp.*. (9%).There was no significance difference between age wise and sex wise prevalence (i.e. $p>0.05$) in both protozoan and helminths parasites.

- The presence of infection in the goats was found and studied in season of February in this period temperature was moderate which was suitable for the development and survival of parasites. Some common risk factors observed during the study period were contaminated food and water, ingestion of contaminated grasses, ingestion of moist aquatic plant, contaminated vegetables, ingestion of green grasses near the river, grazing on contaminated field, contaminated soil feeding. Examination of soil and water sample from the grazing site should be carried out so as to confirm the possible risk factors of parasite transmission.
- Coccidiosis is a major problem in these goats hence mass treatment program is needed against it and must be initiated regularly.
- Knowledge on intestinal parasite of goat seems poor among farmers hence regular training of goat farming focused on disease aspect should be provided to goat farmers.

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EFFECT OF POULTRY MANURE RATES AND DAYS AFTER ANTHESIS ON THE FRUIT QUALITY OF OKRA (*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

The cultivation of okra (A. esculentus) is crucial for sustaining food security and meeting nutritional demands, yet optimizing fruit quality remains a challenge. This research aimed to determine the effect of poultry manure rates and days after anthesis on quality of okra fruits. The experiment was carried out at the Crop section of the Teaching and Research farm of Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria. The experiment was laid in a 3×3 factorial design consisting of two factors namely poultry manure rates (0, 7.5 and 12.5t/ha) and days after anthesis (7, 14, and 21 days) in a Randomized Complete Block Design (RCBD) and replicated three times. The plot area was $6m^2$ with alley way of 1m between blocks and plots. The poultry manure was incorporated to the soil two weeks before planting and Okra seed were sown at a spacing of 50cm x 75cm in intra-row and inter-row spacing respectively. Data collected include: number of flowers/plots, number of fruits/plots, fruit length, fruit girth and the quality evaluation of okra fruits were evaluated. The result of the experiment revealed that the moisture content, dry matter, ash content, crude protein, carbohydrates and energy value of okra fruits were not significantly influenced by different rates of poultry manure and days after anthesis. However, significant differences were observed in the crude fat and crude fibre as application of 0t/ha of poultry manure produced significantly higher crude fat while 21 days after anthesis produced higher crude fibre.

Keywords: Days after anthesis, fruit quality, Okra, poultry manure

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench), a versatile and valuable vegetable widely grown in tropical and subtropical regions, is known by many local names like "lady's finger" in England, "gumbo" in the U.S., and "bhindi" in India (Benchar, 2012). Its cultivation offers unique economic and nutritional benefits, adapting well to varying moisture levels and producing dependable yields, though it is sensitive to extremes such as frost, drought, and waterlogging (Santos et al., 2019). Belonging to the Malvaceae family, okra is cultivated for its edible pods, which serve as a critical dietary component in many parts of the world (Reddy et al., 2012).

Nutritionally, okra is rich in essential nutrients, including vitamins C and B9, calcium, iron, and fiber, along with medicinal properties that promote digestive health, cardiovascular function, and immune support (Uka et al., 2013). Additionally, okra seeds contain beneficial oils, comparable in nutritional value to poultry eggs or soybeans (Omotoso et al., 2007). This nutritional profile makes okra especially valuable in developing regions where diets may lack protein and diverse nutrients. Okra is also widely used in various culinary applications, either cooked, processed, or eaten raw when young and tender (Singh et al., 2018).

Marketability of okra depends heavily on fruit quality factors, including pod length, diameter, color, and mucilage content, which are important for consumer acceptance (USDA, 2018; Santos et al., 2019). Enhanced varieties of okra, achieved through genetic hybridization, offer further advantages by improving resistance to pests and diseases, increasing yield, and optimizing nutritional content. Hybridization, the process of crossing plants to produce new traits, allows selective breeding for desirable characteristics that better meet market demands and cultivation challenges (Whitney et al., 2010).

A promising approach to boosting okra productivity is using organic fertilizers, particularly poultry manure, which improves soil health and crop quality without the environmental risks associated with inorganic fertilizers (Williams and Harris, 2019). Poultry manure is rich in organic matter and nutrients, enhancing the soil's fertility and structure while promoting sustainable farming practices. Unlike synthetic fertilizers, which can lead to groundwater pollution and other ecological concerns, organic manure provides a safer, eco-friendly alternative that aligns with the global push for sustainable agriculture (Kumar and Jangid, 2018).

However, research on how varying poultry manure rates and the timing of fruit development stages (measured as days after anthesis) affect okra's fruit quality remains limited. These factors may influence nutrient density, fruit size, and other

quality markers, which directly impact okra's nutritional value and market appeal (Rajurkar et al., 2011). Understanding the specific effects of these variables can help optimize okra production, enabling farmers to achieve higher-quality yields while maintaining sustainable agricultural practices. This study was aimed to determine the effect of poultry manure rates and days after anthesis on the quality of okra fruits. The specific objectives were to determine the effect poultry manure rates on the proximate analysis of okra fruits and to determine the effect of days after anthesis on the quality of okra fruit.

MATERIALS AND METHODS

This experiment was carried out at the Crop section of the Teaching and Research farm of Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria. The experimental site is located on latitude 9º4'11''N and 6º34'21"E in the Southern Guinea Savanna zone of Nigeria with mean annual temperature ranging between 21ºC and 36.5ºC. The experiment was a factorial experiment laid in a 3×3 factorial design consisting of two factors namely poultry manure rates (0, 7.5 and 12.5t/ha) and days after anthesis (7, 14, and 21 days) in a Randomized Complete Block Design (RCBD) and replicated three times. The plot area was $6m^2$ with alley way of 1m between blocks and plots. The poultry manure was incorporated to the soil two weeks before planting. Okra seed were sown at a spacing of 50cm x 75cm in intra-row and inter-row respectively. Improved seeds of Okra seeds were obtained from the National Institute of Horticultural Research (NIHORT) in Ibadan, Oyo State, Nigeria. Poultry manure was obtained from Animal Section of Teaching and Research farm of IBBU, Lapai while working tools was obtained from the Crop Section of the Teaching and Research farm of IBBU, Lapai.

The land was cleared manually using cutlass and all debris were removed. The land was ploughed and ridged with aid of tractor mounted plough and ridge. Okra seeds were planted in the field at a spacing of 50cm within the row and 75cm between the rows and a depth of 4cm. 3 seeds were planted per hole and later thin to 2 per stand. Poultry manure was incorporated into the soil two weeks before planting. This is to allow mineralization to take place.

The following data were measured: Number of flowers per plot, Number of fruits per plot, Fruit length and Fruit weight. The determination of Dry matter (%), moisture content (%), ash content (%), crude fibre (%), crude protein (%), crude fibre (%), CHO (%) and Energy value (Kcal) were determined following the methods of the Association of Official Analytical Chemists (AOAC, 2002).

Data analysis

All data collected were subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences version 25 and significant means were separated using Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Physiochemical analysis of in soil and poultry manure

Table 1 shows the physicochemical analysis of available N, P and K in the soil prior to the commencement of the experiment. The result revealed that both the soil and poultry manure had a considerable amount of N, P and K prior to the experiment. The experimental soil showed higher amount of available P and K while there poultry manure had higher N content. The textural class of the soil was Sandy loam.

Table 1. Physio-chemical analysis of the soil and manure before the experiment

Physical Properties	**Soil**	**Poultry Manure**
Sand (%)	71.3	
Silt (%)	18.1	
Clay (%)	10.6	
Textural Class	Sandy Loam	
Chemical properties		
pH in H_2O	6.48	6.30
pH in $CaCl_2$	5.40	
Organic carbon (g/kg)	0.35	25.29
Organic matter (g/kg)	20.64	74.71
Total N%	0.54	0.95
Available P(mg/kg)	0.08	0.25
Available K(Cmol/kg)	0.56	2.33
Exchangeable Base		
Na^+	0.46	2.12
K^+	0.29	2.33
Mg^{2+}	1.28	0.42
Ca^{2+}	2.38	1.36
CEC	3.84	

Effect of days after anthesis and poultry manure on number of flowers and fruits

The effect of days after anthesis and poultry manure rates on the number of flower and number of fruits of Okra is presented in Table 2. The result showed that variety has a significant ($p<0.05$) difference in the number of flowers of okra as improved variety had the highest number of flowers. Similarly, application of poultry manure at 12.5t/ha significantly produced higher number of flowers followed by application rate of 7.5t/ha while control (0t/ha) produced the least number of flowers at 5% probability level.

Table 2. Effect of Days after Anthesis and Poultry Manure on the Number of Flowers and Fruits of Okra

Treatment	Number of Flowers	Number of Fruits
Variety		
Local	9.20b	8.97b
Improved	12.17a	11.50a
Poultry Manure (t/ha)		
0	9.20c	8.60c
7.5	10.91b	10.34b
12.5	12.65a	12.32a

Values followed with same letter(s) across the column are not significantly different ($p<0.05$) using DMRT.

Table 3. Effects of days after anthesis and poultry manure on fruit length and fruit girth

Treatment	Fruit length	Fruit girth
Local	20.50a	25.31a
Improved	19.52a	19.87a
Poultry manure		
0	18.12a	23.18a
2.5	22.26a	23.40a
7.5	19.44a	22.96a
12.5	20.22a	20.83a

Values followed with same letter(s) across the column are not significantly different ($p<0.05$) using DMRT.

The result of the study also reveal that variety significantly influence the number of fruits of Okra as improved variety significantly produced higher number of fruits compared to local variety. Moreso, application of poultry manure rate of 12.5t/ha significantly ($p<0.05$) produced higher number of okra fruits while control (0t/ha) had the least number of fruits.

Fruit Weight

The consequence of days after anthesis on fresh fruit weight (kg) per plant and fruit yield was shown in table 4. (*Abelmuschus esculenus).* The result show that there was significant difference as improved variety performed higher than local variety, While at poultry manure 12.5ton per hectare had a highest performance with 0ton per hectare having poorest performance.

Table 4. Effects of days after anthesis and poultry manure (kg) on fruit weight

Treatment	**Fruit weight**
0.22b	356.46b
Improved	0.26a
Poultry manure	
0	0.18c
2.5	0.23b
7.5	0.27a
12.5	0.29a

Values followed with same letter(s) across the column are not significantly different ($p<0.05$) using DMRT.

Proximate Composition of Okra Fruit as influenced by Poultry Manure Rates and Days after Anthesis

The effect of poultry manure rates and days after anthesis on the proximate analysis is presented in Table 5. The result revealed that there were no significant ($p<0.05$) differences in the dry matter and moisture content of okra fruits as influenced by poultry manure rates as well as days after anthesis. However, application of poultry manure rate of 7.5t/ha had the highest moisture content of okra fruits but was not statistically significant from other application rates. Similarly, there were no significant differences in the ash content of okra fruits but application of poultry manure at 12.5t/ha and 21days after anthesis had higher

ash content value but were not statistically different from other treatments respectively as observed.

With regards to the crude fibre of okra fruits, poultry manure showed a significant ($p<0.05$) difference. Application of poultry manure at 0t/ha (control) significantly had the highest crude fat compared to other application rates but there were no significant differences in the application rates of 7.5 and 12.5t/ha of poultry manure. Similarly, there were no significant differences in the crude fat of okra fruits as influenced by days after anthesis.

Application of poultry manure at 0t/ha had the highest crude protein although it was not statistically significant from other poultry manure application rates. Similarly, days after anthesis had no significant effect on the crude protein of okra fruits.

The result of the experiment also showed that there were significant differences in the crude fibre of okra fruits as inflicted by days after anthesis as 21days after anthesis significant ($p<0.05$) had highest value of crude fibre compared to other treatments. However, there were significant differences in CHO and energy value of okra fruits as influenced by poultry manure rates and days after anthesis in southern guinea savanna ecological zone of Nigeria.

Table 5. Proximate Composition of Okra Fruit as influenced by Poultry Manure Rates and days after Anthesis

	Dry matter (%)	Moisture content (%)	Ash (%)	Crude fat (%)	Crude protein (%)	Crude fibre (%)	CHO (%)	Energy value (Kcal)
Poultry Manure Rates (t/ha)								
0	96.61a	3.45a	8.70a	10.12a	18.58a	9.47a	49.68a	367.36a
7.5	95.45a	4.56a	8.66a	6.93b	15.98a	9.30a	54.58a	374.53a
12.5	96.43a	3.57a	9.53a	5.85b	16.55a	9.88a	49.74a	347.79a
SE±	0.420	0.413	0.593	0.847	1.089	0.518	3.564	10.892
Days after Anthesis								
7	96.42a	3.65a	8.59a	8.48a	17.56a	9.24ab	52.49a	369.53a
14	96.04a	3.96a	8.55a	6.19a	17.77a	8.83b	55.37a	359.13a
21	96.04a	3.97a	9.76a	8.23a	15.78a	10.58a	46.13a	360.92a
SE±	0.420	0.413	0.593	0.847	1.089	0.518	3.564	10.892

Values followed with same letter(s) across the column are not significantly different ($p<0.05$) using DMRT.

The result of the findings revealed that there is a significant difference in the number of flowers and number of fruits of okra as influenced by varieties and poultry manure rates. This effect on the number of flowers and number of fruits of okra variety can be attributed to the differences in the genetic make-up of the okra plant.

The application of different rates of poultry manure was observed to be significant in the number of flowers as well as number of fruits. Application of poultry manure at 12.5t/ha significantly ($p<0.05$) produced the highest number of flowers and number of fruits of okra, this could be attributed to the fact that poultry manure has been reported to be a good source of nutrient for crops likewise the attributes of easy availability and best conditions for quick absorption of nutrient by the plant. Earlier studies have found similar positive effects of PM (Onwu *et al*. 2014, Tiamiyu *et al*. 2012, Ali *et al*. 2014, Voor *et al*. 2018). According to Uka *et al*., (2013), using poultry droppings resulted in plants with the greatest fruit characteristics and yield.

The proximate composition of okra fruits as influenced poultry manure and days after anthesis no significant differences in the percentage of dry matter, moisture content, ash content, crude protein, CHO and energy value. The application of poultry manure is known to enhance soil fertility and nutrient availability, potentially impacting the nutritional composition of crops. However, the lack of significant differences in the measure parameters may indicate that the poultry manure rates did not induce substantial variations in nutrient uptake by okra plants. This result is in line with the findings of Ojeniyi *et al*., (2019) who reported that while organic amendments like poultry manure positively influenced soil nutrient level, the impact on crop nutrient content could vary depending on factors such as soil type and plant species. Days after anthesis can significantly affect the nutrient composition of fruits as they undergo various metabolic processes during development. In this study, the non-significant differences may imply that the nutrient composition of okra fruits was relatively stable across different stages of development. Similar results were reported by Oladipo *et al.* (2017) in a study on the influence of growth stages on the proximate composition of okra fruits.

The observed differences in the crude fat and crude fibre of okra fruits as influenced by poultry manure rates and days after anthesis suggest that these factors have a notable impact on the nutritional composition of the fruits Yadav *et al*., (2017) in his research reported that the impact of organic amendments is not always linear and an excessive application may not necessarily lead to increased nutrient accumulation. Furthermore, 21days after anthesis significantly produced higher crude fibre. The growth and development stages of fruits are

known to influence fibre content. This finding is consistent with the research by Uwah *et al* (2020), which demonstrated that the proximate composition of okra fruits including fibre content can vary at different growth stages. The plant's metabolic processes during fruit development, particularly as it approaches maturity can contribute to variations in fibre composition.

CONCLUSION AND RECOMMENDATIONS

The result of the experiment revealed that the moisture content, dry matter, ash content, crude protein, carbohydrates and energy value of okra fruits were not significantly influenced by different rates of poultry manure and days after anthesis. However, significant differences were observed in the crude fat and crude fibre as application of 0t/ha of poultry manure produced significantly higher crude fat while 21 days after anthesis produced higher crude fibre.

It is therefore recommended that further research be conducted on considering different poultry manure application rates to determine the optimal application rates that can enhance the proximate composition of okra fruits.

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A STUDY ON FEEDS AND FEEDING PRACTICES OF DAIRY ANIMALS IN SMALL SCALE FARMS OF KAVRE DISTRICT, NEPAL

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ABSTRACT

The study was conducted in selected wards of Panchkhal Municipality, Kavre, Nepal. A structural questionnaire was used to collect the primary information from the farm. The information collected were farm demographics, feeding practices, types of feed used, and the challenges encountered in ensuring adequate nutrition for their animals. The results revealed zero grazing, was the predominant farming method among dairy farmers in the area. Approximately 80-88% of the dairy animals raised were of crossbred type (79% Jersey cross and 8% Holstein Friesian cross). Dairy farmers primarily utilized locally available feed resources such as seasonal green grasses, forage crops, and crop residues, complemented by feedstuffs like broken rice, rice bran, wheat bran, rice polish, mustard cake, corn flour, molasses, salt, and thyme seeds. Mostly the feed was fed to the animals in the traditional method termed as "kudo" (meaning mixing of all available feed resources with water) to give to the productive animals. This study revealed that a total of 21 (51%) of respondents cultivated their fodder grass, with Napier grass (Pennisetum purpureum) being the most favored, followed by fodder oats (Avena sativa), and other grass varieties. About 33 (80.5%) of the farmers favored the artificial insemination (A.I) method, whereas 8 (19.51%) respondents opted for natural mating as their preferred breeding technique. The average milk yield per day was 10.26 liter. These findings provided valuable insights into the intricate challenges faced by regional dairy farmers, shedding light on their feeding practices, livestock management techniques, and the broader agricultural landscape.

Keyword: Feed, feeding practices, fodder, forage, agricultural landscape

INTRODUCTION

Livestock is a vital sector in Nepal's agriculture, contributing 26% to the Agricultural GDP and 6.23% to the national GDP (MoALD, 2023). It provides essential products like meat, milk, eggs, wool, hides, and manure. The country's

livestock population includes 7.4 million cattle, 5.1 million buffalo, 0.7 million sheep, 13 million goats, 1.5 million pigs, and 66 million poultry (MoALD, 2023). Dairy farming is a significant subsector, with buffaloes contributing two-thirds of milk production and cattle contributing one-third. Of the 7.4 million cattle, only 16.49% are milking cows, and of the 5.1 million buffalo, only 32.47% are milking buffaloes. Kavre district, with 27,476 milking cows and 57,043 milking buffaloes, produces 90,758 tons of milk annually (MoALD, 2023).

Dairy farming helps farmers in many respects, such as, vital sources of cash income, sources of family nutrients, sources of manure for their agricultural land, source of biogas, and source of animal draft power. To take full advantage of dairy farming, farmers need to have access to good species of animal, extension services along with the provision of dairy infrastructure such as chilling centers, milk processing centers, and credit facilities in order to avail the necessary seed money particularly by the resource poor (Limbu, 2017). Dairy farming is an important sector in Nepal's agriculture contributing to the country's economy and providing livelihoods to many farmers. It provides employment opportunities to around 65 percent of the total population (MoALD, 2019).

Nepal's diverse ecological zones influence its livestock population. Most households own small herds of 5-7 animals. Buffaloes, especially native breeds like Lime, Parakote, and Gaddi, and the improved Murrah breed, contribute significantly to the 72% of milk and 65% of domestic meat supply (Osti, 2020). Cattle, including native breeds like Siri, Pahadi, Khaila, and Terai, and exotic breeds like Jersey and Holstein, contribute to the remaining 28% of national milk supply. Livestock production systems vary across the country. Extensive and semi-extensive systems are common in the mountains and hills, where animals graze on natural pastures and are supplemented with crop residues and forest products. In the Terai, semi-intensive and intensive systems are more prevalent, with animals often confined to stalls and fed a combination of commercial feeds, crop residues, and green fodder. Locally made semi-solid feeds, like "Kudo," which is made with kitchen waste, and maize flour mixed with rice bran are also used to supplement the diet of productive animals (Osti,2020) .

Traditionally, livestock in Nepal relied on communal grazing lands and off-farm fodder resources. However, increasing pressure on land and restricted access to communal resources have reduced the availability of these resources. As a result, farmers are increasingly reliant on lower-quality crop residues from their own farms. Seasonal feed shortages, particularly of high-quality feeds, limit livestock

holdings and productivity, especially for poorer communities with limited land and resources (Hendy *et al*., 2001).

Livestock ration primarily comprises dry fodder, cultivated green fodder, tree leaves, pastures, and grazing land depending upon the availability. In addition, conventional concentrates/compound cattle feed is supplemented in the ration especially of milk animals. More than 95% of the total concentrates used for livestock feeding are important and are the most expensive component of the ration especially protein meals/cakes. Feeds and fodders are not fed in right proportions as a result cost of production is higher, productivity is low and net profit to the livestock keepers is low (Garg & Upreti, 2019).

A balanced ration provides essential nutrients for animal growth, development, and reproduction. In Nepal, livestock primarily rely on crop residues like wheat and rice straw, maize stover, tree leaves, and green fodder. Maize, rice bran, wheat bran, and oilseed cakes are used as concentrates. However, domestic production of these concentrates is insufficient to meet the growing demand from poultry and dairy industries. As a result, Nepal imports these feeds, primarily from India. The overall feed deficit in Nepal is significant, with deficiencies of 33% in dry matter, 38% in crude protein, and 42% in metabolizable energy (Osti, 2020).

A study conducted in Chitwan, found that common grasses and fodders were Siru (*Imperata spp.*), Kans (*Saccharum spp.*), Banso (*Paspalum spp*), Maize (*Zea mays*) and Oat concentrates. Inclusion of rice straw as a major feeding resource was common in the entire land holding group and dry matter requirement was found deficit (Pant, *et al.*, 1994).

In a field study conducted by Saurav, *et al.*(2023), the information revealed that group stall feeding, common salt feeding were done by the majority of the respondents, and 79% of the dairy farmers self-cultivated the green fodder. Only 23.89% of the respondents fed mineral mixture to the lactating animals. It was observed that the dairy farmers were unaware of the importance of the concentrate mixture, balanced feeding, and proper housing management practices.

A study in Kavre (Gautam *et al.*, 2021) surveyed 122 livestock farmers. Improved housing, experienced farmers, legume-rich roughage, oilcake-supplemented concentrates, and timely veterinary care positively impacted production efficiency. Most farmers were small-scale, with an average herd size of 4.7 animals. Dairy herds consisted of 62% milking animals, 28% calves/heifers, and 10% dry animals. Maize was the primary concentrate feed, followed by rice bran,

wheat bran, soybean meal, and other oilseed cakes. Cattle and buffaloes received additional vitamins and minerals during weakness and lactation. Artificial insemination was widely used, with cattle producing an average of 1800 liters of milk per lactation over 300 days, while buffaloes produced 1300 liters per lactation over 320 days.

Another study conducted in Chitwan found that 75-80% of household in study sites raised at least 2-3 cross bred milking cows and 20% keep 1-2 buffaloes. Different green fodders, crop residues, mainly rice straw and commercial feed available throughout the year, contributed to the diet of the dairy animals. Management system adopted was complete stall fed. Herd recorded mastitis as a major disease (63.16%) followed by infertility (13.16%), milk fever (10.53%), helminths (7.89%) and remaining (abortion, poisoning, diarrhea, viral like lumpy skin disease etc.) (5.26%) (Pandey, *et al.*, 2023).

Poudel, *et al.*, (2023), carried out a study on productive and reproductive performances of two common breeds, Jersey Cross and Holstein Cross from a sample of 120 dairy herds using semi-structured questionnaire in Bharatpur Metropolitan city, Chitwan. The author found the average daily milk yield, lactation length, lactation milk yield, peak yield and dry period for Jersey Cross and Holstein Cross with the Nepalese hill cattle were 7.39±0.87 and 9.30±0.76 L./day; 303.31±8.12 and 314.18±12.75 days; 2253.39±265.28 and 2936.36±237.55 L.; 12.77±0.92 and 15.11±0.85 L. and 65.26±7.71 and 70.83±10.27 days respectively.

According to the findings of the study conducted in Myanmar, smallholder dairy farmers in Myanmar primarily use zero-grazing systems. They rely on locally available feeds like cut-and-carry grass, forage crops, crop residues, and various feedstuffs such as broken rice, rice bran, wheat bran, sorghum, yellow corn, mineral block, and oilseed cakes. While feed availability and quality vary, farmers carefully select and combine feeds to provide adequate nutrition for sustainable production. Two main feeding practices are common: compound cattle feeding and home-mixed feeding. A majority of farmers (84.77%) prefer compound feeds. Natural mating is more prevalent than artificial insemination. Milk production averages 7.45 liters per cow per day during the wet season and 6.48 liters during the dry season. Approximately 73% of farmers use concentrates based on milk production levels (Myint & Muang, 2020).

According to the study conducted in North Bihar, Group stall feeding, common salt feeding were done by the majority of the respondents, and 79 per cent of the

dairy farmers self-cultivated the green fodder. Only 23.89 per cent of the respondents fed mineral mixture to the lactating animals. It was observed that the dairy farmers were unaware of the importance of concentrate mixture, balanced feeding, and proper housing management practices (Saurav, *et al.*, 2023).

The animal in Nepal are under fed with 36 percent feed deficient, mainly during winter in the country. In the context of available Total Digestible Nutrient (TDN) 29 percent is deficient (NAFLQML, 2019). There have been a significant change (build up area (65.5%) in land use pattern in Nepal over 2 decades (1990-2010), (Garg & Upreti, 2019).

Challenges in the dairy sector

Nepal's dairy farmers face significant challenges, including feed quality, quantity, pricing, storage, and water scarcity. High feed costs, accounting for 70% of production expenses, particularly burden small-scale farmers. Limited grazing and fodder availability during dry seasons exacerbate the issue. Researchers are exploring ways to improve feed utilization, especially crop residues, to increase milk production and profitability. Key bottlenecks to the dairy sector's growth include low cattle productivity, limited market access, unscientific pricing, and lack of product diversification (Sigdel, 2016).

Dairy farmers in the region face numerous challenges, as highlighted by Khanal (2015). The degradation of forests and land has led to severe feed shortages. Inadequate government support, including limited veterinary services, breeding programs, and advisory services, further hampers the sector. High opportunity costs for land and labor, coupled with labor migration, exacerbate the situation. Poor infrastructure and limited market access restrict growth, while rising input costs and unregulated milk prices pose significant financial burdens on farmers (Khanal, 2015).

Livestock, the dairy sector in particular, has traditionally contributed to the Nepalese economy and livelihoods even though vegetarian centered food habits predominate. However, the sector has not seen significant improvement. The International Livestock Research Institute's (ILRI) FEAST(Feed Assessment Tool) has been used to assess feeding systems in Kapilvastu, Palpa, and Arghakhanchi districts. Youth migration has reduced agricultural land, and the lack of fodder crops limits feed availability, hindering commercial dairy growth. Other challenges include labor shortages, competition with rice cultivation, indigenous breeds, and policy barriers like credit constraints and inadequate government support. To achieve self-sufficiency in milk and dairy products by

2020, a dairy-focused program is needed to utilize land and resources and commercialize the sector (Paudel et al., 2019).

The overall objective of the study is to assess the feed and feeding practices in dairy cattle in Kavre district with a focus on identifying current practices, identifying challenges and opportunities for improvement, in providing adequate nutrition to dairy cattle. This study has several limitations. Firstly, the study was conducted over a relatively short duration, which may limit the ability to capture long-term trends in feed and feeding practices. Secondly, the sample size was small, which may affect the generalizability of the findings to the entire population of dairy farms in the region. Thirdly, since a survey method was employed for data collection, there is a potential for recall bias, as respondents provided information based on their memory and estimation. Lastly, the dairy farms in the study area exhibit significant heterogeneity in terms of size, management practices, and available resources, making it challenging to generalize the data across all farms.

MATERIALS AND METHODS

Study area

The present study was conducted in different wards of Panchkhal Municipality of Kavrepalanchowk district. The traditional main occupations in this area are farming, animal husbandry, and trading (Anon, 2022). A descriptive study was carried out on feed and feeding practices of dairy animals in ward no. 3, 4 and 10 of Panchkhal municipality of Kavrepalanchowk district as shown in Figure 1.

Study population

Altogether 42 small- scale dairy farmers situated within the study sites were visited, each of whom maintained a minimum of one dairy animal.

Data collection

Snowball sampling technique was used to gather primary data using a pre-designed questionnaire, through face-to-face interviews and personal observations conducted on each farm. The structured questionnaires were administered to the dairy farmers to gather data on farm demographics, feeding practices, types of feed used, and the challenges encountered in ensuring adequate nutrition for their animals.

Secondary data on recent studies, animal population, and current situations were gathered from a variety of sources, including research papers, newspaper, journals, and articles, among others.

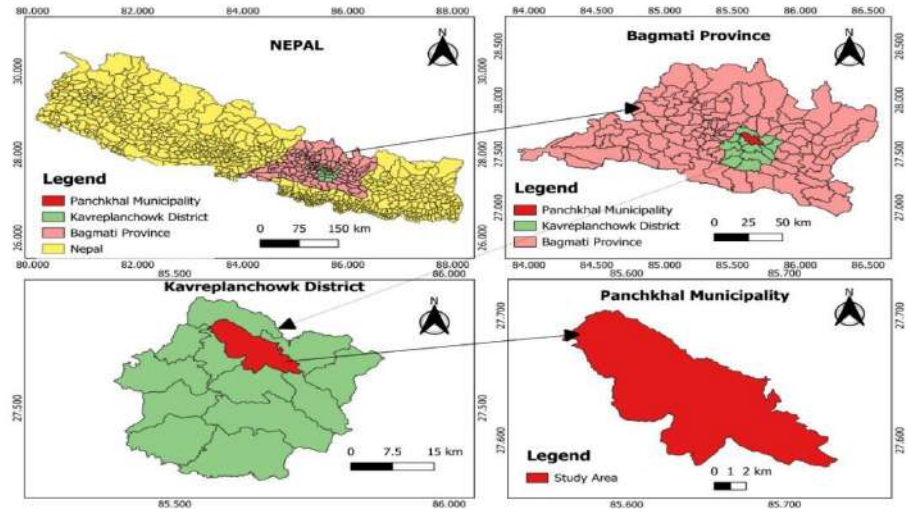

Figure 1. Map showing study area (using QGIS)

Study population

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Data analysis

The primary data collected were coded, tabulated and analyzed using descriptive statistics using Microsoft Excel.

RESULTS AND DISCUSSION

General observations

The predominant production method adopted by dairy farmers in the study area was found to be zero grazing. Management system adopted was complete stall fed. Most of the dairy farmers with land grow their own grass and maize stovers

to feed their animals and those that don't have land source forage from various locations, including communal grazing lands, roadsides, and riverbanks. In the dry season when forages are scarce, dairy farmers give feeds such as rice straw (*Oryza sativa*), corn husks (*Zea mays)*, grass hay and silage.

Livestock system

Livestock in the study sites served primarily as a means of generating income and providing manure for use in agricultural fields. Among the livestock species kept by households for milk production, cross-bred Jersey cows are the predominant choice, with approximately 79% of households owning them. A smaller percentage, 8%, raises Holstein Friesian cross cattle, while 3% keep Holstein Friesian cattle, and 10% opt for local cattle breed respectively (Figure 2).

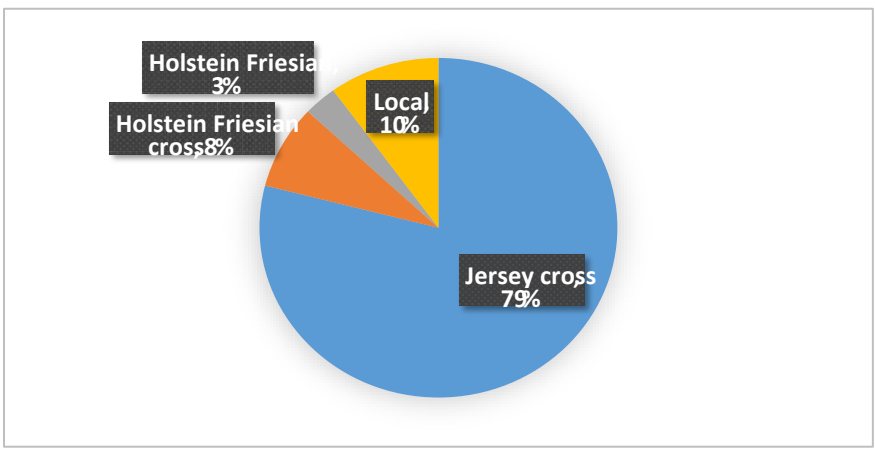

Figure 2. Breeds of cattle

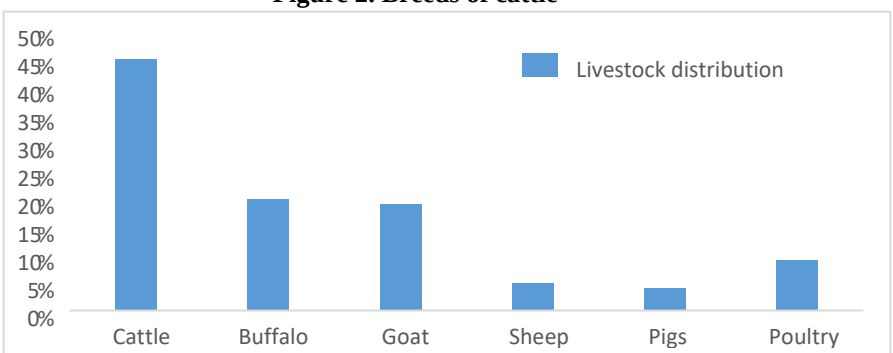

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Figure 3. Livestock distribution in the study area

Additionally, 20% of households keep buffalo, predominantly the Murrah Buffalo, for milking purposes. Around 19% of households raised goats for eventual sale as meat, while only 5%, 4%, and 9% of households raised sheep, pigs, and poultry, respectively, primarily for household consumption (Figure 3). This study findings underscored the significant role of large ruminants, particularly cross-bred Jersey cows, as a major source of income within the study site.

Feed resources

In the study area, farmers feed their dairy animals with crop residues like rice straw, wheat straw, maize straw, and legumes. Rice straw is the most common, followed by maize fodder. They also use hulls from different crops as a significant food source. Additionally, farmers collect green resources from forests and use grasses and legumes from cultivated lands. Some farmers grow specific grasses like Napier (*Pennisetum purpureum)*, Fodder oat (*Avena sativa*), Stylo (*Stylosanthes guianensis*), and Teosinte (*Zea diploperennis*). Seasonal green grasses are Siru (*Imperata spp*.), Kans (*Saccharum spp*.), and Banso (*Paspalum spp*.), among others. Maize flour is the preferred concentrate, followed by rice and its by-products, along with oilseed cakes and meals. Lactating animals are given thyme seeds and molasses for their nutritional needs (Figure 4).

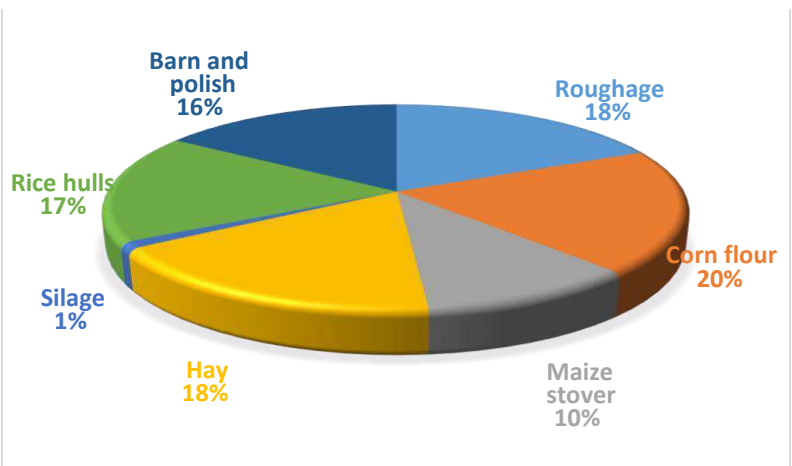

Figure 4. Dietary overview of the animals in the study area

Farmers mostly keep their animals in confined spaces (zero grazing) and use a tie-stall feeding system. About 49% of them make their own animal food, while 49%

combine homemade mixtures with compounded cattle feed. Only 2% prefer using solely compounded cattle feed. Most farmers feed their animals twice a day (76%), with 24% feeding three or more times a day. Traditional methods are common, with 93% preparing a mixture called "kudo" by cooking concentrates with water, and 7% giving concentrates directly without processing.

Regarding fodder, 51% of farmers grow their own, with Napier grass being the most popular choice. About 49% feed hay, 15% feed maize stover, and 36% use both as dry fodder. Supplements like molasses (12%), calcium (15%), and thyme seeds (9%) are provided, mainly during lactation or when needed (Table 1).

Table 1. Feeding practices of dairy animals followed by dairy farmers

S.N.	Feeding Practices	Percentage
1	**Feeding system**	
a.	Zero grazing	100%
b.	Grazing	0
2	**Frequency of feeding (concentrates)**	
a.	Twice	76%
b.	Thrice or more	24%
3	**Type of concentrate**	
a.	Homemade mixture	49%
b.	Compound cattle feed	2%
c.	Both	49%
4	**Method of feeding concentrate**	
a.	Kudo	93%
b.	No	7%
5	**Fodder cultivated**	
a.	Yes	51%
b.	No	49%
6	**Cultivated fodder**	
a.	Napier	51%
b.	Fodder oats	22%
c.	others	17%
7	**Dry fodder mostly fed**	
a.	Hay	49%
b.	Maize stover	15%
c.	Both	36%
8	**Supplements**	
a.	Molasses	12
b.	Calcium	15%
c.	Thyme seeds	9%

Breeding technique adopted in the study site

In the study site, 80.49% respondents preferred artificial insemination and 19.51% preferred natural method of breeding technique (Table 2). Natural mating methods face limitations such as the absence of male bulls in nearby areas and concerns about disease transmission, prompting farmers to opt for AI as a more practical and efficient alternative.

Table 2. Breeding technique

S.N	Breeding method	Percentage
1.	A.I.	80.49
2.	Natural mating	19.51

Milk yield (liter/day/cow) of lactating cows as reported by the respondents

In the study area, the average daily milk production per cow is 10.26 liters, with the lowest being 4 liters and the highest being 16 liters. Most of this milk is either sold to nearby dairies or used by the households. However, it's important to note that the price of milk can vary a lot in the local dairy market. On average, milk is sold for about Rs. 16.73 for every 1 percent of fat in the milk, as the price depends on how much fat the milk has.

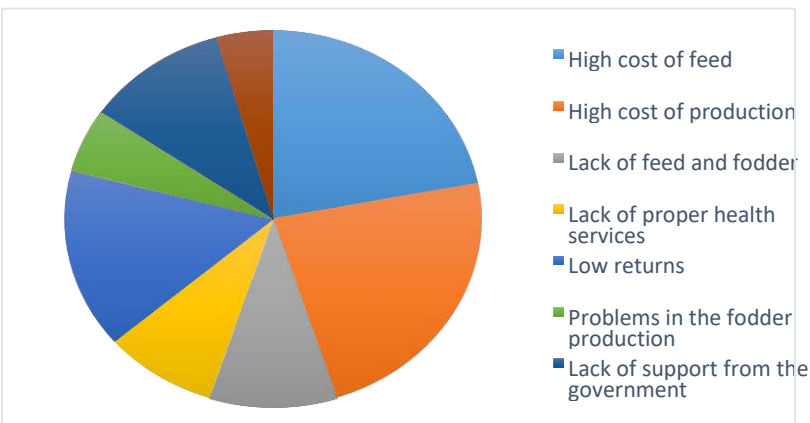

Figure 5. Problems faced by the dairy farmers in the study area

Problems

On the basis of answers given by the respondents, one of the major problems in the dairy animals is high cost of production (51.2%) followed by high cost of feed (48.8%), low return (34.1%), lack of feed and fodders (22%), lack of health services (19.5%), lack of support from the government (24.4%). Problems in the

fodder production (12.2%) and 9.8% find there are no problems in providing the feeds in the dairy animals (Figure 5).

Health situation

The study result revealed that the most prevailing disease in the study site were mastitis (41 %) followed by milk fever (15%), repeat breeding (17 %), parasitic infection (6 %) and others (toxicity, allergy, pneumonia) (9%) (Figure 6)

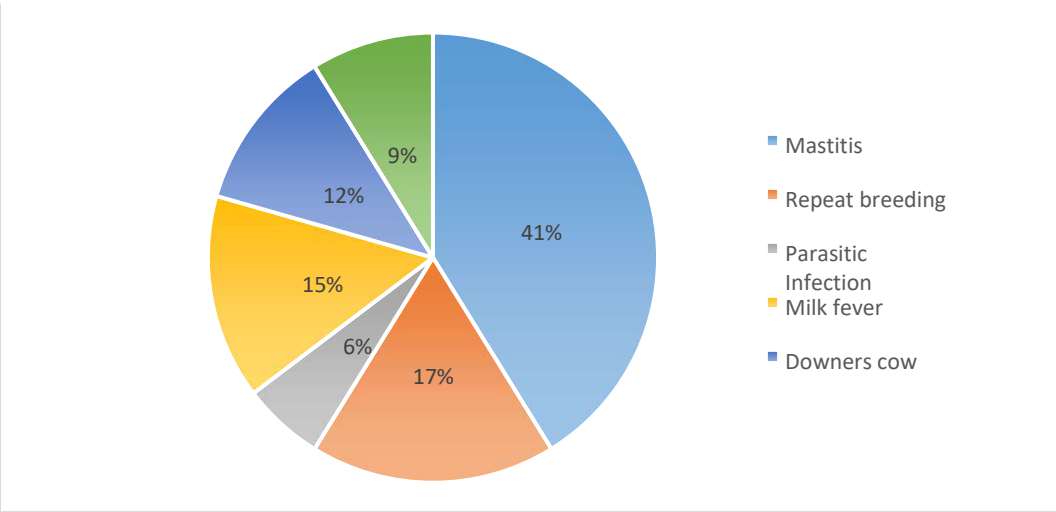

Figure 6. Health situation in the study site

Discussion

The study on feeds and feeding practices of dairy cattle in small-scale farms of Kavre district, Nepal, provides valuable insights into the current practices, challenges, and opportunities for improvement. The study found that zero grazing is the predominant farming method among dairy farmers in the area. This is likely due to the limited land availability and the need to protect crops from grazing animals. Additionally, zero grazing allows for more efficient feed management and waste disposal. However, this practice can also lead to nutrient imbalances and inefficient feed utilization, as evidenced by the high reliance on costly concentrates and imbalanced supplementary feeds in the study area.

The majority of dairy animals raised are cross-bred cattle, primarily Jersey cross. This is likely due to the superior milk production potential of cross-bred cattle. However, it is important to note that cross-bred cattle can be more susceptible to diseases and require more intensive management. Dairy farmers primarily utilize locally available feed resources such as crop residues, fodder tree leaves, and

grass from fields and forests. This is likely due to the high cost of commercial feed and the limited availability of credit. However, it is important to note that locally available feed resources can be variable in quality and quantity, which can impact animal performance.

The traditional feeding method of "kudo" is also a common practice in Nepal. This method involves mixing all available feed resources with water and feeding the mixture to the animals. While this method is simple and convenient, it can lead to nutrient imbalances and inefficient feed utilization.

The average milk yield per day of 10.26 liters in the study area is relatively low compared to the genetic potential of cross-bred cattle. This is likely due to a number of factors, including inadequate nutrition, poor management practices, and disease. The major challenges faced by dairy farmers in the study area, including high cost of feed, low milk yields, limited access to markets, inadequate nutrition, poor management practices, and disease, are also consistent with the findings of previous studies. These challenges are likely contributing to the low milk yield and profitability of dairy farms in the area.

These findings are in accordance to the findings of Gautam, *et al.* (2021) that showed small scale farmers at Kavre district mostly practice mixed traditional farming system and tie-stall feeding system with complete integration of crops, livestock and forest resources. In concentrate, maize was the main feed ingredient followed by rice bran, wheat bran, soybean meals, mustard cake, sunflower cake and other legumes byproducts. Vitamins and minerals were provided when the cattle and buffaloes were weak and during milking stage. AI breeding method was highly used then natural breeding method in study areas.

The results align with similar studies conducted in Myanmar and India by Saurav *et al.* (2023) and Myint & Muang (2020) respectively. Saurav *et al.* found that in India, the majority practiced group stall feeding and self-cultivated green fodder, with only 23.89% providing mineral mixture to lactating animals. In Myanmar, Myint & Muang noted widespread zero grazing among smallholder farmers, utilizing local resources like cut and carry grass, crop residues, and various feedstuffs.

Crop residue i.e. hay/straw is the major dry fodder provided to the dairy animals mainly in the winter season. This finding was in line with the findings of Sah, he found that Crop residue i.e. straw contributes almost 50% of total DM supplied to the animal in all the districts which was low in nutrient content. The feeding of

concentrates was not practiced in required amount because livestock are traditionally reared in all the districts (Sah, *et al.*, 2018).

This study gives us important information about milk production, showing that cow produces an average of 10.26 liters per day. However, the prices of milk in the market can change a lot, and this tells us that we need to have fixed prices and make sure farmers get fair pay. There are other studies by Upadhyaya *et al.* (2018), which found an average daily milk yield of 9.24±0.21 liters per cow in Chitwan, and by Poudel *et al.*, (2023), which documented an average of 8.26 liters. The higher average milk production in our study area could be because we looked at a smaller group of cows, and there are more crossbred dairy animals in our area.

Our study's data aligns with research conducted in Chitwan by Pandey, *et al.*,2023, indicating that the most prevalent diseases in the study site were mastitis (63.16%), followed by infertility (13.16%), milk fever (10.53%), helminths (7.89%), and other conditions such as abortion, poisoning, diarrhea, and viral diseases like lumpy skin disease (5.26%). These findings are consistent with our research results.

Dairy farmers encounter a myriad of challenges that encompass high production costs, costly feed, diminished returns, insufficient government assistance, and limitations in healthcare services, all of which present substantial obstacles. Furthermore, the intricate interaction of factors including land scarcity, labor migration, and difficulties in accessing markets compounds these challenges. Interestingly, these findings are consistent with those reported by Paudel, *et al.*, (2019) and also with (Khanal, 2015).

CONCLUSION

The study on feeds and feeding practices of dairy animals in small scale farms in Kavre district, Nepal, provides valuable insights into the intricate challenges faced by regional dairy farmers. The findings highlight the need for interventions to improve feed management and promote sustainable dairy production practices. . The prevalence of zero grazing, coupled with the complex balance of crop residues and supplementary feeds, underscores the multifaceted nature of dairy farming in this region. The variability in milk prices based on fat percentage underscores the urgency of implementing standardized pricing mechanisms to ensure fair returns for farmers.

RECOMMENDATIONS

The key recommendations of the study are as follows:

- Promote the cultivation of forage crops to provide a nutritious and cost-effective feed source for dairy animals.
- Raise awareness of balanced feeding practices and the importance of using quality feed ingredients.
- Provide subsidies for inputs such as seeds and fertilizers, and promote access to technical knowledge and extension services.
- The government should develop policies and programs to support dairy farmers, such as providing access to credit and markets
- The government should standardize the pricing mechanism to ensure fair returns to the farmers

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A RETROSPECTIVE ANALYSIS OF TRENDS IN INFLUENZA VACCINATION UPTAKE AT SUKRARAJ TROPICAL AND INFECTIOUS DISEASE HOSPITAL, KATHMANDU, NEPAL

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ABSTRACT

Influenza is one of the widespread public health problems. Influenza vaccination rates have fluctuated extensively between 2075 and 2081, influenced by the COVID-19 pandemic and seasonal patterns. Annual rates fell sharply between 2076-77 and 2077-78, most likely due to the redirection of healthcare resources and public reluctance to visit facilities, while recovering by 2080-81 with 208 doses. Monthly data showed peaks in winter and monsoon months like Magh and Asar, while in summer months like Baisakh, the doses are low due to low influenza transmission. The females received more vaccinations due to targeted pregnancy campaigns initially, while the males outgrew them by 2080-81, reflecting post-pandemic behavioral changes. Such trends highlight the effect of the pandemic on vaccination rates, besides underlining adaptive strategies in response to any health crisis and seasonal outbreaks.

Key words: Adaptive strategies, COVID 19, health crisis, pandemic

INTRODUCTION

Influenza is an infectious respiratory illness caused by influenza viruses that spreads easily through close contact with an infected person(WHO, 2024b). Influenza pathology was widely examined during three pandemics in the 20th century, with the most recent occurring in 1968 (Kuiken and Taubenberger, 2008) killing up to 100,000 individuals in the United States of America (USA) alone (Taylor, Boulos and Memoli, 2021). The pandemic's impact on public health

remains uncertain, despite the possibility of an influenza-related pandemic (Taubenberger and Morens, 2006).

Influenza affects 10-20% of the global population annually (Peasah *et al*., 2013) with an estimated 3-5 million cases of severe illness and about 290,000-650,000 deaths globally (WHO, 2024b). Vaccination is the most effective way to prevent infection (World health organization, 2022) and serious complications caused by influenza viruses (WHO, 2024a). Vaccination against influenza averted 7,900 influenza-related deaths, 4.8 million influenza-related medical visits, 9.8 million influenza-related illnesses, and 120,000 influenza-related hospitalizations in USA (Centres for Diseases Control and Prevention [CDC], 2024). Thus, enhanced global influenza epidemiological research is crucial for allocating life-saving resources like vaccines and antiviral medications, (Fischer *et al.*, 2014). In Nepal, influenza vaccination campaigns have played major role in mitigating the disease's burden (Jha *et al.*, 2020). Sukra Raj Tropical & Infectious Disease Hospital, a leading referral hospital in the country, plays a critical role in administering vaccines and monitoring influenza trends. Understanding vaccination patterns, timely management and preparedness is essential for optimizing immunization strategies and addressing gaps in coverage to control possible outbreaks in Nepal (Acharya *et al.*, 2020).

This study aims to analyze influenza vaccination trends at Sukra raj Tropical & Infectious Disease Hospital from 2075- 2081 B.S. (2018-2024 A.D), focusing on temporal patterns, seasonal variations, and gender-based differences. By examining data spanning six years, this research seeks to identify key trends and provide evidence-based recommendations to enhance vaccine coverage and improve public health outcomes.

MATERIALS AND METHODS

Study design

This research employed a retrospective descriptive study design to analyze vaccination trends.

Data source, management and analysis

Vaccination records were obtained from Sukra Raj Tropical and Infectious Disease Hospital's record section, covering six fiscal years (2075-2081 B.S./2018-2024 A.D.). Data were organized and analyzed using Microsoft Excel 2013. Descriptive statistics were used to identify trends, seasonal patterns, and gender-based differences. Graphical representations and bar charts were created to visualize the findings.

Ethical consideration

Permission to access hospital records were obtained from relevant authorities.

RESULTS AND DISCUSSION

Results

The yearly distribution of influenza vaccinations showed significant fluctuations. In 2075-76, a total of 172 doses were administered, with a sharp decline to 55 doses in 2076-77. Vaccination efforts reached their lowest in 2077-78, with only 4 doses recorded. Recovery began in 2078-79, with 73 doses administered, and followed by a significant increase to 181 doses in 2079-80. The highest vaccination numbers were achieved in 2080-81, with 208 doses recorded (Figure 1).

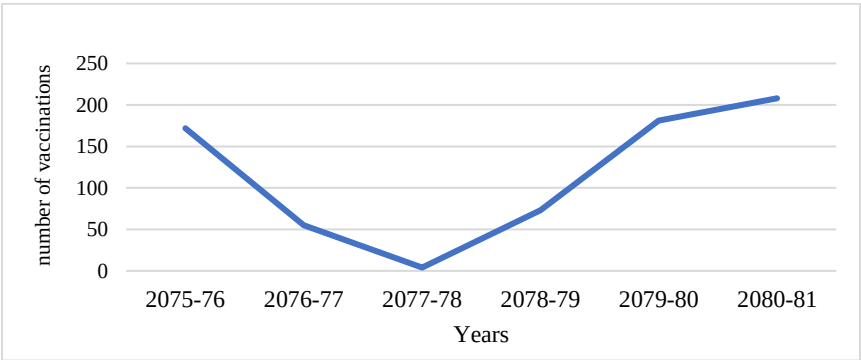

Figure 1. Yearly distribution of influenza Vaccinations from 2075-76 to 2080-81. Source: Sukra raj Tropical and Infectious Disease Hospital, Kathmandu,

The monthly distribution showed that highest vaccination rates were recorded during Magh, in 2075-76. Similarly, Asar in 2079-80 showed a peak for vaccinations. On the other hand, the lowest vaccination numbers were observed in summer and pre-monsoon months such as Baisakh and Jeth, where several years recorded zero doses (Figure 2).

Over the first six years, females received more vaccinations than males. For instance, in 2075-76, 103 females were vaccinated as opposed to 69 males. However, by 2080-81, the trend had shifted, with males receiving 122 vaccinations as opposed to 86 for females. Vaccination rate declined between 2076 and 2077 with no records available for several months (Figure 3).

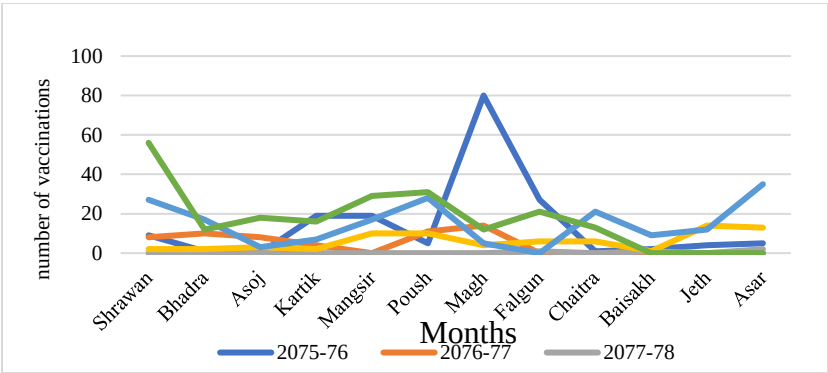

Figure 2. Monthly distribution of influenza vaccination from 2075-76 to 2080-81. Source: Sukra Raj Tropical and Infectious Disease Hospital, Kathmandu, Nepal

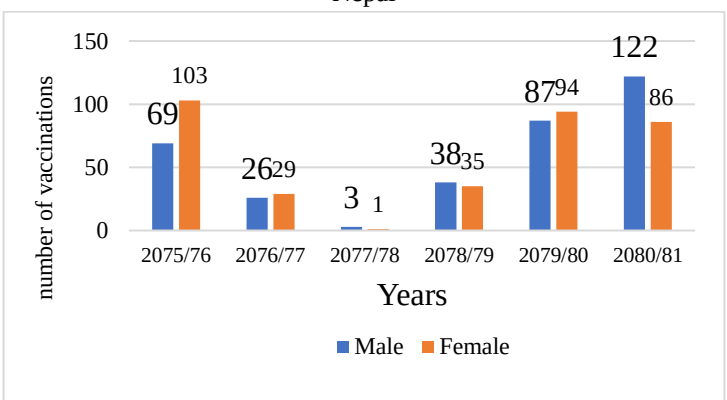

Figure 3: Sex-wise distribution of influenza vaccination (2075-76 to 2080-81) Source: Sukra raj Tropical and Infectious Disease Hospital, Kathmandu, Nepal

Discussion

Annual vaccination rates shows alterations that can be attributed to a variety of factors. The sharp decline observed in 2076-77 and 2077-78, with vaccinations dropping from 172 in 2075-76 to 55 and then 4 doses, is most likely due to the COVID-19 pandemic. Healthcare resources were redirected to pandemic management during this time as hospital policy also shifted to focus solely on COVID patients and public reluctance to visit medical facilities might have also played a role in the decline of vaccination rates. This is consistent with a study conducted in the USA, where vaccine uptake rates decreased in several countries during the COVID-19 pandemic (Vojtek, Wouw and Thomson, 2024). The recovery of vaccination rates in 2078-79 (73 doses) and subsequent increase to

181 doses in 2079-80 and 208 doses in 2080-81 demonstrate that the pandemic had beneficial effects on influenza vaccination rates (Shamoun *et al.*, 2022).

The monthly distribution of influenza vaccination revealed distinct seasonal pattern influenced by Nepal's climatic changes. The peak rates of vaccination, such as during Magh, corresponding to winter in 2075-76, and Asar corresponding to the monsoon period in 2079-80, are concurrent with seasonal changes in Nepal. This might be because of the fact that incidence of influenza infection increases when there is cold (Keswani, Meharda and Gupta, 2019; Sapkota and Upadhyay, 2020) or high humidity (Moura, Perdigão and Siqueira, 2009).

In contrast, the lowest vaccination rates were observed during summer and pre-monsoon months such as Baisakh and Jeth, with several years recording zero doses. These months are typically characterized by lower influenza transmission rates, which may result in reduced intention to receive influenza vaccination (Yang, Cowling and Liao, 2015).

During the initial years of study period, female received more vaccinations. It might be influenced by the strategy of influenza vaccination during pregnancy aiming to safeguard the pregnant women, the fetus and the young infant (Maltezou and Rodolakis, 2021). However, the trend shifted by 2080-81 with male recording higher vaccination number than female as reason for vaccination uptake changed post COVID-19 pandemic. It aligns with the study conducted in Germany where vaccination rate of male increased significantly from 50.5% to 66.2% (Kromer *et al.*, 2024) post pandemic.

CONCLUSION

The study indicated that influenza vaccination trends were dynamic in nature and were influenced by external crises and seasonal variation. The sharp decline during the COVID-19 pandemic underscores the importance of continued routine vaccination even during emergency periods. Peaks in seasonal vaccination rates indicate that well-timed vaccination campaigns must be planned in relation to the high-risk periods for their maximum effectiveness. Furthermore, vaccination trends have shifted toward becoming gender-based, and this may call for a better understanding of behavior and access to reduce disparities. Adaptive and targeted strategies are important in maintaining and increasing vaccination coverage, especially in the face of new future health challenges.

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A STUDY ON COFFEE LEAF RUST AND FARMER'S MANAGEMENT PRACTICES IN LALITPUR DISTRICT

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ABSTRACT

This study was conducted to assess coffee leaf rust (CLR) prevalence and farmers' management practices. Eighty farmers from five VDCs in Lalitpur were interviewed. The survey found diseases to be the primary issue for 60% of farmers, with CLR being the most damaging (80%). White stem borer infestations were also significant (91%). Thuladurlung had the highest disease incidence (71%), while Gimdi had the lowest (57.5%). The average disease intensity was 2.65 on a scale of 1-4, with Gimdi scoring the highest at 2.52 and Pyutar the lowest at 2.22. Most farmers (79%) used Bordeaux mixture, and 48% had received training on CLR. The study identified a lack of cultural practices, organic manure, essential nutrients, and biological control agents, and a need for more research on CLR in Nepal.

Keywords: Coffee leaf rust, Disease, Management, White Stem Borer

INTRODUCTION

Coffee is one of the most important cash crops in Nepal as well as the world. Coffee plants belong to the genus *Coffea* L. of the family Rubiaceae. *Coffea arabica* L. (arabica coffee) and *Coffea canephora* Pierre ex Froehner (robusta coffee) are the two species of Coffea now commercially cultivated throughout coffee-growing countries. Of the two, Arabica produces the better beans – and consists of about 70 percent of the harvest in the world (Acharya et al., 2014).

Nepal produces around 450 metric tons of green bean coffee annually, almost 70 percent of which is exported. In Nepal there are about 27 thousand farmers growing coffee in 40 mid-hill districts. However, organized coffee farming under the Nepal Coffee Producers Association (NCPA) is reported in 22 districts only (Karki, 2012). Among the different agricultural goods produced in and exported from Nepal, the competitiveness of coffee has quickly increased in recent years,

thus contributing to the improvement of rural livelihoods. According to the NTCDB (2014), the production of coffee parchment swelled to 536 tons in 2013/14 from 144 tons in 2003/04 (Dhakal, 2005).

In Nepal, coffee is predominately grown by resource-poor and small-scale farmers under marginal upland conditions (Shrestha et al., 2008). In most cases, coffee cultivation is using unproductive, fallow and lands prone to degradation and thus it helps to conserve soil erosion, degradation of land and also provides 20-25 percent extra income than traditional cereal crops like maize and millet (Chaudhari et al., 2008).

Coffee cultivation has an enormous potential to provide farmers with good employment and income generation opportunities, especially in the mid-hills regions where there is a huge amount of land and suitable climatic conditions for growing coffee successfully. Nepalese coffee has high demand in Japan, America, South Korea, Germany, and the Netherlands. There has been growing interest from both government and non-government sectors in promoting organic coffee and farmers are also motivated to produce coffee owing to higher demand in the international market (Tiwari, 2010).

Insect pests and diseases can significantly affect quality, yield, and cost of production. Farmers in Nepal have limited knowledge of controlling coffee insect pests and diseases. The major insects damaging coffee in Nepal are White Stem Borer (WSB) caused by *Xylotrechus quadripes*, larvae of Red Stem Borer, green scale, mealybugs, and aphids. Grasshoppers, leafhoppers, hairy caterpillars, caseworms, and tortoise beetles are also found as minor pests (Panthi, 2015). The major diseases prevalent in Nepal are Coffee leaf rust, Bacterial blight, Brown Eyespot & Berry Blotch, Phoma, and Coffee Berry Disease.

Hemileia vastatrix causes coffee leaf rust, the most important disease of coffee worldwide. It was first discovered in the vicinity of Lake Victoria in East Africa in 1861 and later identified and studied in Ceylon (Sri Lanka) in 1867. The disease soon spread to much of Southeast Asia and eventually throughout the southern, central, and western coffee-growing regions of Africa. Coffee leaf rust was not known in the western hemisphere until 1970 when it was found in Bahia, Brazil. The rust infects mainly leaves, but also young fruit and buds. Resistant varieties of coffee and fungicides are used to control the disease but have added to the cost of coffee production (Hernández, 2005).

Coffee rust was officially identified by the Plant Pathology Division, Khumaltar, NARC in Nepal in April 2015. Before this, it was reported in Nepal. It had not been noticed in areas where coffee plantations are at the commercial level (Palpa, Gulmi). But nowadays, it has become the major disease of coffee plantations. It occurs all year round, but it is severe during high temperature and high humidity (August-November). It can cause up to 70% loss of the crop. Transmission can occur through wind, water, insects, birds, animals, and even humans (Shrestha, 2010).

Coffee Leaf Rust is a very serious disease of coffee plantations that has severely affected many coffee orchards in Lalitpur and other districts in the country. Coffee farmers and stakeholders have been warned that Nepali coffee might be wiped out within a few years from now if no urgent steps are taken to protect it from the endemic coffee leaf rust disease. The disease was reported to have damaged coffee plantations in *Lalitpur, Kavre, Syangja*, and *Kaski* districts. The chances of the transmission of the disease in other parts of the country are equally high as the disease is transmitted through air. *Thuladurlung, Gimdi, Chandanpur, Pyutar*, and *Kamidanda* are the major coffee-producing village development committees (VDCs) in the Lalitpur district (Pokhrel, 2005). The study was done to know about the incidence and severity of coffee leaf rust in the major coffee production areas of Lalitpur district.

MATERIALS AND METHODS

Lalitpur district was chosen for a field survey due to its high coffee leaf rust incidence. The study focused on five major coffee-producing areas: Chandpur, Thuladurlung, Gimdi, Pyutar, and Asrang. The survey aimed to assess the disease situation in farmers' fields. Eighty farmers were randomly selected from the five VDCs and interviewed about their coffee cultivation practices and disease challenges. Data was collected through field observations, interviews, questionnaires, and secondary sources like reports, books, and journals. Demographic information such as education, family size, ethnicity, occupation, and landholding was recorded. Focus group discussions provided insights into farmers' perceptions and attitudes towards coffee cultivation.

Disease incidence was measured by counting diseased and healthy trees (100 trees per site), and disease intensity (DI) was assessed on a scale of 1 to 4 based on rust pustules per leaf. The DI formula was:

$(n1+n2\times2+n3\times3+n4\times4)/(n1+n2+n3+n4)$(n1+n2×2+n3×3+n4×4)/(n1+n2+n3+n4),

where n represents the number of leaves in each class.

Data from primary and secondary sources were edited, coded, and analyzed using Microsoft Excel, with results presented in tables, bar diagrams, and pie charts.

RESULTS AND DISCUSSION

The total area and Coffee Cultivation Area of the respondents

The total area of all the respondents was 1775 ropani. Among them, coffee production was done in 335 ropani areas (19%). This showed that although coffee was grown as a commercial crop, still majority of the cropping area was still used for cereal crops for subsistence production.

Cropping Pattern

The cropping pattern of the farmers interviewed was diverse. Farmers who knew the diseases and their management approaches had grown shading plants like ipil-ipil, banana, etc. as border plants. Other farmers cultivated coffee with maize as a mixed crop to utilize the land and obtain extra output.

Varieties grown

The respondents when questioned about the coffee varieties used, were only able to tell us that they were local Arabica varieties. This showed that none of the farmers had exact information or were not aware about the variety of coffee grown. However, the varieties grown in the area as obtained from the organization HELVETAS are listed as:

Table 1. Varieties of coffee grown in Lalitpur

Pakamara	Katura
Pacas	Selection-10
Tekisik	Catimor
Tipika	Cabery
Katisik	Bourbon

Irrigation

The farmers of Thuladurlung and Gimdi (33) had no access to irrigation sources and thus left their land unirrigated (41.75%). Among the remaining 47 farmers, the majority of the farmers used sprinkler irrigation (82%) while some of the farmers also had installed drip irrigation systems (18%). The source of irrigation was wells and rivers.

Source of plant material used by the respondents

The majority of the respondents i.e. about 56% used planting materials from their neighbors and relatives. About 28% of the farmers used the saplings from the nursery as a planting material. The remaining 16% of the farmers buy the planting materials from the co-operatives.

Training and Pruning

Among the respondents interviewed 18.75% (15) were trained by INGOs and had the knowledge of training and pruning. The majority of the farmers i.e. 53.75% (43) randomly trained and pruned their plants as per pruning requirements. The remaining 27.5% (22) didn't train or prune their plant.

Major problems Faced by the farmers

The major problem faced by the farmers in the field was that of diseases (60%). After that, the major loss in production occurred due to insects (35%). Weeds also caused a loss in production of coffee production in small amounts (5%).

Diseases

Among the field surveyed area, the major disease was Coffee Leaf Rust (CLR) which had a disease frequency of about 80%, which was similarly followed by Brown eye spot (8%), Berry Blotch (6%), Anthracnose (2%), Brown blight (2%) and twig die-back (2%). This showed that the other diseases were only present in lower intensity and that the coffee leaf rust required immediate attention.

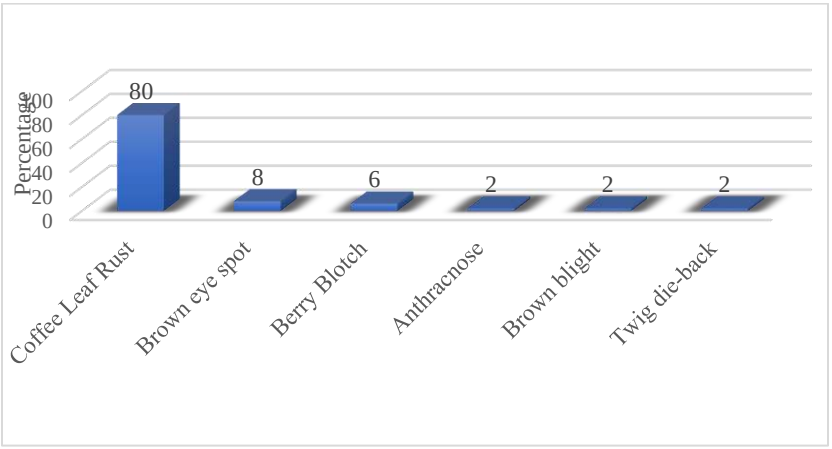

Figure 1. Major diseases of coffee in Nepal

Insect

The major insect pest affecting the locality was White Stem Borer (WSB), affecting about 91 percent of the orchards which was followed by Red stem borer (3%). Other groups of insect pests like grasshoppers, leaf miners, scale insects, rodents, birds etc. in combination had some minimal effect (6%) on production as compared to borers.

Scoring of CLR

Among the 80 respondents, the diseases frequency was found to be 75% on average.

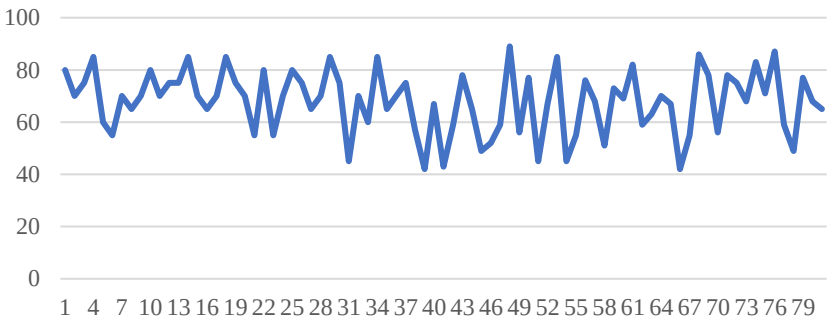

Figure 2. Disease incidence of CLR

The average disease incidence was found to be highest in Thuladurlung with a disease frequency of 71%. The lowest disease incidence was found in Gimdi VDC with a disease incidence of 57.5%.

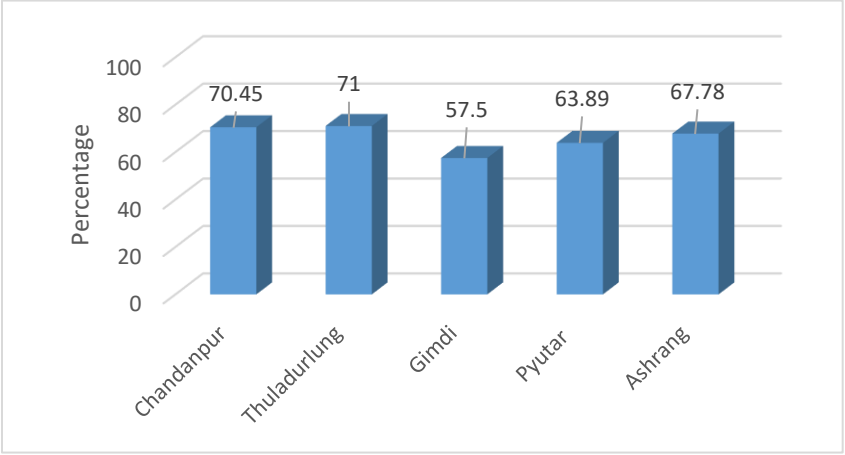

Figure 3. Disease Incidence in Different VDCs

The disease intensity (DI on a scale of 1 – 4) was based on the scale developed by Hindorf & Ritschel. The disease intensity of the farmers' field on average was found to be 2.65.

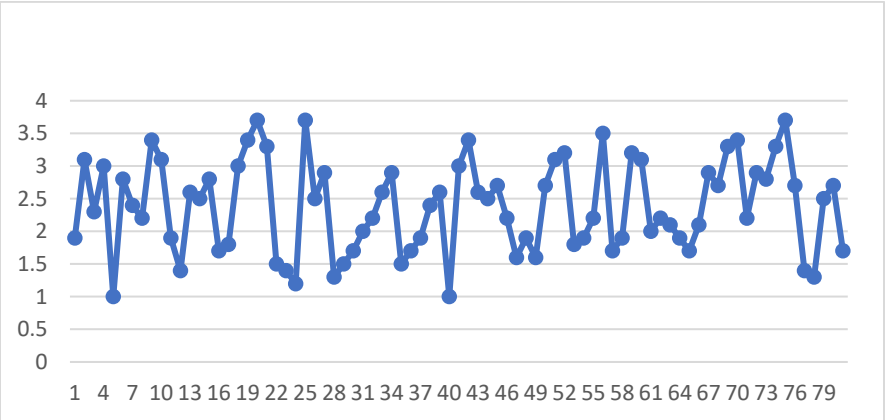

Figure 4. Disease intensity of CLR

The disease intensity was found to be similar in almost all VDCs. However, it was slightly maximum in Gimdi VDC with a score of 2.52. The lowest disease intensity was in Pyutar VDC with a score of 2.22.

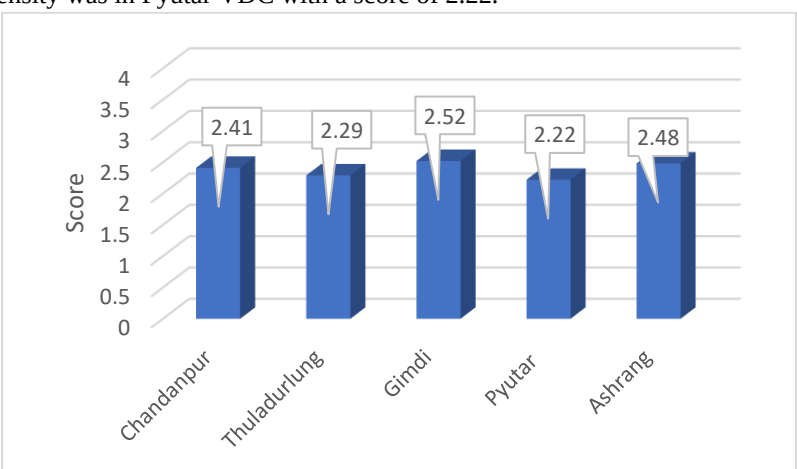

Figure 5. Disease Intensity in Different VDCs

CLR management practices adopted by the farmers

Out of the 80 respondents surveyed, seventy-nine percent of the respondents managed the CLR by using Bordeaux mixture. Eighteen percent of the

respondents used the shading effect to overcome the rust and three percent of the respondents adopted resistant varieties. Since the farmers adopted organic coffee production in the Lalitpur area, chemical pesticides were not used against Coffee Leaf Rust.

Respondent's training status on CLR management

Among the 80 respondents, some of them were found to have received training regarding the CLR management, 38 of them had got training on Coffee Leaf Rust and about remaining respondents had not received training which was conducted by HELVETAS in coordination DADO, NARC, NTCDB, and PPD.

CONCLUSION

The study showed that, there were many diseases and insect pests causing loss to the coffee plantation in Lalitpur district. Among them, Coffee leaf rust (CLR) was one resulting in severe economic losses (80%). The disease was prevalent in every season, increasing its incidence in the rainy season as well as the fruiting season. Many farmers (48%) have received training on coffee leaf rust and management techniques like growing resistant varieties, shading effect, and use of Bordeaux mixture. The disease was found to be controlled to some extent by the use of the above management practices. Still, the incidence of the disease was high, and further control measures were required. The farmers did not use any chemical pesticides in their fields as the area was an organic coffee production site. Also, botanical pesticides were not used for the management of the diseases. The farmers did not have proper knowledge of IPM practice and awareness. Also, no efforts were made to manage the incidence of white stem borers. The farmers lacked the use of organic manures in the field and there was a serious ignorance of the cultural practices. Weeding, applying nutrients, field sanitation, etc. was not proper in the coffee-cultivated fields. It revealed that there was a lack of research activities on coffee leaf rust in Nepal. Since the occurrence of this disease is very high, researchers and government officials engaged in agriculture should be encouraged to conduct more research activities on this disease, rather than depend on foreign journals and articles for disease management. The major focus of the research should be to learn about CLR epidemiology and control measures.

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EVALUATION OF MORTALITY MAGNITUDE AMONG HOLSTEIN FRIESIAN CALVES AND ITS RISK FACTORS EVALUATION IN AN ORGANIZED FARM OF QUETTA PAKISTAN

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ABSTRACT

A 24-year (1999-2022) retrospective study investigated calf mortality and its causes in Holstein Friesian calves. Divided into eight periods, the data explored how time, season, sire, sex, age and cause of death impacted mortality. Female calves exhibited significant variation ($P<0.01$) across these periods. The highest mortality (28%) for females occurred during period 4 (2008-2010), while the lowest overall mortality (5% for both sexes) was observed in period 6 (2014-2016). Season also significantly affected ($P<0.01$) mortality in both sexes and overall. Spring had the highest rates (16% overall, 13% male, 21% female), while summer comprehended the lowest (4% overall, 2% male, 8% female). Interestingly, sire selection played a crucial role on mortality, calves from natural sires had the highest mortality (25%), whereas calves born via artificial insemination with imported semen from different bulls exhibited varying mortality rates. No clear pattern emerged in the overall mortality across different age groups. Finally, a significant relationship ($P<0.01$) was observed between calf mortality and occurrence of various diseases. Gastrointestinal diseases were the leading cause of death (44%), followed by a group of other diseases (25%) including lower mortality causes like respiratory (13%), Foot and Mouth Disease (10%) and the lowest mortality observed was attributable to tick-borne illnesses (8%). These findings highlight potential risk factors like season, sire selection and disease prevention strategies to reduce calf mortality and morbidity in Holstein Friesian herds.

Keywords: Calf mortality, Dairy cattle, Holstein Friesian, Risk factor, Quetta

INTRODUCTION

Peri-urban commercial milk production in Quetta has grown rapidly in recent years to meet the growing demand for fresh milk in the city. Dairy farms in Quetta typically have herds of 20 to 600 cattle, almost all of which are adult females. Cross breeding with exotic European dairy breeds has also helped to establish a significant number of herds of crossbred cows in and around Quetta, which produce two to three times more milk than the local cattle for the same cost.

In the late 1970s, Livestock and Dairy Development Department, Government of Balochistan devised a dual-purpose strategy to address the persistent milk shortage in the region. The strategy had two primary goals; to introduce modern commercial dairy farming practices including scientific feeding and management methods and to establish elite cattle herd for production of genetically superior young bulls for production of male germ plasm and its dissemination through artificial insemination. These practices were to be showcased on designated farms to educate progressive farmers about contemporary farming techniques, and to facilitate the accessibility of high-yielding livestock to farmers at the grassroots level.

The ultimate aim of this strategy was to boost milk production within the province, reducing its reliance on milk imports from other regions. This project proved successful, leading to continued growth and development in Balochistan's livestock sector, making a substantial contribution to its economy.

To fulfill this approach, provincial Livestock & Dairy Development Department established Holstein Friesian Cattle Farm with the funding of Asian Development Bank (ADB) during the years 1977–79 with the import of 100 pregnant heifers and 2 breeding bulls from Denmark, housing them at Government Dairy Farm in Quetta Balochistan. Nucleus stock at the farm has been raised effectively, environmental constraints have limited the exploitation of its genetic potential. Production data spanning the past twenty-four years is available for various categories of animals and is crucial to utilize this data to assess the herd performance.

The primary objectives of this study was to leverage the accessible data to monitor disease incidence and mortality rates, pinpoint underlying issues and propose strategies to rectify these challenges, thus improving herd health and productivity and economic outcomes.

MATERIALS AND METHODS

Study Area

Quetta, the capital of Balochistan is the largest province of Pakistan from land-stretch constituting approximately 43% of the entire country land, holds a significant place. It is Pakistan's tenth largest urban center, boasting a population of 2.595 million with a growth rate of almost 3% (Census, 2023)**.** Located between $30^0$12'34" N and $67^0$01'05" E absolute locations (Quetta Data, 2024), and nestled in the Southwestern region of Pakistan, Quetta finds itself cradled within a valley, hemmed in by towering mountains from all directions. Notably, Quetta stands as Pakistan's lone high-altitude major city, with an average elevation of 1680 meters (5510 feet) above sea level. The geographic landscape surrounding Quetta presents a challenging terrain, characterized by arid conditions and predominantly mountainous terrain. Here, rainfall remains scarce, typically falling within the range of 100 to 300 millimeters per year, and temperatures exhibit extreme fluctuations between the scorching summers and frigid winters. The city has endured recurring episodes of drought, sudden flash floods and seismic tremors (Quetta geography and climate data, 2023).

Data Collection

In this study, raw data regarding death of Danish Holstein Friesian cattle calves stationed at Government Dairy Farm in Quetta Balochistan, Pakistan were taken from the record sheets and annual reports of the farm over a period of twenty-four years i.e. from January 1999 to December 2022 while excluding stillbirths and abortions.

At the farm newly born calves were identified by ear tagging, placed in individual pens and fed colostrum at the rate of 10% of body weight (twice / day) for consecutive three days and later on milk is offered for 90 to 106 days of age along with offerings of other feed ingredients (green fodder / corn silage, wheat straw and concentrates). While timely vaccination and routine deworming are performed as per schedule.

Calves were reared without any preference of sex, male calves are also remaining on high demand from progressive farmers and different local / national level organizations for breeding purposes whereas female calves play a crucial role in future herd replacement, progeny testing and / or production of superior class male production.

The dataset consisted of precise details about individual animals, including but not limited to their date of birth, date of demise, gender, genetic lineage (relative sire / dam), seasonal attributes and the causative factors leading to mortality. Rough data for pre-processing were undertaken to ensure its suitability and subsequent statistical analysis. The main objective of this analysis was to explain mortality patterns within distinct age cohorts present within the herd.

Data Classification

Over a duration of twenty-four years, the data collection period was divided into eight distinct periods, each spanning three years. These periods were characterized as P1 (1999–2001), P2 (2002–2004), P3 (2005–2007), P4 (2008–2010), P5 (2011–2013), P6 (2014–2016), P7 (2017–2019) and P8 (2020–2022). Furthermore, each year was characterized into four seasons: Spring (March to May), Summer (June to August), Autumn (September to November) and Winter (December to February), respectively.

Moreover, to investigate the effects of different diseases on calves of different ages, the calf data were divided into five age groups: 1–7 days, 8–21 days, 23–60 days, 60–106 days and young stock up to one year of age.

The data encompass information about calf births, which resulted from either bull service performed at the farm and / or the use of imported semen as indicated in the relevant table.

To facilitate a meaningful comparison of mortality rates associated with various diseases, the data were classified into several categories; including *Gastro-intestinal* conditions (primarily diarrhea or complex syndromes involving diarrhea), Respiratory ailments (mostly Pneumonia or complex respiratory illnesses), Tick-borne diseases (encompassing *Babesiosis*, *Anaplasmosis* and *Theileriosis*), Foot & Mouth Disease and other fewer common diseases / conditions such as Navel ill, Anaphylactic shock, *Sepsis*, *Colibacillosis*, liver *cirrhosis* and lumpy skin disease.

Statistical Analysis

The data were entered and compiled in Microsoft Excel spreadsheet and analyzed using the procedure described by Snedecor and Cochran (1991). The mean values and proportions were calculated using the descriptive statistical functions in Microsoft Excel.

RESULTS AND DISCUSSION

Incidence of mortality by time period

The data regarding mortality incidence across various time periods is presented in Table 1. A chi-square test of independence was conducted to investigate the relationship between time periods and the mortality of male calves, female calves, and overall mortality for both genders.

The results of the chi-square test demonstrated that there was no substantial association between the mortality of male calves and different time periods ($p>.05$). Likewise, no significant relationship was observed between mortality among all calves and varying time periods ($p>.05$). However, a significant relationship was detected between the mortality of female calves and different time periods ($p<.05$).

The highest percent overall mortality observed was (14% in P4), mortality of male calves (12% in P1) and mortality of female calves (28% in P4), while the lowest percent overall mortality, mortality of male calves and mortality of female calves happened as 5% in P6; 3% in P7 and P8 whereas 5% in P6, respectively.

Our findings align with the observations of Haley et al. (2016); Gupta et al. (2016); Hossain et al. (2013); Khattab et al. (2013); De Vries and Veerkamp (2011); George et al. (2010); Prasad et al. (2004); Somavanshi (1995); Rawal and Tomear (1994) and Debnath et al. (1990), all these workers reported a higher incidence of mortality in female calves compared to their male counterparts. This increased mortality in female calves can be attributed to their smaller size and weaker constitution at birth, making them more susceptible to hypothermia, Pneumonia, and other diseases. It may also be linked to the prevailing environmental conditions, including climatological and management features.

While contrary to this Kharkar et al. (2017) and Islam et al. (2005) noted higher mortality in male calves, more likely it may be due to the experience dystocia or difficult birth, which can further increase their risk of mortality.

Season-wise incidence of mortality

The data concerning mortality incidence across various seasons is presented in Table 2(a). A chi-square test of independence was conducted to investigate the relationship between different seasons and the mortality of male calves, female calves, and overall mortality for both genders. The findings obtained from the chi-square test revealed a statistically significant association among the variables

under investigation, specifically in relation to the mortality rates of male calves, female calves, and overall mortality, across different seasons ($p<.05$).

Highest mortality rates were observed during the spring season, with an overall mortality rate of 16%, while 13% in male and 21% in female calves. Conversely, the lowest mortality rates were recorded during the summer season, with an overall mortality rate of 4%, while 2% in male and 8% for female calves. Our data analysis revealed a significantly higher incidence of calf mortality during early spring, as 44% of spring season's mortality, this was followed by mid-spring with 36% and late spring with 20% of the total mortality **Table 2(b)**. These findings corroborate those reported by NAHMS (2017); Kharkar et al. (2017); Kumar et al. (2017); Heuser and Green (2013); De Vries et al. (2007) and Kemp et al. (2002), further strengthening the consistent observation of increased calf mortality in early spring. This pattern may be attributed to the unpredictable weather conditions specific to this season, posing a greater challenge to calf resilience and survival. Early spring in Quetta is characterized by alternating periods of cold and occasional wet conditions, interspersed with sudden warm spells. These abrupt climatic shifts can disrupt the thermoregulatory processes of newborn calves, impairing their ability to maintain a stable internal body temperature. This, in turn, increases their susceptibility to hypothermia, pneumonia and other respiratory infections.

Influence of Sire on calves' mortality incidence

The data pertaining to the impact of sire on the incidence of mortality in calves is presented in Table 3. A chi-square test of independence was conducted to explore the relationship between various sires and the mortality of the total calf population. The results of the chi-square test unequivocally revealed a statistically significant relationship among these variables ($p<.05$), affecting both the mortality rate and percentage of mortality in these calves.

The highest overall survival percentage (94%) was observed in the off springs of naturally sired animals. Similarly, survival was consistently low in the calves from dams conceived through artificial insemination with imported semen from different bulls. The data revealed these figures as 97% and 92% in male calves born from bull service and artificial insemination respectively. Same consistent trend was observed in the survival of female calves with 91% and 80% survival rate in female calves sired from natural mating and artificial insemination, respectively.

The data revealed overall mortality rates of 12% and 29% for calves born from bull service and those born from artificial insemination respectively. Study

findings are in agreement with Yeshwas et al. **(**2022) and Wudu et al. **(**2008) who reported that exotic genetic influence is also one of the major risk factors that affects calf morbidity, these findings are also in line with findings of Gunawan et al. (2011) whose data revealed an overall pre-weaning calf mortality of 8.99% in calves produced from artificial insemination than 7.05% in calves produced from natural mating system.

Table 1. Period wise mortality in exotic Holstein Friesian calves in Quetta

Period	Male calves' mortality			Female calves' mortality			Overall mortality		
	No. of Birth	No. of Death	Mortality (%)	No. of Birth	No. of Death	Mortality (%)	No. of Birth	No. of Death	ortality (%)
P1 (1999–2001)	60	7	12	61	10	16	121	17	8
P2 (2002-2004)	93	4	4	68	12	18	161	16	10
P3 (2005–2007)	99	7	7	62	7	11	161	14	9
P4 (2008–2010)	76	7	9	25	7	28	101	14	14
P5 (2011–2013)	56	2	4	50	11	22	106	13	12
P6 (2014–2016)	69	3	4	62	3	5	131	6	5
P7 (2017–2019)	80	2	3	60	6	10	140	8	6
P8 (2020–2022)	64	2	3	57	7	12	121	9	7
Chi-Square Statistics		**21.78**			**51.71**		**22.73**		
P–Value		**0.083NS**			**0****		**0.073NS**		
NS = Non-Significant				*Significant at P <0.05			**Significant at P <0.01		

Table 2(a): Season wise mortality in exotic Holstein Friesian calves in Quetta

Season	Male calves' mortality			Female calves' mortality			Overall mortality		
	No. of Birth	No. of Death	Mortality (%)	No. of Birth	No. of Death	Mortality (%)	No. of Birth	No. of Death	Mortality (%)
Winter	227	11	5	151	26	17	378	37	10
Spring	86	11	13	67	14	21	153	25	16
Summer	195	3	2	162	13	8	357	16	4
Autumn	89	9	10	65	10	15	154	19	12
Total	**597**	**34**		**445**	**63**		**1042**	**97**	
Chi-Square Statistics		**43.42**			**28.96**		**42.53**		
P–Value		**0.00000010****			**0.000061****		**0.0000014****		
*Significant at P <0.05				**Significant at P <0.01					

While these findings were found contrary to those reported by other workers like Philip et al. (2011) and further Lardner et al. (2015) who advocated artificial insemination system more beneficial than that of natural mating system. It is inferred from their studies that natural mating systems often involve the use of older bulls, which are more likely to produce calves with genetic defects that can lead to death. Nevertheless, definitive conclusions regarding the cause of the increased mortality rate cannot be drawn without further investigation and access to more comprehensive data.

Effect of age on calf mortality

The data relating to the mortality in calves of different age groups is shown in Figure 1. A chi-square test of independence was conducted to explore the relationship between mortality and different age groups. The results of the chi-square test did not expose a statistically significant relationship among these variables ($p>.05$), both the total mortality and percentage of mortality in these calves. No legible pattern was visible in overall mortality percent among different age groups.

According to present study, the first 21 days of age was the most critical period of calf life with 62% of the neonatal mortality occurring during this time only. Results in the current study revealed a higher mortality during first 21 days of neonatal life. The results of the present study correspond to the findings of **Mishra et al. (**2015) **and** Gusbi and Hird **(19**83); who reported a mortality incidence of 12.5–26% in cow calves at four weeks of age.

Table 2(b). Effect of early, mid and late spring season on mortality in exotic Holstein Friesian calves, Quetta

Season	Mortality	
	No. of Death	Mortality (%)
Early Spring (March)	11	44
Mid Spring (April)	9	36
Late Spring (May)	5	20
Total	25	100
P–Value	0.32***	0.01*
*Significant at P <0.05;	**Significant at P <0.01	***Nonsignificant P<0.05

The robustness of the findings from the present study is further reinforced by the observations of Moran (2011) and Ahrar and Khan (1991). In their review papers, they reported that neonatal calf mortality within the first month of life accounts for approximately 84% of total mortality, with a particularly high incidence during the third week of life.

Table 3. Birth, mortality and survival data in progenies of both natural and artificial inseminated bulls

Particular	Birth Data	Number Died	Number Survived	% cent Survived	Chi-square Statistics	P value	% cent Died	Chi-square Statistics	P value
Male									
Bull Service (BS)	301	9	292	97	18.24	0.0001**	3	21.32	0.000**
Artificial Insemination (AI)	296	25	271	92			9		
Total	**597**	**34**	**563**						
Female									
Bull Service (BS)	249	23	226	91	17.29	0**	9	25.03	0**
Artificial Insemination (AI)	196	40	156	80			20		
Total	**445**	**63**	**382**						
Overall									
Bull Service (BS)	550	32	518	94	31.17	0**	12	35.77	0**
Artificial Insemination (AI)	492	65	427	87			29		
TOTAL	**1042**	**97**	**945**						
NS = Non-Significant				*Significant at P <0.05			**Significant at P <0.01		

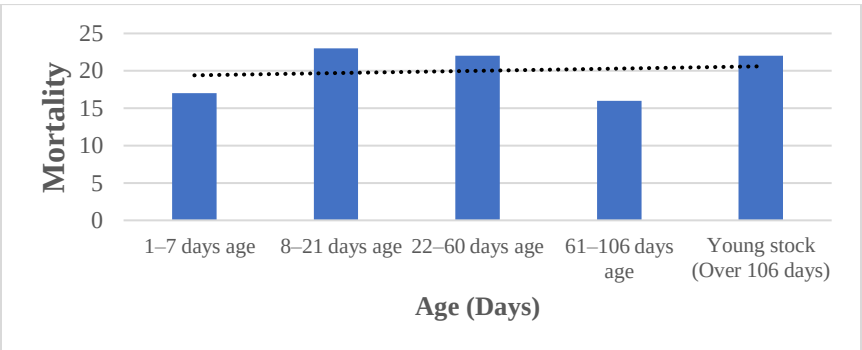

Figure 1. Incidence of total mortality in different age groups of calves (%)

Influence of diseases on Calves Mortality

The data relating to the mortality of calves due to various diseases is shown in the Table 4 (a) and (b) below. A chi-square test of independence was conducted to explore the relationship between mortality and different diseases.

The results of the chi-square test revealed a statistically significant relationship among these variables ($p<.05$), both on the mortality and percentage of mortality due to various diseases in these calves.

Occurrence of gastro-intestinal diseases was found as the main cause of mortality with highest mortality rate (44%), it was followed by group of other diseases – including diseases that erupted in minor numbers (25%), which was followed by respiratory diseases (13%), FMD (10%) and Tick-borne diseases (8%). Obviously, gastrointestinal diseases were the main cause of mortality which was followed by respiratory diseases.

Previous findings also agreed with our findings whom stated the two most common causes that affect calves' mortality are gastrointestinal disorders and respiratory disease from birth to 3 to 6 months of age group life; and these causes were influenced by housing conditions, colostrum intake and feeding management of calves (Abebe et al. 2023; Ahmedin and Assen 2023; Alemu et al. 2022; Yeshwas et al. 2022; Gomes et al. 2021; Hadgu et al. 2021; Hordofa et al. 2021; Tsegaw et al. 2020; Sarita et al. 2020; Pathak et al. 2018; Kharkar et al. 2017; Kranti et al. 2017; Fentie et al. 2016; Islam et al. 2015; Mishra et al. 2015; McCorquodale et al. 2013; Bhat et al. 2012, Torsein et al. 2011; Balvir et al. 2009; Wymann et al. 2006; Islam et al. 2005; Verma et al. 1996; Rao and Nagarcenkar 1980).

Table 4 (a). Incidence of total mortality in calved due to different diseases

Diseases	**Mortality**	**Mortality (%)**
Gastro-intestinal	83	44
Tick Borne	16	8
Respiratory	24	13
Others	48	25
Foot and Mouth Disease	18	10
Chi-Square Statistics	84.78	44.7
P–Value	0.00**	0.00**
*Significant at P <0.05		**Significant at P <0.01

In accordance with earlier research by Ahrar and Khan (1991), the current study demonstrates a clear association between neonatal calf mortality and various infectious agents, including rotavirus, coronavirus, Entero-pathogenic *Escherichia coli*, *Salmonella* species, and *Cryptosporidium*. These findings offer further support for the established link between these pathogens and calf death. Ahrar and Khan (1991) also identified several other significant contributors to calf mortality, including immunodeficiency, seasonal variations, difficult parturition, and inadequate management practices. These factors highlight the multifaceted

nature of calf mortality and emphasize the dire need for comprehensive preventative strategies.

Table 4 (b). Mortality due to different diseases as % calf mortality due to various diseases in different age groups

Diseases	**Age at death**				
	1–7 Days	**8–21 Days**	**22–60 Days**	**61–106 Days**	**Young Stock (Over 106 Days)**
Gastro-Intestinal	17	30	25	9	19
Tick Borne	6	6	6	38	44
Respiratory	29	29	4	17	21
Others	19	15	32	17	17
Foot & Mouth Disease	5	22	17	28	28
Chi-Square Statistics	123.94				
P–Value	0.00*				
*Significance at P <0.05		**Significant at P <0.01			

CONCLUSION

Young stock management is a major concern in many small dairy farms of the area. Age group from birth up to one year age receive insufficient care due to their non-income generation character for many months. Especially from birth to three months age which is the most expensive period of a dairy animal's life. And emphasis on prevention is critical, limiting need for subsequent intervention, particularly in the management of gastrointestinal and respiratory system diseases.

Mortality in early age of calf not only decreases milk and meat production, but also lowers the genetic pool by making problems in the breeding programmes. Furthermore, to run a profitable dairy business, it is an utmost need of the situation to control mortality in calves and young stock. Study shows different causes of calf mortality which can be minimized so that economic losses shall also be decreased. If we lower down the calf mortality rate in these days we can get a better opportunity for economic and genetic improvement in the herd.

To achieve these objectives, a strict dairy management plan including biosecurity and prophylactic measures along with a balanced nutritional plan should be

devised and implemented to control mortality in their early age period, particularly considering the prevailing dairy practices in this enterprise.

In general, for a successful dairy farming development programme and particularly in livelihood initiative, information sharing regarding the risk factors of calf morbidity and mortality among dairy farmers is dire need of this enterprise.

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MORPHOMETRICS AND MANAGEMENT OF CHINESE CITRUS FLY, *Bactrocera minax* (Enderlein) (DIPTERA: TEPHRITIDAE) IN KATHMANDU, NEPAL

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ABSTRACT

The study was performed at the citrus orchard of Chhahari Retreat in Budhanilkantha, Kathmandu, examined the morphological measurements of both pupa and adult of Bactrocera minax, with a study from March to July 2023. The average pupal length of the Chinese citrus fly determined 9.44 ± 0.10 mm, with a corresponding breadth of 4.33 ± 0.09 mm and weight of 0.051 ± 0.002 gm. Notably, the body length of adult female B. minax surpassed that of males, measuring at 13.9 ± 0.20 mm compared to 11.93 ± 0.33 mm for males, while females exhibited broader bodies (3.92 ± 0.06 mm) in contrast to males (3.18 ± 0.05 mm). Furthermore, adult females displayed a wider wingspan (22.21 ± 0.23 mm) relative to adult males (21.36 ± 0.30 mm), along with longer wings (9.22 ± 0.16 mm) compared to males (8.86 ± 0.16 mm). The ovipositor length was 4.62 ± 0.62 mm. The average weight of female adults calculated 0.0228 ± 0.001 gm, whereas male adults exhibited an average weight of 0.0141 ± 0.002 gm. This research emphasizes significant morphological differences between male and female flies. Furthermore, an attempt was made to manage this pest through the implementation of Area-wide Control Program (AWCP), involving the application of a lethal protein bait comprising 25% protein hydrolysate and 0.1% abamectin (Great fruit fly bait), through spot application at weekly intervals from 8th May to 24th July 2023. A notable decline in fruit loss was observed, decreasing to 1.24% from the previously recorded 27.68% during the 2023 harvest season. This substantial reduction in overall fruit loss, amounting to a noteworthy 26.44% decrease in comparison to 2022 ($p<0.00$), was effectively attained.

Keywords: Area-Wise Control Program, *Bactrocera minax*, morphometric, protein bait

INTRODUCTION

Citriculture, the cultivation of citrus fruits, holds cultural significance in Nepal, particularly with fruits like Mandarin (*Citrus reticulata*) and Sweet Orange (*Citrus sinensis*) traditionally thriving in the mid hill region. The country indeed serves as a hub for citrus diversity, nurturing numerous species within its borders (Adhikari and GC, 2020). In Nepal, citrus was traditionally grown in the mid-hill's region, but nowadays, it is also grown commercially in the Terai region (Acharya and Adhikari, 2019). Citrus cultivation is done in 66 districts covering 49,306 ha of area (MoALD, 2023). Citrus crops attract many insects, with tropical regions hosting up to three times as many pests as highland and Mediterranean areas due to warmer temperatures and humidity (Hussain et al., 2022*).* The primary insect pests affecting citrus crops include the fruit flies, Asian citrus psyllid, citrus leaf miner, thrips, green stink bug, as well as fruit piercing moths and mites. These pests collectively pose significant challenges to citrus cultivation (FAO, 2021. Research and development organizations dedicated to citrus fruit cultivation must explore novel and environmentally friendly chemical and cultural solutions to effectively address these emerging challenges (Adhikari, 2023).

The Chinese citrus fly (*Bactrocera minax* (Enderlein)) is a highly destructive pest in south-central China, capable of causing complete fruit loss under severe conditions. It has also spread to nearby regions, affecting orchards in Bhutan, northwest India (Sikkim and West Bengal), and Nepal (Xia et al., 2018). This fly's range expanded from China to Nepal through Bhutan and India. Geographically, it is limited to China, Bhutan, India (Sikkim and West Bengal), and Nepal (CABI, 2020). Contrary to the majority of pest species, the males of this species of *Bactrocera* are not attracted to any known chemical lures. Both sexes can be observed using protein bait traps (either protein hydrolysate or protein autolysate), although they also catch a lot of unrelated insects. *B. minax* infestation levels are consistently high, which emphasizes the need for a deeper understanding of its biology and ecology in order to develop and apply more efficient control strategies (Dong et al., 2014). This research has been conducted to investigate the morphology and assessment of the implementation of management strategies for the Chinese citrus fly in citrus orchards in Kathmandu, Nepal.

MATERIALS AND METHODS

Research site: The study was conducted in a problematic citrus orchard in Kathmandu, chosen for its location and compatibility with the field owners, as well as cost and proximity considerations. The site was situated at Chhahari Retreat in Budanilkantha at 1485.17 meters above sea level (27.7863210° N, 85.3542847° E).

Rearing of pupae for adult emergence: A total of 64 maggots were collected on 10th November 2022 from infested sweet oranges. Six transparent cylindrical containers, each 10 cm tall with a diameter of 4 cm, made of smooth, clear plastic, allowing full visibility of the contents, were used. The containers were filled two-thirds with loamy soil, and maggots were placed inside the soil. To prevent the escape of adult flies while allowing for ventilation, the containers were covered with muslin cloth. After the adults emerged, they were used to measure significant morphometric parameters.

Measurement of morphological features of pupae and adult specimens: Morphological analysis of pupae and adult specimens aimed to understand visible attributes during these life stages. A manual Vernier Caliper was used to measure body length, breadth, wingspan, wing length, and female fly ovipositor length as shown in Figure 2. Body length was measured from head to abdomen tip, while breadth was assessed at the mesothorax. Wingspan was measured from one forewing tip to the other, and wing length from joint to tip. Ovipositor length was gauged from abdomen joint to tip. These measurements were conducted to capture various morphological features and dimensions of the studied specimens (Adhikari et al., 2022a). The weight of both pupae and adult specimens was documented using a digital weighing balance (SINKO Level CIE 320g*0.001g) and (OHAUS analytical balance) respectively for precise weight measurements.

A B C D E

Figure 1. Measurement of adult of Bactrocera minax using Vernier Caliper (A: Body length, B: Body breadth, C: Body weight, D: Wingspan, E: Length of wing

Management of Chinese citrus fly, *Bactrocera minax*: The management of Chinese citrus fly (*Bactrocera minax*) involves the use of protein-based baits to attract and control the population of these pests.

Preparation and application of protein bait solution: The solution used in our citrus orchard was prepared by combining water and bait in a 2:1 ratio. The protein bait employed, "Great Fruit Fly Bait", consisted of 25% protein hydrolysate and 0.1% abamectin. The initial step in preparation of solution formation involved counting a total of 93 citrus trees in the orchard. For the application of protein bait, 31 spots were selected initially, with an additional 5 spots chosen to ensure

coverage along the border lines. These spots were marked using colored ribbons tied to branches of selected trees. A mixture consisting of two parts water and one part protein bait was prepared, resulting in a 51 ml solution for each tree (17 ml of bait with 34 ml of water). For one spraying session, a total of 612 ml of protein bait was mixed with 1224 ml of water, totaling 1836 ml (bait + water) sprayed in each session.

12 spraying sessions were conducted weekly at Chhahari Retreat in Budanilkantha. Protein bait application was avoided during rainfall to prevent solution washout. Strategically placed small amounts of protein-based bait on the lower part of leaves ensured accessibility and minimized washout risks. Precautions and sanitation measures were diligently observed during application using a Knapsack sprayer.

Spray session: Weekly applications of spraying took place from 8th May 2023 to 24th July 2023. The specific dates and times of these spraying sessions are provided as follows (Table 1).

Table 1. Details for spraying session

Spray no.	Date of spray	Starting time of spray
1	8th May 2023	1:00 pm
2	15th May 2023	1:00 pm
3	22nd May 2023	2:00 pm
4	29th May 2023	1:00 pm
5	5th June 2023	2:00 am
6	12th June 2023	12:15 pm
7	19th June 2023	1:20 pm
8	26th June 2023	3:00 am
9	3rd July 2023	1:00 pm
10	10th July 2023	1:00 pm
11	17th July 2023	2:00 pm
12	24th July 2023	3:00 pm

Statistical analysis: The data collected were analyzed by using Microsoft excel 2013. The collected survey data were sorted and coded in Microsoft Excel. This organized data was then analyzed using Microsoft Excel 2013.

RESULTS AND DISCUSSION

Measurement of pupae of Chinese citrus fly, *Bactrocera minax*

Table 2 shows the measurements of the pupae of Chinese citrus fly, ranged from 7.8 mm to 10.9 mm in length, with an average of 9.44 ± 0.10 mm. Pupal breadth

ranged from 3.3 mm to 5.8 mm, averaging 4.33 ± 0.09 mm. Pupae weighed between 0.018 gm and 0.084 gm. The average weight was recorded as 0.051 ± 0.002 gm as shown in table 2. Regmi et al., (2023) reported that the average pupal length was measured at 9.9 mm, the breadth at 4.42 mm, and the weight at 0.07 gm.

Table 2. Length, breadth and weight of pupae of Chinese citrus fly, *Bactrocera minax*

Length (mm)		Breadth (mm)		Weight (gm)	
Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
7.8 - 10.9	9.44 ± 0.10	3.3 - 5.8	4.33 ± 0.09	0.018 - 0.084	0.051 ± 0.002

(n = 50), ± SE= Standard Error

Adult emergence of Chinese citrus fly, *Bactrocera minax*

Adult emergence of the Chinese citrus fly was noted in the third week of April, with the highest frequency occurring in the first and second weeks of May. The date of adult emergence was recorded as April 17, 2023. These findings align with the observations of Regmi et al. (2023), who also reported that the emergence of the Chinese citrus fly took place in April and May.

Measurement of adult of Chinese citrus fly, *Bactrocera minax*

The adult Chinese citrus fly displayed a notable range in body dimensions as shown in Table 3, 4 and 5. Lengthwise, the span extended from 11.8 mm to 15.2 mm, with a mean length of 13.9 ± 0.20 mm of female and 9.7 mm to 13.7 mm with a mean length of 11.93 ± 0.33 mm of male. The breadth measurements revealed a variance from 3.4 mm to 4.3 mm, capturing an average breadth of 3.92 ± 0.06 mm of female and 2.8 mm to 3.6 mm with average breadth 3.18 ± 0.05 mm of male. Whereas, Gazmer et al. (2023) measured the adult male fruit flies body lengths ranging from 9.44 mm to 11.65 mm, with an average of 10.10 ± 0.25 mm and adult female fruit flies had an average body length of 11.28 ± 0.18 mm, with body lengths ranging from 10.34 mm to 11.88 mm. Also, the body width of adult female fruit flies is broader, measuring 3.60 ± 0.06 mm (ranging from 3.32 to 3.96 mm), which is notably different from adult males, whose body width is 3.09 ± 0.10 mm (ranging from 2.66 to 3.56 mm). As for the wingspan, the adults showcased a wingspan spectrum of 20.6 mm to 24.8 mm, averaging at 22.21 ± 0.23 mm of female and 19.7 mm to 23.3 mm averaging at 21.36 ± 0.30 mm of male. Delving into weight, the recorded range extended from 0.0041 gm to 0.0294 gm, aligning around an average weight of 0.0141 ± 0.002 gm of male and 0.0065 gm to 0.0308 gm with average weight of 0.0228 ± 0.001 gm of female. According to Adhikari et al., (2022), adult female fruit flies have a larger wingspan (ranging

from 21.55 mm to 25.45 mm) compared to adult males (ranging from 20.40 mm to 24.50 mm). The difference in wingspan between females and males is statistically significant with females having a mean difference of 0.71 mm. Diving further into wing specifics, the range of wing measurements spanned 8.1 mm to 10.3 mm, with an average wing length of 9.22 ± 0.16 mm of female and 7.7 mm to 10.1 mm with average wing length of 8.86 ± 0.16 mm of male. Generally, fruit flies have a wing length ranging from approximately 2 mm to 8 mm Gazmer et al. (2023), although specific species may fall outside this range. Another distinctive feature, the ovipositor length, varied from 5.5 mm to 3.2 mm, showing an average ovipositor length of 4.62 ± 0.14 mm. In a study by Adhikari et al. (2022), it was reported that the typical length of the ovipositor in female *Bactrocera minax* was approximately 4.52 mm. This comprehensive insight into the varied dimensions of the adult Chinese citrus fly provides a holistic understanding of its morphological characteristics.

Table 3. Body length, breadth and weight of adult Chinese citrus fly, *Bactrocera minax*

Sex	Length (mm)		Breadth (mm)		Weight (gm)	
	Range	Mean ± SE	Range	Mean ± SE	Range	Mean ± SE
Male (n=16)	9.7 - 13.7	11.93 ± 0.33	2.8 - 3.6	3.18 ± 0.05	0.0041 - 0.0294	0.0141 ± 0.002
Female (n=19)	11.8 - 15.2	13.9 ± 0.20	3.4 - 4.3	3.92 ± 0.06	0.0065 - 0.0308	0.0228 ± 0.001

Table 4. Wingspan and length of wing of adult Chinese citrus fly, Bactrocera minax

Sex	Wingspan (mm)		Length of wing (mm)	
	Range	Mean± SE	Range	Mean± SE
Male (n=16)	19.7 - 23.3	21.36 ± 0.30	7.7 - 10.1	8.86 ± 0.16
Female (n=19)	20.6 - 24.8	22.21 ± 0.23	8.1 - 10.3	9.22 ± 0.16

Assessment of Chinese citrus fly, *Bactrocera minax* management using protein bait in 2023

A significant decrease in fruit loss was achieved, dropping to 1.24% from the previously recorded 27.68% during the 2023 harvest season. This considerable reduction, amounting to a notable 26.44% decrease compared to 2022 ($p<0.00$), was successfully realized as shown in Table 6. It is clear that the effect of Area-Wide Control Program of Chinese citrus fly using the protein bait in citrus orchard contributed a reduction in mean fruit damage. Similar result was published by Adhikari et al., 2021 entitled “Area-Wide Control Program in management of

Chinese citrus fly, *Bactrocera minax* (Enderlein) (Diptera: Tephritidae), in citrus orchards, Sindhuli, Nepal".

Table 5. Length of ovipositor of adult Chinese citrus fly, Bactrocera minax (Female)

Length of ovipositor (mm) (n = 19)	
Range	3.2 - 5.5
Mean ± SE	4.62 ± 0.62

Table 6. Assessment of Chinese citrus fly, *Bactrocera minax* management using protein bait

Particulars	Fruit loss due to *B. minax* maggots' infestation in 2021	Fruit loss due to *B. minax* maggots' infestation in 2022	Fruit loss due to *B. minax* maggots' infestation in 2023
Mean fruit damage (%)	86.80	27.68	1.24
Variance	34.08	16.31	8.79
Observations	25.00	25.00	25.00
Pearson Correlation		0.11	-0.03
df		24.00	24.00
t Stat		39.63	-25.98
t-test for mean fruit damage % P(T<=t) one-tail		0.00	0.00
t Critical one-tail		1.71	1.71
t-test for mean fruit damage % P(T<=t) two-tail		0.00	0.00
t Critical two-tail		2.06	2.0

Source: Data of 2021 and 2022 (Thapa et al., 2023)

CONCLUSION

The morphometrics study highlighted notable morphological differences between male and female *Bactrocera minax*. Females were consistently larger and heavier than males. The implementation of an Area-wide Control Program (AWCP) using a lethal protein bait led to a remarkable reduction in fruit loss, decreasing from 27.68% in 2022 to just 1.24% in 2023. This substantial 26.44% reduction illustrates the effectiveness of the control measures and demonstrates their significant impact on reducing fruit loss.

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STATUS OF CLIMATE CHANGE AND FOOD SECURITY IN KATHMANDU DISTRICT

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ABSTRACT

Climate change and its impact on agriculture and food security are serious global challenges we are facing today. This study investigates the specific impacts of climate change on agriculture and food security among farmers in Kathmandu district, Nepal. With farmers forming a significant portion of the agricultural workforce, understanding their unique challenges and adaptive strategies is crucial for developing effective interventions. Conducted over three months from April 22, 2024, to July 22, 2024, the research sampled 50 households using simple random sampling techniques. Data collection comprised both primary and secondary sources. Primary data were obtained through semi-structured interviews with respondents, field observations, and discussions with local facilitators, extension workers, and community leaders. Secondary data were gathered from published documents. The study's findings provided a detailed socio-economic profile of the respondents. Agriculture was the primary occupation for 67% of respondents, highlighting their dependence on this sector for livelihood. Land ownership patterns varied, with 34 respondents owning their land, 6 practicing sharecropping, and a few relying on leased land. Irrigation was primarily sourced from boreholes (58%), supplemented by drip irrigation, rainwater harvesting, and natural rainfall. Despite their efforts, 62% of respondents reported insufficient food production, leading to prevalent food shortages. Food insecurity was a significant issue, with 74% of respondents experiencing annual food shortages and only 24% having food security throughout the year. Many respondents resorted to purchasing food or working as laborers to meet their daily needs.

Keywords: Adaptive strategies, agriculture, climate change, food security, irrigation methods

INTRODUCTION

Climate change poses a formidable threat to agriculture and food security worldwide, and Nepal, with its diverse topography and agrarian economy, is particularly vulnerable to its impacts. Among the most affected are farmers in Kathmandu district, whose pivotal roles in agriculture are increasingly jeopardized by shifting weather patterns and environmental degradation (Gautam, 2021).

Nepal's agricultural sector is a cornerstone of its economy, contributing significantly to GDP and employing a large portion of the population. However, the sector faces mounting challenges exacerbated by climate change, including rising temperatures, erratic precipitation, and more frequent extreme weather events (Gautam, 2021). Climate change has worsened the living conditions of especially resource-poor households dependent on subsistence farming, fisheries and forest resources (Rajbhandari, 2024).

Kathmandu District, while mostly urban, still has rural areas where farming is important. Many farmers here are struggling to deal with changes in weather patterns, such as less predictable rain and warmer temperatures. These shifts not only reduce crop yields but also make farming more difficult by increasing problems like soil degradation and pest infestations. Studies show that the production of important crops like rice and maize in Nepal has dropped by 10-20% in recent years due to these climate-related challenges.

Food security, which means having reliable access to enough nutritious food, is at risk in places like Kathmandu. As climate change disrupts farming, many farmers in the region face uncertain futures. This thesis aims to understand how farmers in Kathmandu District perceive climate change and how these changes are affecting their ability to produce food. By learning about their experiences and challenges, we can better understand the current status of food security in the region and identify possible solutions to help farmers adapt to the changing climate.

MATERIALS AND METHODS

The study was conducted in Kathmandu district, located in the Central Bagmati Province of Nepal. This district lies within the subtropical highland climate zone and experiences four distinct seasons: spring, summer, monsoon, and winter. The elevation ranges between approximately 1,300 and 1,400 meters above sea level, with the Kathmandu Valley covering around 50 square kilometers. The selected study areas included Gokarneshwor, Budanilakantha, Shankharapur, Kageshwori,

Tarkeshwor, and Nagarjuna, representing urban and peri-urban areas. The region, serving as the headquarters of the Bagmati Zone, has a dense population of about 1.5 million people, with a population density of approximately 30,000 per square kilometer. Nepali is the primary language spoken in the area, which operates on Nepal Standard Time (UTC+5:45).

The study was conducted over three months, from April 22, 2024, to July 22, 2024. A total of 50 households were selected using a simple random sampling technique to represent the urban population of Kathmandu district. With an estimated urban population of 1.5 million, a sample size formula for proportion-based studies was applied, considering a 95% confidence level, a 10% margin of error, and a proportion of 0.5 to account for maximum variability. This calculation indicated that 50 households would provide a representative sample. The sampling ensured that the selected households reflected the diverse socio-economic characteristics of the district.

Data collection involved a combination of primary and secondary sources. Primary data were gathered through semi-structured interviews with respondents, field observations, and discussions with facilitators, extension workers, and community leaders. These methods provided detailed insights into the experiences and challenges faced by the study population. Secondary data were collected from books, journals, research papers, and annual publications of various institutions. Additional resources such as internet materials and publications from relevant organizations further supported the comprehensive analysis of the research topic.

RESULTS AND DISCUSSION

Primary occupation of the respondents

The involvement of people in any activity which plays a primary role to generate income and fulfill their need to sustain their livelihood of own self and their family is referred as primary occupation. In the study site, the major occupation of the respondents was found to be agriculture with the highest frequency and percentage of 67 (Figure 1). The frequency and percentage of respondents having secondary occupation as service, business and others were percentage of 20, 5 and 8. In addition, the above figure also shows that only 16 Respondents had a primary occupation other than agriculture with the percentage of 8. This concludes that the majority of the respondents in the study site were dependent upon agriculture for their livelihood.

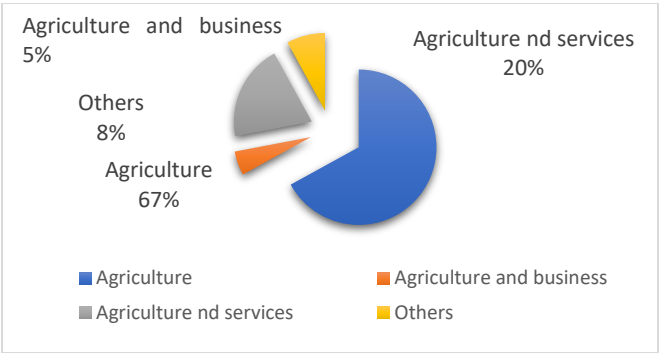


Figure 1. Primary occupations of respondents in the study site

Types of land

The type of land indicates what sort of land the respondents own. For example: Own land, lease land, share cropping. Out of the total interviewed respondents, only 34 had their land, 6 respondents employed shared cropping system, 8 respondents owned land as well as others' land and 2 respondents had their own as well as leased land (Figure 2).

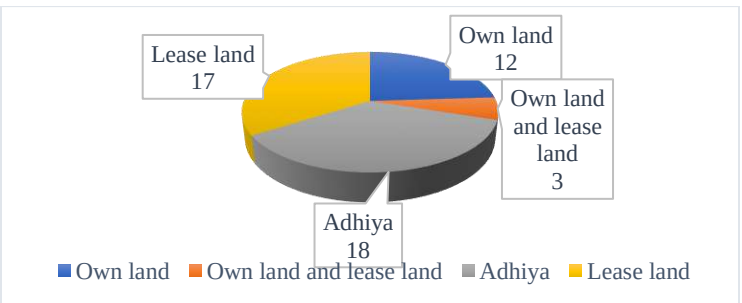


Figure 2. Types of land cultivated by the respondents

Thus, the above figure 2 clearly showed that the 24% of respondents that have their own land whereas the percentage of others land i.e. Adhya was 36. People with lease land was 34% whereas, own land and lease land was 6%.

Perception of farmers on climate change

Over 86% of respondents participating in the questionnaire surveys and focus group discussions (FGDs) indicated that they had observed significant changes in weather patterns, including rising temperatures, erratic rainfall, an increase in the number of hot days, and a decrease in cold days. Furthermore, 32% of the

participants in the household surveys and FGDs reported that the growing frequency and severity of floods and flash floods have adversely impacted food availability. These extreme weather events have caused extensive damage to agricultural land, resulting in the loss of productivity across several hectares and leaving large areas of farmland barren. This alarming trend highlights the critical challenges faced by farmers and communities as they struggle to adapt to changing climatic conditions and the consequent effects on their livelihoods and food security. Bhatta, Nepal and Rajbhandari (2024) have reported similar findings. Rajbhandari (2024) has reported that frequently more intense and extreme weather conditions have had adverse impacts on food production, availability, accessibility and supply in rural areas; and that ultimately had magnified food insecurity.

Types of irrigation method and sources

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. In this survey site, almost all of the respondents had irrigation facilities.

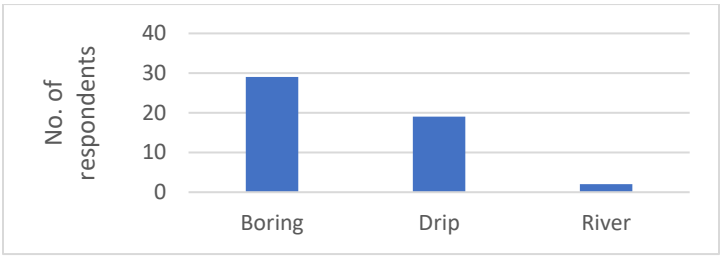


Figure 3. Types of irrigation methods and sources used by respondents

The main source of irrigation in the study area was boring which was used by 58% of respondents. Similarly, drip, rainwater and rainfall was also used as a source of irrigation by 38% and 4%, respectively.

Impact of climate change on agriculture

Thirty four percent of farmers reported a decline in rice and wheat production due to the changing and unpredictable onset and withdrawal of monsoon and winter rainfall. These alterations in timing and rainfall patterns have significantly impacted farmers' decision-making regarding seedbed preparation and crop transplantation. Eighteen percent of farmers shared their challenges of having to transplant older paddy and millet seedlings as a result of delayed rainfall, illustrating the direct effects of climate variability on agricultural practices. The loss of agricultural land has exacerbated the economic burden on these farmers,

increasing their reliance on market access for food. Flooding has led to the direct loss of arable land, crops, livestock, and critical infrastructure, including road networks, foot trails, and water supply systems. Additionally, prolonged dry spells and reduced water availability for both household and agricultural use—particularly during the winter—have further diminished agricultural productivity. The winter dry spell has adversely affected winter crops and vegetables, such as wheat and potatoes, in agricultural zones that rely heavily on this produce. The perceived decrease in winter rainfall has reduced the area sown with winter crops, jeopardizing the food security of communities and smallholder farmers who depend on winter agricultural production and sales (Karki, Thapa,and Sharma, 2021).

Moreover, 73% of farmers noted that rising temperatures have led to decreased soil moisture, which in turn has contributed to lower agricultural yields. These rising temperatures have also negatively impacted livestock rearing and the production of quality livestock-derived products. Farmers have observed an increase in pests, crop diseases, and weed infestations, which they attribute to the rise in temperature and irregular rainfall patterns. They reported specific challenges, including the increased incidence of aphids and caterpillar invasions in vegetables, as well as borer, leaf blight, and seed blight issues in rice plants. Consequently, farmers have had to invest more in weeding, chemical fertilizers, insecticides, pesticides, and irrigation to combat these problems (Martin, 2011).

Additionally, the study highlights a trend of male members migrating to Gulf countries in search of alternative livelihood opportunities. This migration has resulted in an increased overall workload for those left behind, leaving farmers, children, and the elderly in vulnerable situations as they cope with climate-induced hazards such as floods and landslides. The combination of economic strain and environmental challenges underscores the urgent need for adaptive strategies to support farmers in navigating these complex issues (Buisson, Clement, and Leder, 2022).

Impact of climate change on food security

Food availability:

1. **Agricultural Productivity**: According to 56% of respondents, climate change has resulted in altered precipitation patterns, rising temperatures, and extreme weather events, all of which adversely affect crop yields. Farmers indicated that these changes could lead to a decrease in the availability of local food supplies.
2. **Pest and Disease Proliferation**: Warmer temperatures have facilitated the spread of pests and crop diseases, posing further threats to

agricultural productivity and food security, as noted by 39% of respondents. A significant percentage of farmers reported that this increase in pests and diseases has negatively impacted food availability.

3. **Crop Diversity**: Due to changing local conditions, traditional crops have become less viable, prompting some farmers to shift toward monoculture practices. Only 5% of farmers indicated that this trend has contributed to a reduction in the overall availability of diverse food options.

Food Access:

1. **Economic Strain**: Climate-induced disruptions in agriculture have resulted in rising food prices, making it increasingly challenging for low-income households to afford nutritious food. As a consequence, 28% of households are struggling to access adequate food, contributing to food insecurity.
2. **Infrastructure Challenges**: A significant 72% of farmers reported that inadequate infrastructure, including poor transportation and limited market access, has hindered their ability to bring products to market. This issue has been further exacerbated by disruptions caused by climate-induced weather events.

Status of food sufficiency from their agricultural production

The survey results revealed that only 38% of farmers reported having sufficient food production from their agricultural activities, indicating a significant level of food insecurity among the farming community (Figure 4). The findings suggested an urgent need for targeted interventions and support systems to enhance food security and improve agricultural productivity for the majority of farmers in the region. Addressing these challenges will be essential for fostering a more resilient agricultural sector and ensuring sustainable livelihoods for farming households as pointed out by Adhikari, 1999.

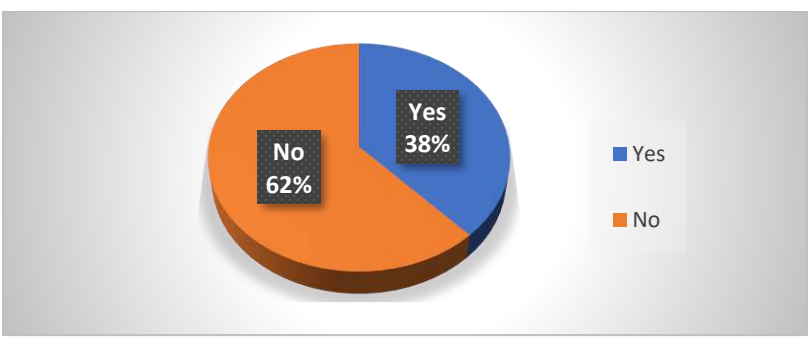
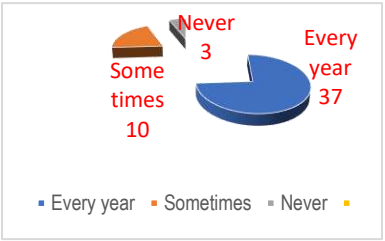


Figure 4. Status of food from their own agricultural productions

Status of problems of food shortage faced by the respondents

The majority of farmers in the study area were facing the problem of food shortage every year.



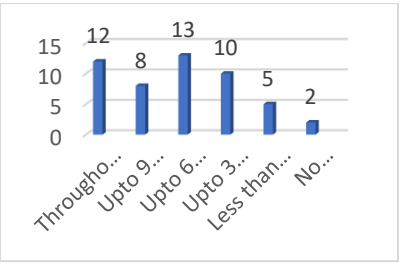


Figure 5. Problem of food shortage Figure 6. Status of food security among respondents

The survey results indicated that a significant portion of respondents experienced food shortages annually, with 74%, reporting consistent challenges in food availability. Additionally, 10 respondents (20%), indicated that they faced food shortages intermittently, while only 3 (6%), reported never experiencing food shortages (Figure 5) . These findings suggested that the majority of respondents in the study area were confronted with food insecurity on a regular basis, primarily stemming from insufficient agricultural production. To cope with these food shortages, many respondents resorted to purchasing food from the market, while some engage in labor worked to supplement their daily food needs. This reliance on external sources highlights the critical issue of food insecurity in the region, underscoring the need for targeted interventions to enhance local agricultural productivity and improve overall food access for the community (Chemjong and K.C, 2020).

Status of food security in the family of respondents

The percentage of respondents who had food security i.e food self-sufficiency throughout the year and up to 9 Months was 24% and 16%. About 26% respondents had food for six months, 20% respondents had food for 3 months, and for less than 3 months only 10% were secure. Similarly, only 4% of respondents had no agricultural production (Figure 6).

Major changes in agriculture production after the impact of climate change

There was major changes found in agriculture production after the impact of climate change in respected area. Some major changes were shift in crop patterns, water stress, vulnerability to pests' outbreak, extreme weather events and so on

(Table 1). These findings agree with those of Bhatta, Nepal and Rajbhandari(2024).

Table 1. Major changes in agriculture production

S.N.	Major Changes in agriculture production	%
1.	Shift in crop pattern	82
2.	Increased pest and disease outbreak	68
3.	Food insecurity	66
4.	Shortened growing season	23
5.	Reduced crop yield	48

Note: Total is more than 100% because of multiple choices

CONCLUSION

A study of 50 households in the Kathmandu district revealed several significant challenges related to demographics, education, agriculture, and land ownership. The average family size was 4.52, with a substantial portion of respondents aged between 38 and 48 years, reflecting a predominantly mature population. Agriculture emerged as the primary livelihood for most households, with only 8% of respondents engaged in occupations outside this sector, underscoring the critical role of agriculture in the local economy. Educational attainment among respondents was alarmingly low, with 40% classified as illiterate and only 14% having pursued higher education, indicating a significant gap in educational opportunities and access to knowledge. Land ownership was prevalent, as 68% of respondents owned land; however, the plots were generally small, which may constrain agricultural productivity and limit food security.

Furthermore, irrigation practices predominantly relied on water pumps and drainage systems, which could pose challenges for sustainable agricultural practices. The impact of climate change on food security was evident, with 56% of respondents noting that altered precipitation patterns, rising temperatures, and extreme weather events adversely affected crop yields, leading to decreased availability of local food supplies.

Additionally, 39% of respondents highlighted the proliferation of pests and crop diseases as further threats to agricultural productivity. Economic strain emerged as a critical factor, with 28% of households struggling to afford nutritious food due to rising prices driven by climate-induced disruptions in agriculture. Moreover, 72% of farmers reported inadequate infrastructure, including poor transportation and limited market access, hindering their ability to bring products to market. These findings underscore the necessity for targeted interventions to address educational deficits, enhance agricultural productivity, and improve access to resources in the community, thereby fostering sustainable development and strengthening food security.

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ADOPTION AND IMPACT OF INTEGRATED PEST MANAGEMENT IN TOMATO CULTIVATION IN LALITPUR AND BHAKTAPUR NEPAL

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ABSTRACT

This study evaluates the knowledge, adoption attitudes, practices, and challenges of Integrated Pest Management (IPM) in controlling insect pests in tomato cultivation in two districts of Kathmandu Valley, Nepal. Conducted between May 25 and June 30, 2024, in Bhaktapur and Lalitpur districts of Bagmati Province, the research involved 90 commercial tomato farmers selected through purposive random sampling. Data were collected using semi-structured questionnaires and interviews. The findings revealed that 82% of farmers in Lalitpur and 89% in Bhaktapur lacked adequate knowledge and awareness of IPM principles. Limited access to resources (39%) and high initial costs (33%) were significant obstacles, alongside regulatory and policy challenges (26%). The study also identified key pests, with Tuta absoluta being the most damaging (36%), followed by Bemisia tabaci (29%), Helicoverpa armigera (19%), and Aphis gossypii (13%). The results highlight the urgent need for targeted IPM training, improved resource access, and stronger policy support to promote sustainable pest management in tomato farming.

Keywords: Adoption, agricultural challenges, Farmer's knowledge, Pest management, Tomato

INTRODUCTION

Agriculture is the backbone of Nepal's economy, providing livelihoods, income, and employment to a significant portion of the population (Shrestha, 2012). Within the agricultural sector, horticulture plays a key role, with vegetable cultivation contributing over Rs. 36 billion to the national economy. Among the various vegetable crops, solanaceous crops—particularly tomatoes and potatoes—account for 13.57% of the country's total vegetable production. Tomatoes are cultivated on 17,273 hectares, yielding approximately 232,897 tons

annually. The Kathmandu Valley, along with Lalitpur and Bhaktapur districts, is central to tomato production in Nepal (Durbar, 2014).

Tomatoes are a high-value crop with substantial market potential. Increasingly, tomatoes are cultivated year-round, particularly through the use of plastic houses that enable off-season production (Ghimire et al., 2017). They thrive in warm, dry climates, with an optimal temperature range of 20-24°C, and are predominantly grown in winter. Popular varieties in Nepal include Abinash, Trishul, Sirjana, and Pusa Ruby. Farming tomatoes in plastic houses offers significant financial benefits, generating a net profit of NPR 85,400 (~700 USD) per ropani annually—2–3 times more profitable than open-field farming (Budhathoki, 2006).

Despite its economic importance, tomato cultivation faces challenges, primarily related to the use of agrochemicals for pest and disease management. Inappropriate pesticide use has led to chemical residues in tomatoes, which pose health risks to consumers and the environment (Karungi et al., 2011). Globally, tomatoes are among the most pesticide-treated vegetables (Gatahi, 2020). Conventional tomato farming practices, including intensive irrigation, weeding, pruning, and pest control, are labor-intensive and contribute to these challenges (Jones et al., 2012).

Integrated Pest Management (IPM) offers a solution by minimizing the reliance on chemical pesticides and promoting more sustainable farming practices. IPM is an environmentally sensitive approach that combines biological, cultural, and chemical methods to manage pests effectively (EPA, 2020; Burlakoti & Rajbhandari, 2016). Although IPM adoption has grown globally, particularly in the United States and Europe, its uptake in Nepal has been slow. The market for IPM-grown vegetables is still in the early stages, and there is a lack of comprehensive market data (Bhatta et al., 2008). However, there is an emerging trend among urban consumers demanding safer and healthier produce, which could help accelerate the adoption of IPM in Nepal.

This study aims to provide valuable insights into the adoption and effectiveness of Integrated Pest Management (IPM) practices in tomato cultivation in the Lalitpur and Bhaktapur districts of Nepal. By assessing farmers' knowledge and awareness of IPM, and evaluating its impact on managing key insect pests such as *Tuta absoluta*, *Bemisia tabaci*, and *Helicoverpa armigera*, the research seeks to identify the challenges and potential benefits of IPM. The findings will contribute to the development of sustainable pest management strategies that can boost tomato production while minimizing the environmental and health risks associated with excessive pesticide use.

MATERIALS AND METHODS

The study was conducted from May 25 to June 30, 2024, in Lalitpur and Bhaktapur districts, specifically focusing on the Godawari and Mahalaxmi municipalities in Lalitpur, and the Changunarayan and Suryabinayak municipalities in Bhaktapur. A total of 90 commercial tomato farmers were selected, with 45 respondents from each district. Semi-structured questionnaires were designed to collect data on demographic characteristics, cultivation practices, pest management strategies, and pest control methods.

Primary data were gathered through direct interviews with farmers, supplemented by personal interviews and field observations. Secondary data were sourced from books, journals, research papers, reports from the Nepal Agricultural Research Council (NARC), Ministry of Agriculture and Livestock Development (MoALD), and other relevant publications. Descriptive statistics, including percentages and frequencies, were applied for data analysis. The findings were presented using Microsoft Excel in the form of tables, pie charts, and bar diagrams.

RESULTS AND DISCUSSIONS

Major Tomato Pest Species

The study identified the key insect pests affecting tomato crops in both Lalitpur and Bhaktapur districts. The most damaging pest was *Tuta absoluta* (Meyrick), which caused significant damage to tomato crops, accounting for 36% of the pest occurrences. Other major pests included *Bemisia tabaci* (Gennadius) (whitefly), which contributed to 29% of the pest damage, and *Helicoverpa armigera* (Hubner) (tomato fruit borer), which caused 19% of the damage (Table 1). Aphis gossypii (Glover) and *Spodoptera litura* (Fabricius) were less prevalent, causing 13% and 3% of the damage, respectively. These findings are consistent with previous studies, such as that by Lamsal et al. (2018), which highlighted *T. absoluta* as the most devastating pest, leading to substantial crop losses in the absence of proper pest management.

Adoption of IPM Practices

The adoption of Integrated Pest Management (IPM) practices varied between districts. In Lalitpur, 25% of respondents used botanical pesticides like Jholmal, while in Bhaktapur, 27% of respondents used them. The use of pheromone traps such as TLM lure and Helilure was reported by 33% of respondents in Lalitpur and 27% in Bhaktapur. Yellow sticky traps, a common method for controlling aphids and whiteflies, were used by 45% of respondents in Lalitpur and 50% in

Bhaktapur. Chemical pesticides were still widely used, with 81% of respondents in Lalitpur and 79% in Bhaktapur relying on them for pest control (Table 2).

Table 1. Major Tomato Pest Species

Pest Name	Local Name	Scientific Name	f, %
South American Tomato Leaf Miner	Paat Khane Kira	*Tuta absoluta* (Meyrick)	36
Tomato Fruit Borer	Gabaroo	*Helicoverpa armigera* (Hubner)	19
Whitefly	Seto Jhinga	*Bemisia tabaci* (Gennadius)	29
Aphid	Lahi	*Aphis gossypii* (Fabricius)	13
Tobacco Caterpillar	Surti Ko Paat Khane Kira	*Spodoptera litura* (Glover)	3

(Source: Field survey, 2024)

These findings align with the study by Joshi et al. (2017), which reported the widespread use of both chemical and biopesticide methods, including botanicals and pheromones, for managing pests like *T. absoluta* and *Helicoverpa armigera*.

Table 2. Adoption of IPM Practices

Practices	Target insect pests	Respondents in			
		Lalitpur		Bhaktapur	
		f	%	f	%
Botanicals (Neemazin, Jholmol)	Aphids, Tomato leaf miner	23	25	24	27
Pheromones such as TLM lure, Helilure	*Tuta absoluta* (Meyrick), Tomato fruit borer	30	33	24	27
Yellow sticky trap	Aphids, whiteflies	41	45	45	50
Cow urine	Whitefly	12	13	11	12
Chemical method	Tomato leafminer, Tomato fruit borer, whitefly, aphids	73	81	71	79

(Source: Field survey, 2024)

Effectiveness of IPM Components in Pest Reduction

The effectiveness of various Integrated Pest Management (IPM) components was demonstrated by significant reductions in pest populations. Biological control, such as using *Coccinellidae* and *Trichogramma* species, reduced tomato fruit borer larvae from 90-100 per 100 plants to 20 (Table 4). Neem-based botanical pesticides reduced whiteflies from 1000 to 150-200, while pheromone and yellow sticky traps decreased pest larvae of *Tuta absoluta*, *Helicoverpa armigera*, aphids, and whiteflies from 120-150 to 20-30 per plant. Mechanical controls like hand-picking reduced aphid and *Tuta absoluta* larvae from 250-300 to 50-60 per acre (Table 3). These results suggest that IPM components, particularly biological

control and the combination of pheromone and sticky traps, effectively reduce pest populations and, consequently, the need for chemical pesticide use.

Table 3. Effectiveness of IPM Components in Pest Reduction

IPM Components	Pest Species Targeted	Initial pest Populations (Before IPM)	Final Pest Populations (After IPM)
Biological control (E. g: Coccinellidae, Trichogramma species)	Tomato fruit borer	90-100 larvae per 100 plants	20 larvae per 100 plants
Botanical pesticides (Neem)	Whitefly	Around 1000 Whiteflies	150- 200 whiteflies
Pheromone Traps (E. g: TLM lure, Helilure) and Yellow sticky traps	*Tuta absoluta* (Meyrick), *Helicoverpa armigera* (Hubner), Aphids and whitefly	120-150 larvae/plant	20-30 larvae/plant
Mechanical control (Hand-picking)	Aphids, *Tuta absoluta* (Meyrick)	250-300 larvae/acre, 500-600 aphids/acre	50-60 larvae/acre, 100 aphids/acre

(Source: Field survey, 2024)

Comparison of Yield and Pest Damage with and without IPM

The study reveals that Integrated Pest Management (IPM) significantly improves tomato yields and pest control in Lalitpur and Bhaktapur. IPM-treated fields outperformed non-IPM fields, with yields in Lalitpur ranging from 50,000-80,000 kg/ha, compared to 25,000-50,000 kg/ha in non-IPM fields (Table 5). In Bhaktapur, IPM-treated fields yielded 50,000-75,000 kg/ha, while non-IPM fields ranged from 20,000-45,000 kg/ha. Marketable yields were also higher in IPM fields (80-90%) versus non-IPM (60-80%). Additionally, pest damage was lower in IPM-treated fields, with damage in Lalitpur (10-20%) and Bhaktapur (15-20%), compared to 30-50% in non-IPM fields (Table 5). These findings demonstrate that IPM practices not only boost yield but also reduce pest damage, highlighting its effectiveness as a sustainable and economically viable pest management strategy. However, the low adoption rate of IPM training among farmers calls for greater educational efforts to expand its use.

Cost-Benefit Analysis of IPM Strategies in Lalitpur and Bhaktapur

The cost-benefit analysis of IPM strategies in both Lalitpur and Bhaktapur districts highlights the profitability and effectiveness of various IPM components. In Lalitpur, biological control demonstrated the highest potential for profit, with

net profits ranging from Nrs. 95,000 to 300,000, although at a higher cost (Nrs. 18,000-30,000/ha). Botanical pesticides and mechanical control were also cost-effective, generating net profits of Nrs. 1,340,000 and 1,450,000, respectively (Table 5).

Table 4. Comparison of Yield and Pest Damage: (IPM vs. Non-IPM Fields)

District	Field Type	Average Yield (Kg/ha)	Marketable Yield (%)	Crop Damage by Pests (%)	Increase in Yield (IPM vs. Non-IPM)
Lalitpur	IPM Treated	50,000-80,000	80-90	10 – 20	(10 –15) % But, can vary widely
	Non- IPM Treated	25,000-50,000	60-80	30 – 50	Depends on variety and local pest pressures
Bhaktapur	IPM Treated Fields	50,000-75,000	80-90	15-20	(8 –15) % But, can vary widely
	Non- IPM Treated Fields	20,000-45,000	50-80	35-50	Depends on variety and local pest pressures

(Source: Field survey, 2024)

Table 5. Table-Cost-Benefit Analysis of IPM Strategies in Lalitpur district

IPM Components	**Cost (Nrs/ha)**	**Yield (Kg/ha)**	**Gross Income (Nrs/ha)**	**Net Profit (Nrs/ha)**
Biological control	18,000-Nrs. 30,000	50,000-70,000	2,500,000	95,000 - Nrs. 300,000
Botanical Pesticides	1000-Nrs. 10,000	45,000-80,000	1,350,000	1,340,000
Pheromone Traps	2000- Nrs. 9000	30,000-80,000	900,000 - 150,000	1,40,000
Mechanical Control	5000- Nrs. 8000	20,000-60,000	600,000 - 1,500,000	1,450,000

(Source: Field survey, 2024)

Table 6. Table-Cost-Benefit Analysis of IPM Strategies in Bhaktapur district

IPM Components	**Cost (Nrs/ha)**	**Yield (Kg/ha)**	**Gross Income (Nrs/ha)**	**Net Profit (Nrs/ha)**
Biological control	15,000-Nrs. 30,000	50,000-75,000	2s,500,000	80,000- . 2,470,000
Botanical Pesticides	1000-Nrs. 12,000	40,000-80,000	2,000,000	1,988,000
Pheromone Traps	2000- Nrs. 10,000	30,000-70,000	1,500,000	1,490,000
Mechanical Control	4000- Nrs. 8000	30,000-60,000	1,500,000	1,492,000

(Source: Field survey, 2024)

In Bhaktapur, biological control showed impressive returns with net profits reaching up to Nrs. 2,470,000, while other methods, such as botanical pesticides and mechanical control, also yielded strong profits (over Nrs. 1.9 million) (Table 6). Overall, the data suggests that while biological control and botanical pesticides are costly, they offer substantial returns, making them favorable options for farmers. This emphasizes the viability of IPM in enhancing both productivity and profitability across districts.

CONCLUSION

This study evaluated the adoption and effectiveness of Integrated Pest Management (IPM) practices for controlling insect pests in tomato farming in Lalitpur and Bhaktapur districts. While traditional pesticide-based methods predominated, some farmers unknowingly practiced IPM techniques, such as using traps and lures, which showed significant reductions in pest populations and crop damage. IPM-treated fields demonstrated higher yields, better marketable produce, and less pest damage compared to non-IPM fields. Despite these positive outcomes, the adoption of IPM remains low due to a lack of awareness, training, and limited access to necessary resources. The cost-benefit analysis revealed that although IPM methods like biological control and botanical pesticides involved higher initial costs, they were profitable in the long run.

The findings highlight the effectiveness of IPM in improving yield and reducing pest damage but also point to the need for greater awareness and education among farmers. Overcoming barriers such as high initial costs and resource limitations will require targeted training, policy support, and stronger research and extension services. By addressing these challenges, IPM adoption can be expanded, ensuring sustainable and economically viable pest management for tomato farmers in these districts.

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IMPACT OF *SOLANUM TORVUM* ROOTSTOCKS ON GRAFTED AND NON-GRAFTED TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) CULTIVARS

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ABSTRACT

This study evaluated the growth, yield, and fruit quality of grafted and non-grafted tomato (Lycopersicon esculentum Mill.) cultivars under protected cultivation. Conducted from March to July 2024 at Bhattarai Shiva Shakti Krishi Farm, Bhaktapur, Nepal, the experiment used two cultivars, Heemsikhar and Srijana, as scions grafted onto Solanum torvum (wild brinjal) rootstock. Four treatments—T1: Grafted Heemsikhar, T2: Control Heemsikhar, T3: Grafted Srijana, and T4: Control Srijana—were put in a randomized complete block design with five replications. Key parameters, including plant growth, fruit yield, and quality traits such as firmness, total soluble solids (TSS), titratable acidity (TA), sugar-acid ratio, and vitamin C content, were assessed. Grafting significantly improved fruit yield, TA, and vitamin C content but had no effect on plant height, stem diameter, fruit firmness, TSS, or sugar-acid ratio. The T3 (Grafted Srijana) treatment yielded the highest fruit weight, with 129.60 g/plant in the first harvest and 121.30 g/plant in the second. T1 (Grafted Heemsikhar) followed, with yields of 112.01 g/plant and 84.60 g/plant at the respective harvests. T3 also recorded the highest TA and vitamin C content, highlighting its potential for enhancing both yield and nutritional quality. These findings provide valuable insights for optimizing tomato cultivation through grafting and offer practical recommendations for improving productivity and fruit quality under protected conditions.

Keywords: Grafting, tomato, wild-brinjal, yield

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), with a chromosome number of 2n = 24, is one of the most widely cultivated and consumed vegetables globally. In Nepal, it ranks as the third most cultivated vegetable, following cabbage and cauliflower, covering an area of 22,911 hectares, which constitutes 7.9% of the total vegetable cultivation area. The annual production of tomatoes in Nepal is approximately 30,523 metric tons (MoALD, 2023).

Tomatoes are prone to various biotic and abiotic stresses, including soil-borne diseases, temperature fluctuations, variations in relative humidity, light intensity, soil moisture, and nutrient availability. These stressors can limit nutrient uptake, disrupt temperature regulation, and exacerbate soil-borne infections, leading to physiological disorders that negatively impact fruit yield and quality (Lee and Oda, 2002). As a result, grafting has emerged as a promising strategy to improve tomato plant productivity and fruit quality by enhancing plant vigor and increasing tolerance to both biotic and abiotic stresses. This approach is particularly valuable in low-input, sustainable, and organic agricultural systems.

Grafting of herbaceous plants, especially for commercial greenhouse production of selected vegetable crops, is a widely practiced technique. It is typically performed shortly after seed germination, when plants are still small, by grafting the rootstock to enhance specific plant traits. Numerous benefits of grafting have been identified, including improved resilience to extreme temperatures (Rivero et al., 2003; Venema et al., 2008), enhanced nutrient uptake (Colla et al., 2010a), increased endogenous hormone synthesis (Dong et al., 2008), better water-use efficiency (Rouphael et al., 2008), and reduced uptake of persistent organic pollutants from agricultural soils (Otani and Seike, 2007). Additionally, grafting has been shown to improve tolerance to alkaline conditions (Colla et al., 2010b), salinity, flooding (Fernández-García et al., 2004; Yetisir et al., 2006; Martínez-Rodríguez et al., 2008; He et al., 2009), and heavy metal toxicity (Savvas et al., 2010). The robust root system of grafted plants further enhances nutrient and water absorption, surpassing non-grafted plants in efficiency (Lee and Oda, 2002), while providing greater resistance to soil-borne diseases (Ioannou, 2001; Crinò et al., 2007; Morra and Bilotto, 2006).

Furthermore, tomato grafting has been shown to mitigate the effects of salinity (Estan, 2005), soil-borne diseases (Louws et al., 2010), and improve nutrient and water absorption (López-Pérez et al., 2006; El-Shraiy et al., 2011; Voutsela et al., 2012). Grafting also aids in nematode control and enhances tolerance to

high temperatures (Rivero et al., 2003), making it an effective approach to improve plant vigor and fruit yield (Barret and Zhao, 2012). However, there is limited research on the effects of grafting methods on tomato plants in Nepal.

This study aims to assess the impact of grafting on tomato growth characteristics, yield performance, and fruit quality, comparing grafted and non-grafted tomato cultivars under field conditions. The results of this study will provide valuable insights into the potential benefits of grafting for enhancing tomato production and will inform horticultural practices in Nepal, especially in low-input agricultural systems.

MATERIALS AND METHODS

The study was conducted at Bhattrai Shiva-Shakti Krishi Farm, located in Suryabinayak-10, Bhaktapur, Nepal, with GPS coordinates approximately 27.6712° N latitude and 85.4370° E longitude. The region has a subtropical highland climate, characterized by distinct seasons and significant solar radiation. The farm receives an annual rainfall averaging around 2596 mm, with the majority occurring during the monsoon season from June to September (Weather and Climate. (2023).

Experimental Design and Treatments

The experiment was structured as a Randomized Complete Block Design (RCBD) with four treatments, each replicated five times. The total experimental plot consisted of 20 plants, with each replication containing four plants. The treatments were as follows shown in table 1.

Table 1. Treatment details

Treatments	Rootstock/ Scion
T1	Grafted Heemsikhar (wild brinjal * Heemsikhar)
T2	Control Heemsikhar
T3	Grafted Srijana (wild brinjal * Srijana)
T4	Control Srijana

The experiment was carried out under a plastic tunnel with a total length of 7.8 meters and a width of 4.26 meters. The seedlings were planted in raised beds, each 2 feet in width and 27 feet in length, raised 1 cm above the ground. A plant-to-plant spacing of 30 cm was maintained, with 60 cm between beds. Experimental units were clearly labeled for treatment identification.

The treatments in this study involved different rootstock-scion combinations to evaluate their impact on tomato plant growth, yield, and fruit quality (Table 1). The tomato variety under experiment were Srijana and Heemsikhar while the rootstock for grafting purpose was Wild Brinjal (*Solanum torvum*). The treatment T1 consisted of grafted Heemsikhar, using wild brinjal (Solanum torvum) as the rootstock and Heemsikhar as the scion. Treatment T2 served as the control for Heemsikhar, where non-grafted Heemsikhar plants were used. Treatment T3 involved grafted Srijana, where wild brinjal was paired with Srijana as the scion. Treatment T4 acted as the control for Srijana, consisting of non-grafted Srijana plants.

Observational Parameters

The following parameters were observed and recorded at 5 and 10 weeks after planting:

1. **Growth Parameters**: Three plants were randomly selected from each replication, excluding the boundary plants, for biometric observations. Plant height was measured using a measuring scale, while stem diameter was recorded 15 cm above the ground using a Vernier caliper, and the data were expressed in centimeters.

2. **Yield**: Yield was evaluated following the first and second harvests. The total fruit weight from each plant was measured and expressed as grams per plant.

3. **Firmness**: Fruit firmness was measured using a digital penetrometer and expressed in kg/cm^2.

4. **Total Soluble Solids (TSS)**: TSS content was determined using a refractometer and expressed in degrees Brix (°Brix).

5. **Titratable Acidity (TA)**: TA was determined by titration with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator, and results were expressed as percentage citric acid. Acidity percentage was calculated using the following formula: Percentage Acidity= titer value * acidity factor * 100% / volume of aliquot (Majidi et al., 2011).

6. **Sugar-acid ratio (TSS/TA):** The sugar acid ratio of the fruit was calculated by using the given formula: Sugar acid ratio = Brix value / % acidity

7. **Vitamin C content**: **Vitamin C Content**: Total vitamin C content was determined using a volumetric method. The amount of ascorbic acid (mg/100 ml sample) was calculated using the formula:

   0.5mg / V1ml X V2ml / 5ml X 100ML / Wt. of the sample X 100

Where, V1= amount of dye solution consumed by 4% oxalic acid
V2 = amount of dye consumed by working solution (G et al., 2020)

Statistical Analysis

Data analysis was performed using R-Studio and Microsoft Excel. An analysis of variance (ANOVA) was conducted to assess the significance of differences across treatments for all observed parameters.

RESULTS AND DISCUSSION

Impact of Grafting on Plant Height in Tomato Cultivars

The study revealed significant differences in plant height between grafted and non-grafted tomato plants (Table 2). Non-grafted plants consistently exhibited higher plant heights at all stages of growth. Specifically, the control treatment T2 (Heemsikhar) recorded the highest plant height at the 5th week (76.43 cm) and 10th week (144.27 cm) post-transplanting. Similarly, T4 (Control Srijana) showed substantial growth with heights of 73.27 cm at week 5 and 137.98 cm at week 10. In contrast, grafted plants (T1, Grafted Heemsikhar) showed significantly lower plant heights, with values of 36.93 cm at week 5 and 84.55 cm at week 10.

This trend aligns with findings from Khah et al. (2006) and Parajuli (2019), which suggested that non-grafted tomato plants generally exhibit superior growth in terms of plant height. The differences observed in plant height between grafted and non-grafted plants can be attributed to the rootstock-scion interaction. Non-grafted plants benefit from direct nutrient and water supply from their root system, supporting faster initial growth and greater plant height.

Influence of Grafting on Stem Diameter in Tomato Plants

Significant differences in stem diameter were observed between grafted and non-grafted tomato plants (Figure 1). At the 5th week after transplanting, non-grafted plants, particularly T2 (Control Heemsikhar), exhibited the largest stem diameter

at 3.562 cm, followed by T4 (Control Srijana) at 3.074 cm. However, by the 10th week, grafted treatments showed considerable improvements in stem diameter. T3 (Grafted Srijana) recorded the highest diameter at 7.634 cm, closely followed by T1 (Grafted Heemsikhar) at 6.954 cm. The non-grafted treatment T4 (Control Srijana) had a slightly smaller diameter of 6.486 cm.

Table 2. Performance of grafted and non-grafted tomato plants for plant height

Treatments	Height of Plant (cm)	
	5th Week	10th Week
T1 (Grafted Heemsikhar)	36.93 a	84.55 c
T2 (Control Heemsikhar)	76.43 a	144.27 a
T3 (Grafted Srijana)	53.15 b	126.93 b
T4 (Control Srijana)	73.27 a	137.98 a
Mean	59.95	123.43
CV at 5%	5.2	3.7
LSD	4.3	6.4

These findings align with the observations of Parajuli (2019), who reported similar trends in stem diameter between grafted and non-grafted tomato plants. The early growth advantage observed in non-grafted plants can be attributed to direct nutrient absorption and resource allocation, enabling a strong root system and promoting vegetative growth in the initial stages.

However, by the 10th week, grafted plants (T3 and T1) exhibited significant improvement in stem diameter. This suggests that the grafted rootstocks, with their enhanced nutrient uptake, disease resistance, and better tolerance to environmental stressors, began to show their advantages, leading to stronger growth. The larger stem diameters in grafted treatments, especially T3 (Grafted Srijana), may also indicate that the rootstocks provided robust support to the scion as the plants matured. Overall, these results suggest that while grafting may cause a temporary lag in vegetative growth, it ultimately contributes positively to the structural integrity and long-term performance of tomato plants.

Yield Results of Grafted and Non-Grafted Tomato Plants

The yield results clearly favor grafting in terms of fruit production (Table 3). Grafted plants (T3, Grafted Srijana) produced the highest fruit yield, with 129.60 g in the 1st harvest and 121.30 g in the 2nd. Grafted Heemsikhar (T1) also yielded higher than non-grafted plants, with 112.01 g in the 1st harvest and 84.60 g in the

2nd. Non-grafted Heemsikhar (T2, Control) exhibited the lowest yields, with 57.68 g in the 1st harvest and 77.55 g in the 2nd.

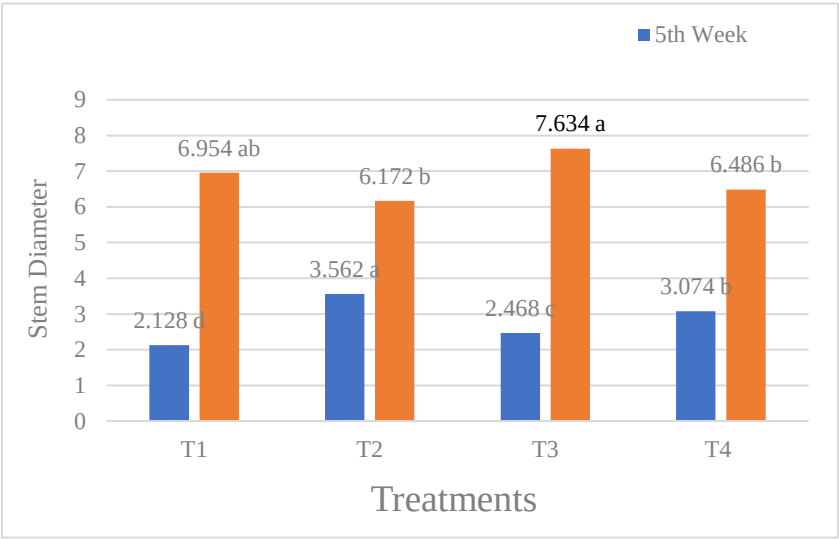

Figure 1. Performance of grafted and non-grafted tomato plants for stem diameter

These findings confirm the positive impact of the 'Wild brinjal' rootstock in enhancing fruit yield, supporting previous studies (Leonardi & Giuffrida, 2006; Rivard & Louws, 2008). The superior root system of the grafted plants, attributed to the 'Wild brinjal' rootstock, contributed to better disease resistance, drought tolerance, and nutrient uptake, leading to higher yields.

Although non-grafted plants showed lower yields, they still produced a reasonable amount of fruit at the second harvest (77.55 g). This suggests that while grafting provides an immediate yield advantage, non-grafted plants remain capable of substantial fruit production.

Impact of Grafting on Tomato Fruit Firmness (kg/cm²)

Grafting did not significantly affect tomato fruit firmness in this study. Non-grafted plants (T2, Control Heemsikhar) had the highest firmness at 3.29 kg/cm², while grafted plants (T1, Grafted Heemsikhar and T3, Grafted Srijana) showed lower firmness values of 2.21 kg/cm² and 2.50 kg/cm², respectively. Interestingly, T4 (Control Srijana) exhibited the lowest firmness at 1.39 kg/cm².

Table 3. Performance of grafted and non-grafted tomato plants for fruit yield

Treatments	Yield (g/plant)	
	1st Harvest	2nd Harvest
T1 (Grafted Heemsikhar)	112.01 a	84.60 b
T2 (Control Heemsikhar)	57.68 b	77.55 b
T3 (Grafted Srijana)	129.60 a	121.30 a
T4 (Control Srijana)	82.88 b	83.00 b
Mean	95.54	91.61
CV at 5%	20.44	25.85
LSD	26.91	32.63

The minimal impact of grafting on firmness can be attributed to several factors, including the complex nature of fruit firmness, which is influenced by genotype, environmental conditions, and harvest maturity. Grafting may not directly affect the biochemical or structural components responsible for firmness, such as cell wall composition or turgor pressure. Additionally, harvest timing and post-harvest handling could contribute to firmness variations, though fruits were harvested at similar stages. These results align with studies by Leoni et al. (1991) and Romano & Paratore (2001), which also found no significant effect of grafting on tomato fruit firmness. While grafting enhances yield and disease resistance, its impact on fruit texture appears minimal. Further studies may explore whether grafting influences firmness under different conditions.

Influence of Grafting on Titratable Acidity in Tomato Fruits

Grafted tomato plants showed higher titratable acidity (TA) than non-grafted ones, with T3 (Grafted Srijana) having the highest TA at 0.073%, followed by T1 (Grafted Heemsikhar) at 0.061%. Non-grafted plants (T2 and T4) had lower acidity levels, ranging from 0.048% to 0.062%. This result aligns with Parajuli (2017), who observed similar findings in grafted tomatoes.

Table 4. Performance of grafted and non-grafted tomato plants for fruit firmness

Treatments	Firmness (kg/cm^2)
T1 (Grafted Heemsikhar)	2.21 a
T2 (Control Heemsikhar)	3.29 a
T3 (Grafted Srijana)	2.50 a
T4 (Control Srijana)	1.39 a
Mean	2.35
CV at 5%	41.70
LSD	1.9

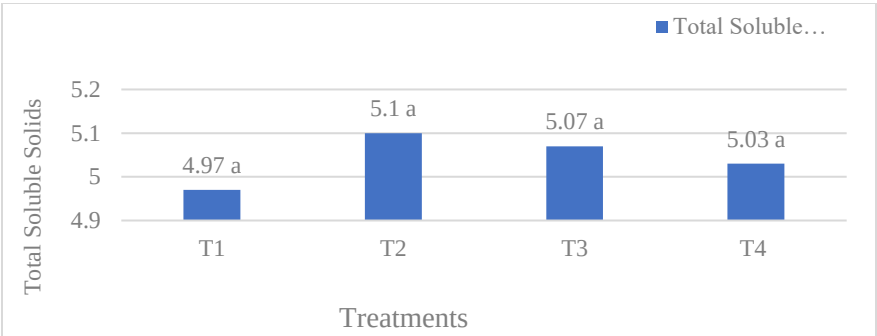

Figure 2. Performance of grafted and non-grafted tomato plants for Total Soluble Solids

Increased acidity can enhance flavor in some cultivars but may be less desirable for consumers preferring milder tomatoes. The higher acidity in grafted plants could be due to the rootstock's impact on nutrient uptake and acid synthesis, particularly the 'Wild brinjal' rootstock. Overall, grafting influences tomato fruit acidity, and the rootstock choice is crucial for both fruit quality and consumer preferences. Further studies are needed to explore the effects of different rootstocks under various environmental conditions

Table 5. Performance of grafted and non-grafted tomato plants for titratable acidity

Treatments	Titratable Acidity (%)
T1 (Grafted Heemsikhar)	0.061 b
T2 (Control Heemsikhar)	0.048 c
T3 (Grafted Srijana)	0.073 a
T4 (Control Srijana)	0.062 b
Mean	0.061
CV at 5%	3.62
LSD	0.004

Impact of Grafting on the TSS/TA Ratio in Tomato Fruits

The TSS/TA ratio, representing the balance between sweetness (TSS) and acidity (TA), was found to be lower in the grafted plants compared to the non-grafted counterparts in this study (Table 6). Specifically, T1 (Grafted Heemsikhar) had a TSS/TA ratio of 82.51, which was significantly higher than T2 (Control Heemsikhar) at 106.51. Similarly, T3 (Grafted Srijana) exhibited a lower TSS/TA ratio (70.02) compared to T4 (Control Srijana) at 81.10. This indicates that grafting may influence the relative concentrations of sugars and acids in tomato

fruits, resulting in a noticeable difference in the sweetness-to-acidity balance. The lower TSS/TA ratio in grafted plants could suggest that grafting, while potentially increasing titratable acidity, may also have a mitigating effect on sugar accumulation, leading to a less pronounced sweetness. This could have a significant impact on the flavor profile of the fruit, as tomatoes with a higher TSS/TA ratio are typically perceived as sweeter, while a lower ratio may indicate a more acidic or tangy taste.

These findings contrast with the studies of Turhan et al. (2011), Mohammed et al. (2012), and Ibrahim et al. (2001), which reported different TSS/TA ratios under similar grafting conditions. The discrepancies in results might be attributed to differences in experimental conditions such as rootstock variety, growing environment, and cultivation practices. Additionally, variations in the scion variety could also contribute to differing TSS/TA ratios in the final fruit.

The reduction in the TSS/TA ratio observed in grafted plants may be a result of complex interactions between the rootstock and scion, particularly in terms of nutrient uptake and metabolic regulation. Given that flavor is a major determinant in tomato quality, understanding the effects of grafting on the TSS/TA ratio will be essential for optimizing tomato varieties for flavor-driven consumer demand.

Table 6. Performance of grafted and non-grafted tomato plants for TSS/TA

Treatments	TSS/TA
T1 (Grafted Heemsikhar)	82.51 b
T2 (Control Heemsikhar)	106.51 a
T3 (Grafted Srijana)	70.02 c
T4 (Control Srijana)	81.10 bc
Mean	85.04
CV at 5%	7.32
LSD	12.43

Effect of Grafting on Vitamin C Content in Tomato Fruits

Grafted tomato plants exhibited significantly higher vitamin C content compared to non-grafted plants. The highest vitamin C content was observed in T3 (Grafted Srijana) at 25.27 mg/100 ml, followed by T1 (Grafted Heemsikhar) at 14.42 mg/100 ml. Non-grafted plants (T2, Control Heemsikhar) showed much lower levels at 7.37 mg/100 ml. This enhancement in vitamin C levels highlights the role of the 'Wild brinjal' rootstock in improving the nutritional quality of tomato fruits, especially in the 'Srijana' scion. This finding is consistent with Mohammed et al. (2009), who reported increased vitamin C content in grafted tomatoes. The

improvement is likely due to the rootstock's influence on nutrient uptake, stress tolerance, and the biosynthesis of ascorbic acid. The rootstock may enhance the scion's ability to accumulate and transport nutrients like vitamin C, suggesting improved root-shoot communication or metabolic changes linked to vitamin C synthesis. This enhancement could provide a valuable nutritional advantage, particularly for markets focusing on functional foods and enhanced food quality.

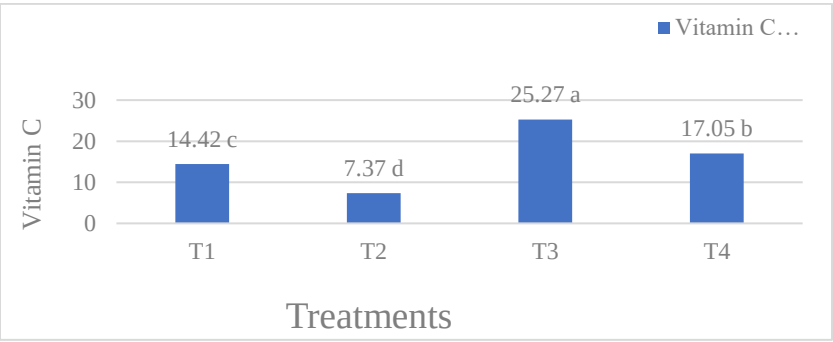

Figure 3. Performance of grafted and non-grafted tomato plants for Vitamin C

CONCLUSION

This study explored the effects of grafting tomato cultivars (Srijana and Heemsikhar) onto wild-brinjal (Solanum torvum) rootstock. The results indicated that grafting significantly enhanced fruit yield and improved certain quality attributes, such as titratable acidity (TA) and vitamin C content. Among the grafted combinations, Grafted Srijana showed the highest yield (121.30 g/plant), increased TA (0.073%), and higher vitamin C content (25.27 mg/100 ml) compared to Grafted Heemsikhar. However, grafting did not have a significant effect on other growth parameters like plant height, stem diameter, or fruit characteristics such as fruit firmness, total soluble solids (TSS), and the sugar-acid ratio. Non-grafted plants exhibited better performance in plant height and TSS content.

In conclusion, grafting with wild-brinjal (Solanum torvum) rootstock resulted in improved yield, titratable acidity, and vitamin C content in both Srijana and Heemsikhar cultivars. Grafted Srijana performed best in terms of yield and fruit quality. However, grafting did not significantly affect other growth parameters or fruit quality traits like firmness and TSS. While grafting demonstrated potential for improving tomato productivity, its impact on flavor and texture was less pronounced. Future research should focus on exploring optimal scion-rootstock

combinations and environmental conditions to better understand grafting's influence on tomato fruit quality and sensory attributes.

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KRISHIDRISHTI: TRANSFORMING NEPALESE FARMING INTO PRECISION AGRICULTURE WITH SATELLITE AND DIGITAL TECHNOLOGY

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ABSTRACT

Satellite remote sensing has emerged as a transformative tool in modern agriculture, providing real-time, large-scale, and cost-effective solutions to enhance both productivity and sustainability. This paper reviews the current applications of satellite data in agriculture, with a particular focus on its potential in Nepal. By examining global use cases in crop health monitoring, soil moisture estimation, weather pattern analysis, and land use classification, the paper emphasizes the value of integrating satellite technology into Nepal's agricultural practices. It also explores the challenges of data accessibility, technical expertise, and policy integration, offering recommendations for overcoming these barriers to foster sustainable agricultural development. The paper introduces KrishiDrishti, a platform designed specifically for Nepal that uses satellite data to deliver actionable insights, empowering farmers and policymakers with tools for precision agriculture. By leveraging the potential of KrishiDrishti, this platform supports the transition to more efficient and climate-resilient farming practices, showcasing its transformative potential in Nepal's agricultural sector.

Keywords: Agricultural information technology, Data-driven agriculture, Precision agriculture, Satellite remote sensing

INTRODUCTION

Agriculture accounts for approximately 27% of Nepal's GDP and employs more than 65% of the population, making it a cornerstone of the country's socio-economic development (World Bank, 2023). Despite Nepal's rich agro-

biodiversity and diverse agro-climatic zones, the sector faces persistent challenges, including low productivity, reliance on traditional methods, and vulnerability to climate variability. Farming practices are predominantly traditional and subsistence-based, shaped by fragmented landholdings and reliance on rain-fed systems. Outdated methods, limited access to modern technologies, and inadequate infrastructure further constrain efficiency and sustainability. Additionally, insufficient market access and underinvestment in research and development exacerbate these challenges. As a result, Nepal's agricultural sector remains underdeveloped, underscoring the urgent need for innovative solutions such as precision agriculture and climate-resilient technologies to enhance productivity, ensure food security, and drive sustainable development.

As a prior success story of such kinds of endeavors, satellite technology has proven to be a game-changer in addressing agricultural challenges. For instance, India's Crop Cutting Experiment, which integrates satellite data to assess crop production, resulted in a 20% improvement in yield predictions and reduced the cost of field surveys by 30% (Srivastava et al., 2020). Similarly, the United States' use of NASA's Landsat imagery has helped optimize fertilizer application and detect pest outbreaks, saving an estimated $1 billion annually in agricultural losses (Mulla, 2013). In Brazil, the National Institute for Space Research employs Moderate Resolution Imaging Spectroradiometer (MODIS) data for soybean crop health monitoring, which has led to a 15% reduction in yield losses caused by undetected stress factors (Hansen et al., 2013). These global examples underscore the transformative potential of satellite data to enhance agricultural efficiency and sustainability.

Nepal's diverse geography and climate necessitate customized satellite data applications. While global methodologies offer valuable insights, their implementation in Nepal must address unique challenges, such as fragmented landholdings, varied agro-climatic zones, and limited infrastructure. Digital technologies integrated with satellite data can provide precise solutions for irrigation, weed management, plant health, soil nutrition, fertilizer applications, and disease diagnosis, enabling precision agriculture tailored to Nepal's needs (Pudasainee et al., 2020). KrishiDrishti, a pioneering platform developed specifically for Nepal, bridges this gap by delivering localized, actionable satellite data in a user-friendly format. Through features such as real-time crop monitoring, soil moisture analysis, weather forecasting, and land use mapping, KrishiDrishti empowers farmers and policymakers to adopt precision farming practices. These innovations promise not only to boost productivity and resilience but also to foster sustainable agricultural development in Nepal.

What is KrishiDrishti?

KrishiDrishti is a cutting-edge platform developed by the team at BOTS Industries to address Nepal's unique agricultural challenges. This platform leverages satellite remote sensing technology with resolutions of up to 1x1 km, integrated with data from an in-house-built ground station. It is specifically designed for researchers, policymakers, and farmers, providing actionable insights through advanced data processing and visualization tools.

KrishiDrishti generates detailed graphs and maps to help users analyze critical agricultural parameters (Figure 1). The platform also offers a user-friendly website and plans to include a mobile application, providing customized suggestions tailored to farmers' specific needs. Additionally, the platform facilitates students and researchers conducting research works or case studies by simplifying the process of data extraction and analysis. Designed to bridge the gap between satellite data and on-ground application, KrishiDrishti aims to facilitate sustainable agricultural practices and data-driven decision-making. It is a versatile tool that supports academic research, policymaking, and daily farming activities, thus serving as a comprehensive resource for stakeholders across the agricultural value chain.

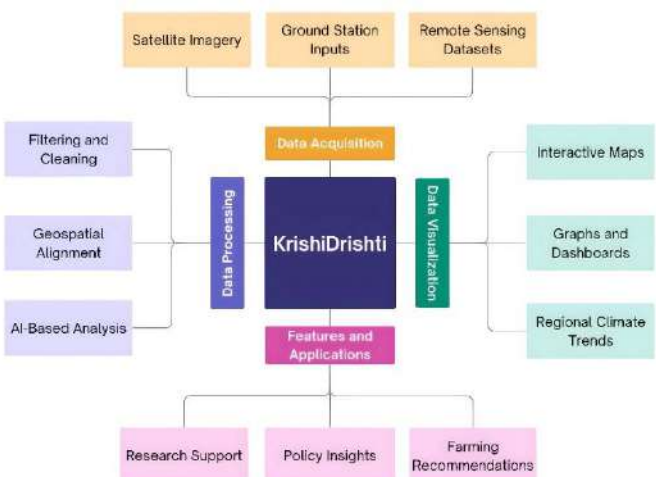

Figure 1. Visual Representation of the KrishiDrishti Platform

Technical Features of KrishiDrishti

KrishiDrishti integrates multiple technical features to provide comprehensive support for agricultural activities. The platform utilizes high-resolution satellite data alongside in-house ground station inputs to generate real-time, location-specific insights. The data integration capabilities allow for multi-layered analysis, including vegetation health indices, soil moisture levels, and weather patterns. These insights are visualized through interactive graphs and maps, enabling users to make informed decisions with ease.

One of the standout features of KrishiDrishti is its predictive analytics engine, which combines historical and real-time data to forecast crop yields, irrigation needs, and potential risks such as pest outbreaks. The platform's mobile-friendly design ensures accessibility, even for farmers in remote areas, while its modular structure supports customization based on specific regional or crop-related requirements. This adaptability makes KrishiDrishti an indispensable tool for promoting precision agriculture and ensuring sustainable farming practices in Nepal.

Leveraging Satellite Data for Agricultural Innovation with KrishiDrishti

Crop health monitoring

KrishiDrishti leverages satellite-derived vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) to deliver real-time insights into crop health. By identifying areas experiencing stress from pests, diseases, or nutrient deficiencies, the platform enables farmers to implement targeted interventions (Figure 2).

The platform also integrates historical and current satellite data to predict crop yields, helping farmers and policymakers prepare for market demands. By combining plant health data with environmental factors, KrishiDrishti offers a predictive framework that enhances decision-making for agricultural output. Furthermore, the platform provides customized alerts and recommendations based on satellite observations, ensuring that farmers apply fertilizers and irrigation optimally, reducing waste and improving sustainability.

Successful precedents highlight the potential of such applications. In India, the Indian Space Research Organization (ISRO) uses satellite data in its Crop Cutting Experiment to assess production and identify stressed areas, improving accuracy and resource efficiency (Srivastava et al., 2020). NASA's Landsat imagery in the United States has been instrumental in detecting pest outbreaks and optimizing fertilizer application, leading to cost savings and improved crop quality (Mulla,

2013). In Brazil, the National Institute for Space Research monitors soybean crop health using MODIS data, reducing yield losses by 15% (Hansen et al., 2013). These successful methodologies exemplify the capabilities KrishiDrishti can bring to Nepal's agriculture, enhancing food security and promoting economic stability.

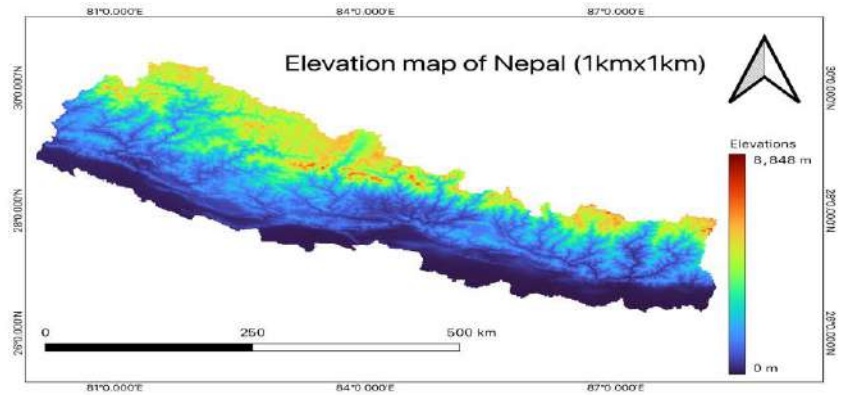

Figure 2. Elevation map of Nepal generated through KrishiDrishti. The figure helps to highlight diverse elevation zones of Nepal, aiding crop health monitoring through altitude-based vegetation indices and stress analysis

Soil Moisture Estimation

KrishiDrishti utilizes microwave remote sensing data to generate accurate soil moisture maps tailored to Nepal's agricultural context. By identifying regions with moisture deficits, the platform enables efficient irrigation planning, optimizing water use across the country. In drought-prone areas, KrishiDrishti facilitates the early detection of water stress, empowering farmers and policymakers to implement proactive mitigation strategies. These insights are particularly valuable for rainfed farming systems, where the platform assists in determining optimal planting schedules to maximize productivity.

Drawing on successful precedents, NASA's Soil Moisture Active Passive (SMAP) mission has mapped soil moisture deficits in Africa, supporting the implementation of effective drought mitigation strategies (Entekhabi et al., 2010). In Australia, SMAP data aids water resource management in arid regions, enhancing crop resilience (Walker et al., 2014). Similarly, the European Space Agency's (ESA) Sentinel-1 radar data plays a crucial role in irrigation planning and water conservation across Mediterranean agricultural systems (Janssen et al., 2021). By incorporating these successful applications, KrishiDrishti ensures

equitable water distribution for farming and promotes sustainable irrigation practices throughout Nepal (Figure 3).

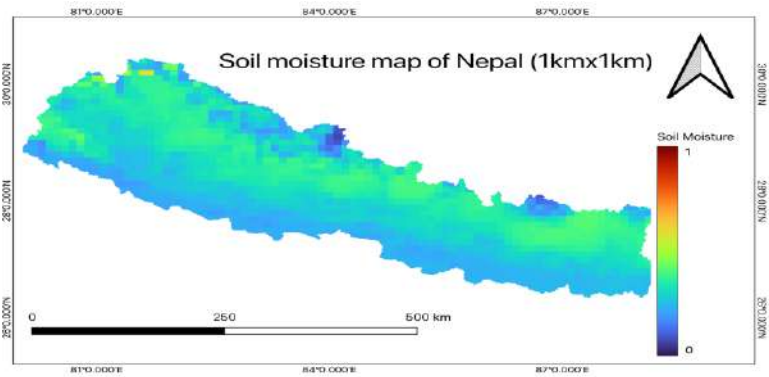

Figure 3. Volumetric soil water map of Nepal generated by KrishiDrishti. The map shows soil moisture distribution across Nepal, supporting irrigation planning and drought management.

Weather Pattern Analysis and Weather Forecasting

KrishiDrishti integrates advanced weather forecasting models with local satellite data to enhance Nepal's agricultural resilience. By providing accurate predictions on monsoon onset, duration, and intensity, the platform plays a crucial role in planning crop cycles. Real-time alerts about extreme weather events enable farmers to take proactive measures to protect their crops and livestock. Additionally, KrishiDrishti tracks long-term climate trends, facilitating the design of sustainable, climate-resilient farming strategies (Fig. 4).

Looking at similar applications globally, Fengyun satellites in China predict typhoon impacts and drought trends, offering critical protection to vulnerable agricultural regions (Zhang et al., 2017). In India, a collaborative effort between the India Meteorological Department (IMD) and satellite agencies has enabled precise monsoon tracking, benefiting millions of farmers (Srivastava et al., 2020). The United States' National Oceanic and Atmospheric Administration (NOAA) combines weather models and satellite data to improve early warning systems for hurricanes and frost, thereby safeguarding agricultural yields (Mulla, 2013). With comparable capabilities, KrishiDrishti seeks to empower Nepalese farmers, helping them adapt to changing weather patterns and protect their livelihoods.

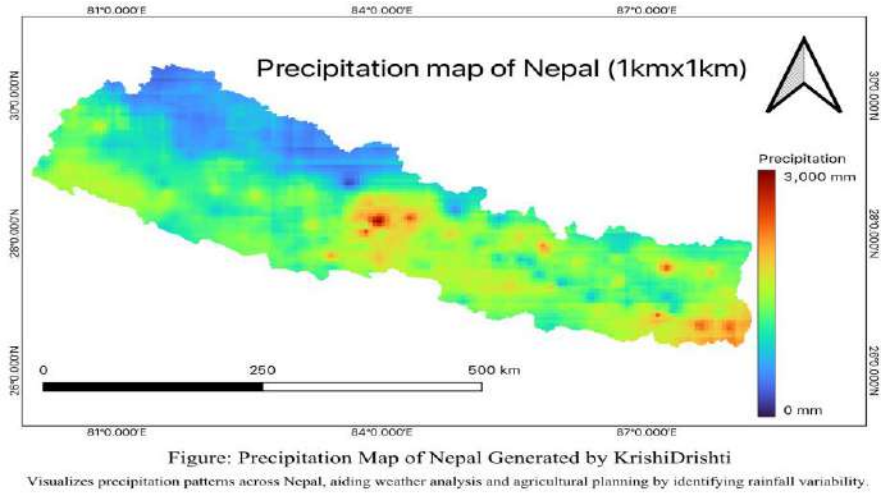

Figure: Precipitation Map of Nepal Generated by KrishiDrishti

Visualizes precipitation patterns across Nepal, aiding weather analysis and agricultural planning by identifying rainfall variability.

Figure 4. Precipitation map of Nepal generated by KrishiDrishti. This map visualizes precipitation patterns across Nepal, aiding weather analysis and agricultural planning by identifying rainfall variability.

Land Use Mapping

KrishiDrishti provides dynamic and detailed land use maps tailored to Nepal's unique needs. It can identify suitable areas for agricultural expansion while preserving ecological balance, ensuring sustainable growth. The platform is designed to monitor urban encroachment, preventing unauthorized land use changes that threaten agricultural lands. Additionally, KrishiDrishti equips policymakers with accurate data for sustainable land management and conservation strategies (Fig.5).

In global scenarios, Brazil's deforestation monitoring using MODIS and Landsat has helped control land encroachment and promote sustainable agricultural practices (Hansen et al., 2013). India extensively uses satellite imagery for balanced policy formulation, supporting industrial and agricultural growth (Roy et al., 2015). In Europe, the Copernicus Land Monitoring Service offers high-resolution data for efficient land use planning across the EU (Janssen et al., 2021). Through similar applications, KrishiDrishti supports sustainable development in Nepal's agriculture sector.

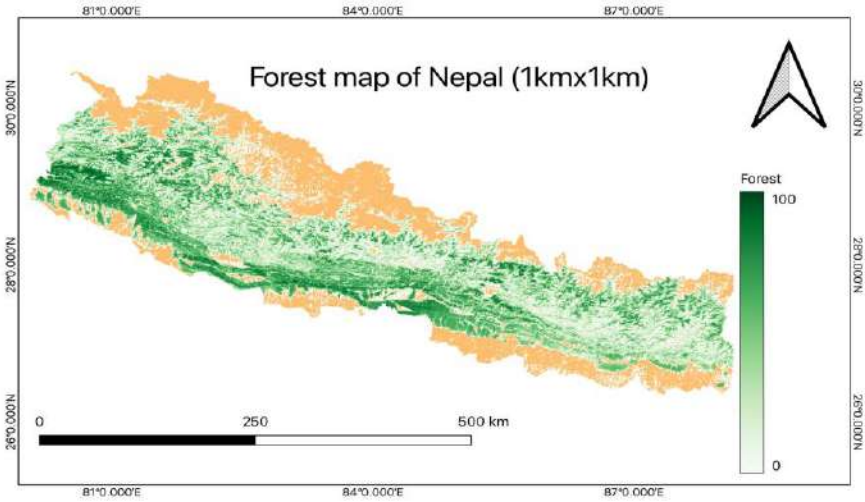

Figure 5. Forest coverage map of Nepal generated by KrishiDrishti. The map depicts vegetation distribution across Nepal, aiding in land use planning and conservation efforts

CHALLENGES

Adopting satellite data in Nepal's agricultural sector presents several significant challenges. Limited internet access and inadequate infrastructure in rural areas impede the accessibility of real-time satellite insights, which are crucial for timely decision-making. Moreover, a lack of technical expertise among farmers and policymakers hinders effective interpretation and utilization of this data. To overcome this, targeted training programs and capacity-building initiatives are essential. Additionally, the absence of a clear policy framework for integrating satellite-based solutions into Nepal's agricultural systems poses a substantial barrier. Without comprehensive policies, scaling and operationalizing these insights for widespread use becomes difficult. Addressing these challenges is pivotal to unlocking the full potential of platforms like KrishiDrishti in transforming Nepal's agricultural landscape.

CONCLUSION

Integrating platforms like KrishiDrishti with satellite data presents a transformative opportunity for Nepal's agricultural sector, addressing challenges such as diverse agro-ecological zones, fragmented farmlands, and small-scale farming practices. By leveraging real-time data, predictive analytics, and climate-smart technologies, KrishiDrishti can enable precision agriculture tailored to Nepal's unique needs. Its features support better climate and weather prediction, stress management, and

land-use planning, fostering enhanced productivity and resilience. However, the successful implementation of such initiatives hinges on sustained investments, comprehensive stakeholder training, and strong partnerships with universities, agricultural agencies, local governments, and farmers. By embedding these technologies into agricultural practices and policies, Nepal can drive sustainable agriculture, bolster food security, and improve farmers' livelihoods, ensuring a more resilient and prosperous agricultural future.

RECOMMENDATIONS FOR FURTHER WORKS

To effectively integrate satellite-based solutions into Nepal's agricultural framework, it is crucial to establish dedicated training centers focused on satellite data interpretation, practical use of platforms like KrishiDrishti, and advanced technologies such as artificial intelligence (AI). AI has the potential to automate anomaly detection, crop yield forecasting, and resource optimization, generating predictive insights that can significantly improve decision-making for both farmers and policymakers. Strong collaboration with international agencies, such as NASA, ESA, and ISRO, alongside local institutions like agricultural universities, cooperative societies, and government bodies, is essential for tailoring Krishi Drishti's functionalities to meet regional needs while ensuring wide accessibility. Expanding the platform's features to include user-friendly, AI-driven analytical tools and ensuring that its data and insights are readily applicable in research, academic theses, and policy-making processes will enhance its effectiveness. Moreover, aligning KrishiDrishti with national agricultural strategies, supported by robust policy frameworks and regulations for AI-driven platforms, will foster innovation and accelerate adoption. These actions will enable stakeholders to harness the transformative potential of satellite data and AI, promoting sustainable agricultural development in Nepal.

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FACTORS AFFECTING CONSUMER PURCHASE INTENTION FOR DAIRY PRODUCTS IN KATHMANDU

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ABSTRACT

The research delved into the intricate factors affecting consumer choices when it came to purchasing dairy products in Kathmandu, Nepal. It examined various psychological factors like attitudes, product knowledge, health consciousness, brand image, and taste preferences, along with external influences such as social networks, price perception, and product accessibility. Additionally, it analyzed demographic variables like age, gender, income, and education to understand their impact on consumer intentions. Using a mixed-methods approach, the study utilized structured questionnaires to survey 385 respondents, employing descriptive statistics and analytical tools like Chi-square, one-way ANOVA, and linear regression to construct a theoretical model. The findings highlighted the significant role of consumer attitudes, with positive outlooks correlating strongly with purchase intentions. Health consciousness and taste preferences also emerged as key drivers, underlining the importance of promoting health benefits and product taste in marketing strategies. A regression equation revealed the nuanced relationships among these factors, with health consciousness, social networks, price perception, and product accessibility standing out as significant influencers. The study emphasized the importance of brand image, social networks, and external factors alongside demographic variables in shaping consumer behavior. These insights offered valuable guidance to dairy product marketers and policymakers, suggesting strategies like improving consumer product knowledge, building strong brand images, and leveraging social networks. Additionally, recommendations included implementing competitive pricing, targeted marketing, ongoing research, and ethical considerations to adapt to changing consumer preferences effectively.

Keywords: Attitudes, brand image, health consciousness, price acuity, social networks

INTRODUCTION

The global food market relies heavily on the dairy industry, which caters to a wide range of consumers with different tastes and preferences. How consumers choose dairy products is affected by factors such as their economic situation, health concerns, environmental consciousness, product characteristics, and marketing strategies. It is essential for dairy producers, marketers, and policymakers to grasp these influences to create successful strategies, maintain their market presence, and encourage the growth of the industry (Jovanovic, 2016; Akbari, 2015).

The dairy industry holds a central position in Nepal's economic landscape and food security. The agricultural sector contributes 23.95% to the national GDP, with the livestock segment accounting for 6.23%. Within this livestock sector, the dairy sub-sector is particularly significant, constituting two-thirds of the livestock gross domestic product (LGDP) and contributing 5.57% to the national GDP (MoALD, 2021). Nepal achieved an annual milk production of 2,479,899 metric tons in 2021, with cows contributing 40% and buffaloes 60% (MoALD, 2021). This sector involves over 500,000 dairy farmers and 1,700 cooperatives, fostering urban-to-rural capital flow and enhancing food security (National Dairy Development Board, 2021). Despite its importance, the dairy industry in Nepal faces challenges such as limited technological advancements, inadequate infrastructure, inconsistencies in milk quality, and low productivity. These challenges are compounded by shifting consumer preferences, growing environmental consciousness, and health concerns, emphasizing the need for research into consumer purchase intentions for dairy products in Kathmandu (Peña-García et al., 2020; Singhal, Jena, & Tripathy, 2019).

This study applies the Theory of Planned Behavior (TPB) to investigate psychological factors (attitudes, health consciousness, product knowledge, and brand image), external influences (social contacts, price perception, and ease of availability), and demographic variables (age, gender, income, and education) affecting consumer purchase intentions. By addressing the research gap, this study offers valuable insights for marketers, producers, and policymakers to align strategies with consumer preferences and drive sustainable growth in Nepal’s dairy sector.

MATERIALS AND METHODS

Research Design

The study employed both descriptive and analytical research designs. The descriptive research design was utilized to ascertain and describe the

characteristics of variables of interest, including the profile of respondents and factors influencing consumer purchase intentions. Analytical research design was applied to identify the nature and strength of the relationships between dependent and independent variables, addressing the research questions to meet the study objectives.

Study Area

Kathmandu Valley was chosen as the study area due to its historical significance as a prominent dairy market, its rich cultural heritage, and its high economic activity. The valley is a thriving hub for commerce, housing numerous dairy processing industries and diverse ethnic and cultural groups with distinct preferences for dairy products.

Data Collection

Both primary and secondary data were utilized. Primary data were collected through surveys using a structured questionnaire developed based on the Theory of Planned Behavior (Ajzen, 2002). The questionnaire employed a 7-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (7). Secondary data were obtained from scholarly journals, books, government publications, and online resources to provide context and supplement primary data.

Sample size and Sampling technique

A non-probability convenience sampling technique was used. The sample consisted of consumers residing in Kathmandu who regularly purchased dairy products such as milk, yogurt, Ghee, and Paneer. The sample size was determined using Cochran's formula (Cochran et al., 2004):

$$n = \frac{z^2 pq}{e^2}$$

Where:

- n = Size of the sample
- p = Population proportion, and q = (1-p). Here, p and q were both set at 50%.
- The confidence level was set at 95%, corresponding to a z-value of 1.96.
- The desired sampling error, denoted as 'e,' was 5%.

By substituting these values into the equation:
n = (0.5 * 0.5 * (1.96) ^2) / 0.05^2
n ≈ 384.16, which was rounded up to 385.

Data Collection Procedure

Participants were approached at dairy stores, sweet shops, supermarkets, and through online platforms like sustainability-focused Facebook groups. University campuses were also targeted. Out of 385 distributed questionnaires, only completed and usable responses were analyzed.

Data Analysis

Data were analyzed using MS Excel and SPSS software. Descriptive statistics (frequencies, percentages, tables, and graphs) were used to understand respondent characteristics. Inferential analyses, including chi-square tests, one-way ANOVA, and regression analysis, were performed to identify relationships between variables and test hypotheses.

Reliability and Validity

The internal consistency of the questionnaire was assessed using Cronbach's alpha, which yielded a value of 0.972, indicating high reliability. A pre-tested questionnaire and a pilot study ensured validity, while data accuracy was cross-verified with participants to minimize bias.

Ethical Considerations

Ethical approval was obtained from the relevant department, and informed consent (both written and verbal) was acquired from all participants. Respondents were assured of their confidentiality and the voluntary nature of their participation, with the option to withdraw at any time.

RESULTS AND DISCUSSION

Descriptive Statistics

The table 1 displays the age distribution of 385 survey respondents. The majority, 58.2%, belong to the 21–30 age group, while 15.8% are aged 31–40. Respondents above 40 years old make up 22.3%, and the smallest group is below 20 years old, at 3.6%. The gender distribution shows 141 (36.6%) females and 244 (63.4%) males. Regarding income, 36.4% reported earning Rs 30,000 to 50,000, 33.2% earned above Rs 50,000, and 30.4% earned below Rs 30,000. For education, 51 respondents had qualifications of intermediate or below, 174 hold bachelor's degrees, 156 had master's degrees, and 4 possessed higher qualifications.

The data from the tables provide insights into the consumption patterns, seasonal purchase trends, and preferred purchase locations for milk and dairy products among the respondents. Regarding consumption frequency, the majority of respondents, 46.0%, consume milk and dairy products "Once a day," followed by

27.5% who consume them "Few times a week." A smaller percentage, 16.1%, reported consuming them "Several times a day," and 10.4% consume them "Once a week."

Table 1. Demographic status of respondents

Demographic Characteristics	Category	Frequency (n) & Percentage (%)
Age Group	Below 20	14 (3.60%)
	21–30	224 (58.20%)
	31–40	61 (15.80%)
	Above 40	86 (22.30%)
Gender	Male	244 (63.40%)
	Female	141 (36.60%)
Income Level	Below Rs 30,000	117 (30.40%)
	Rs 30,000–50,000	140 (36.40%)
	Above Rs 50,000	128 (33.20%)
Educational Qualification	Intermediate or Below	51 (13.20%)
	Bachelor's Degree	174 (45.20%)
	Master's Degree	156 (40.50%)
	Above Master's Degree	4 (1.00%)

Table 2. Milk and Dairy Product Consumption Patterns, Purchase Seasons, and Purchase Locations

Category	Option	Frequency & Percent
Frequency of Milk and Dairy Product Consumption	Few times a week	106 (27.5%)
	Once a day	177 (46.0%)
	Once a week	40 (10.4%)
	Several times a day	62 (16.1%)
Season of Milk and Dairy Product Purchase	Autumn	10 (2.6%)
	Spring	39 (10.1%)
	Summer	150 (39.0%)
	Winter	186 (48.3%)
Location of Milk and Dairy Product Purchase	E-shops	2 (0.5%)
	Local dairy retail outlet	272 (70.6%)
	Supermarket	91 (23.6%)
	Sweet shops	20 (5.2%)

Table 3. Descriptive statistics of psychological and external factors

Factors	Statement	Mean	Standard Deviation
Attitude	I think that purchasing dairy product is beneficial.	5.58	1.591
	I think that purchasing dairy product is a good idea.	5.27	1.559
	I think that purchasing dairy product is safe.	4.84	1.568
Product Knowledge	I am knowledgeable about different types of dairy products available.	5.05	1.551
	Before buying a product, I am aware of the nutritional value of dairy products.	5.04	1.607
	I actively seek information about dairy products before purchase.	4.95	1.696
Health Consciousness	I am concerned about maintaining a healthy diet.	5.49	1.58
	I prefer dairy products labeled as "organic" or "low-fat."	5.19	1.517
	I plan to increase my consumption of dairy products in the future.	4.96	1.536
	I consider dairy products as an essential part of my daily diet.	5.44	1.564
	I pay attention to the nutritional content of dairy products.	5.04	1.622
Brand Image	The dairy product brand is perceived as trustworthy and reliable.	4.98	1.61
	The dairy product brand is visually appealing and informative.	4.81	1.558
	Branded dairy products have a distinct and enjoyable taste.	5.14	1.625
	The brand image aligns with my personal values and preferences.	4.8	1.566
Social Contacts	I often discuss dairy product choices with people in my social network.	3.85	1.8
	I am influenced by the dairy product choices of my family.	5.21	1.685
	I am open to trying different dairy products based on friends' suggestions.	4.69	1.556
	I feel motivated to buy dairy products when others consume them.	4.44	1.645
	I am likely to try new dairy products if recommended by a doctor.	5.45	1.626
Taste	Dairy foods taste as good as similar conventional foods.	4.82	1.627
	I could eat foods that don't taste very good if they offer health benefits.	4.94	1.553
	Health effects are more important than good taste in food.	5.07	1.529
	The taste of dairy products is consistent across batches or purchases.	4.89	1.643
Price Perception	I am sensitive to the prices of dairy products when making decisions.	5.05	1.564
	I perceive a positive relationship between price and quality of dairy.	5.28	1.624
	I am inclined to buy dairy products during promotional offers.	4.57	1.611
	I am willing to pay a premium for health-benefiting dairy products.	5.16	1.632
	I compare prices of different dairy products before purchase.	4.93	1.589

Note: Strongly Disagree=1, Disagree=2, Somewhat Disagree= 3 Neutral=4, Somewhat Agree=5, Agree= 6, Strongly Agree =7

In terms of seasonal purchase, 48.3% of respondents buy milk and dairy products most often in the winter season, while 39.0% prefer summer. Spring and autumn are less popular, with 10.1% and 2.6%, respectively, choosing these seasons for their purchases. Regarding purchase locations, the majority, 70.6%, purchase milk and dairy products from local dairy retail outlets. Supermarkets are the second most popular choice, with 23.6% of respondents buying from there, while 5.2% prefer sweet shops, and 0.5% use e-shops. These patterns offer valuable insights into consumer behavior and preferences related to milk and dairy products.

Respondents generally hold positive attitudes toward purchasing dairy products, valuing their benefits (mean = 5.58) and seeing it as a good idea (mean = 5.27). However, perceptions of safety are somewhat neutral (mean = 4.84), indicating concerns about product safety. Consumers exhibit moderate to high levels of knowledge about dairy products (mean = 5.05), nutritional awareness (mean = 5.04), and active information-seeking behaviors (mean = 4.95). This highlights their consideration of health-related aspects during purchases. Health consciousness is significant among respondents, with a strong focus on maintaining a healthy diet (mean = 5.49) and preference for products labeled "organic" or "low-fat" (mean = 5.19). Consumers also consider dairy products essential to their diet (mean = 5.44) and pay attention to nutritional content (mean = 5.04). Brand trustworthiness (mean = 4.98) and distinct taste (mean = 5.14) are key contributors to consumers' perceptions. However, visual appeal (mean = 4.81) and alignment with personal values (mean = 4.80) show room for improvement, suggesting opportunities to strengthen branding strategies. Family influences (mean = 5.21) and doctor recommendations (mean = 5.45) significantly shape consumer behavior. Discussions with social networks (mean = 3.85) and influence from friends (mean = 4.69) play a moderate role, while visibility of others consuming dairy products (mean = 4.44) slightly motivates purchases. Respondents value the consistency of taste (mean = 4.89) and prioritize health benefits over taste (mean = 5.07). While the taste of dairy products is generally well-received (mean = 4.82), it is not the most decisive factor for all consumers. Price sensitivity is notable (mean = 5.05), with consumers perceiving a positive price-quality relationship (mean = 5.28) and being willing to pay a premium for health benefits (mean = 5.16). Promotional discounts (mean = 4.57) and price comparisons (mean = 4.93) also influence purchasing decisions.

Inferential Analysis

Age, gender, and educational qualification exhibit substantial and statistically significant impacts on Purchase Intention, shedding light on their roles in shaping consumer behavior, while income, although less influential, maintains some significance in this context. Notably, similar to the research conducted by (Kar, Meena and Patnaik, 2018), our study validate the significance of demographic variables such as age, gender, and educational background in shaping preferences and motivations for purchasing dairy products in Kathmandu valley. However, it is worth noting that while our research found income to have a relatively weaker and marginally significant influence on purchase intention, this result corresponds with context-specific variations in the role of income in shaping consumer behavior. Contrary to some prior studies, the daily necessity and consistent pricing

of dairy products in our context might explain why price sensitivity appeared less pronounced.

Table 4. One Way ANOVA test between demographics variable and Purchase Intention

		Sum of Squares	df	Mean Square	F	Sig.
Age	Between Groups	23.673	6	3.946	5.508	.000
	Within Groups	270.753	378	.716		
	Total	294.426	384			
Gender	Between Groups	6.068	6	1.011	4.590	.000
	Within Groups	83.293	378	.220		
	Total	89.361	384			
Educational Qualification	Between Groups	13.646	6	2.274	4.880	.000
	Within Groups	176.188	378	.466		
	Total	189.834	384			
Income	Between Groups	7.882	6	1.314	2.098	.053
	Within Groups	236.679	378	.626		
	Total	244.561	384			

Table 5. Association test between Predictors and Purchase Intention

Variables	Chi-Square Value	(Df)	P-Value
Attitude towards purchasing Dairy Products	457.433	36	0.00
Product Knowledge	467.781	36	0.00
Health Consciousness	544.517	36	0.00
Brand Image	501.308	36	0.00
Social Contacts	554.153	36	0.00
Taste	473.095	36	0.00
Price Perception	618.532	36	0.00
Ease of Availability	711.82	36	0.00

The chi-square tests between various factors and purchase intention reveal significant associations, as all p-values are less than 0.05, rejecting the null hypotheses. Attitude towards purchasing dairy products is significantly associated

with purchase intention ($\chi^2(36) = 457.433$, $p = 0.00$), suggesting that understanding consumer attitudes can impact marketing strategies. Product knowledge is also associated with purchase intention ($\chi^2(36) = 467.781$, $p = 0.00$), emphasizing the role of consumer awareness in influencing decisions.

Health consciousness shows a significant relationship with purchase intention ($\chi^2(36) = 544.517$, $p = 0.00$), highlighting the effectiveness of health-focused marketing. Brand image impacts purchase intention ($\chi^2(36) = 501.308$, $p = 0.00$), indicating the need for strong branding strategies. Social contacts ($\chi^2(36) = 554.153$, $p = 0.00$), taste ($\chi^2(36) = 473.095$, $p = 0.00$), price perception ($\chi^2(36) = 618.532$, $p = 0.00$), and ease of availability ($\chi^2(36) = 711.820$, $p = 0.00$) are also significantly associated with purchase intention, suggesting strategies focusing on these factors can enhance consumer engagement.

Linear regression between dependent and independent variable

The model summary presents the results of a regression analysis aimed at understanding the factors influencing purchase intentions for dairy products. The analysis indicates that the model is highly effective in predicting these purchase intentions. The multiple correlation coefficient (R) demonstrates a strong positive relationship between the predictors, which include attitudes toward purchasing dairy products, social contacts (subjective norm), product knowledge, brand image, taste, health consciousness, price perception, and ease of availability, and the dependent variable. The coefficient of determination (R Square) reveals that approximately 72% of the variance in purchase intentions can be explained by these predictors.

Table 5. Linear regression model summary

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.849[a]	.720	.714	.725	.720	120.949	8	376	.000
a. Predictors: (Constant), Attitude Towards Purchasing Diary Products, Social Contacts (Subjective Norm) , Product Knowledge, Brand Image, Taste, Health Consciousness, Price Perception ,Ease of availability									

Attitude towards purchasing dairy products showed a marginally significant positive effect (Beta = 0.074, $p = 0.057$) on purchase intention. the marginally significant positive effect of attitude towards purchasing dairy products on purchase intention corresponds with the role of attitude in shaping purchase intentions emphasized in previous studies, such as those by (Shirin and Kambiz, 2011; Cazacu, 2015), and(Kichukova, 2017) .

Table 6. Linear regression analysis between dependent and independent variable

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.216	0.293		0.739	0.460
	Attitude Towards Purchasing Diary Products	0.067	0.035	0.074	1.913	0.057
	Product Knowledge	0.054	0.038	0.059	1.429	0.154
	Health Consciousness	0.124	0.047	0.126	2.631	0.009
	Brand Image	0.067	0.040	0.074	1.702	0.090
	Social Contacts (Subjective Norm)	0.165	0.044	0.166	3.762	0.000
	Taste	0.053	0.044	0.053	1.208	0.228
	Price Perception	0.123	0.050	0.121	2.447	0.015
	Ease of availability (PBC)	0.351	0.051	0.357	6.829	0.000
a. Dependent Variable: Purchase Intention (PI)						

Product knowledge (Beta = 0.059, p = 0.154) and brand image (Beta = 0.074, p = 0.090) exhibited positive but non-significant effects. Similarly, the positive association between brand image and purchase intention in our research is consistent with findings in the study by (Mkedder, Bakır and Lachachi, 2021). These results suggest that a positive brand image can cultivate greater trust and loyalty among consumers, making them more inclined to select and repurchase products from that brand. Similarly, our findings regarding the positive influence of product knowledge on purchase intention are in line with studies by (Shirin and Kambiz, 2011; Cazacu, 2015; Kichukova, 2017; Srdjan, Nikolaos and Konstantinos, 2020). This suggests that enhancing product awareness and knowledge can positively impact consumers' purchase intentions, potentially because informed buyers are more aware of product benefits and can make quicker purchase decisions, thus solidifying their preference for a particular product.

Health consciousness had a substantial positive effect (Beta = 0.126, p = 0.009), implying health-conscious consumers have higher purchase intentions. , health consciousness emerged as a significant predictor of purchase intention in our research, which aligns with extensive literature indicating the pivotal role of health considerations in consumer preferences, particularly in the context of dairy

food products (Cash, Wang and Goddard, 2005)Social contacts strongly influenced purchase intention (Beta = 0.166, $p < 0.001$), highlighting the role of recommendations. This aligns with studies like (Pinto *et al.*, 2016; Kichukova, 2017) and highlights the substantial role of word-of-mouth and social influence in shaping consumer behavior within the dairy industry. Price perception showed a notable positive impact (Beta = 0.121, $p = 0.015$), our findings support the idea that higher price does not always have a positive association with purchase intention, as indicated by (Lee, 2008), where consumers with higher price consciousness intend to spend less money on such products.

Ease of availability was a robust predictor (Beta = 0.357, $p < 0.001$). The robust positive predictor of ease of availability in our research is consistent with a wealth of literature emphasizing the importance of product accessibility and convenience in consumer decision-making (Weissmann and Hock, 2022) .This finding pinpoint the significance of consumers' perceptions of how readily and effortlessly they can find and purchase desired products, especially considering that most dairy products are daily consumables. The convenience of buying such products from the nearest location is likely to positively influence consumers' purchase intentions.

The theoretical model generated is:

PI = 0.216 + (0.067 * Attitude) + (0.054 * Knowledge) + (0.124 * Health Consciousness) + (0.067 * Brand Image) + (0.165 * Social Contacts) + (0.053 * Taste) + (0.123 * Price Perception) + (0.351 * Availability).

CONCLUSION

This research identified several influential factors that impact consumer purchase intentions towards dairy products in Kathmandu. Key factors include consumer attitudes, product knowledge, health consciousness, brand image, taste preferences, social networks, price perception, ease of availability, and demographic characteristics. The study emphasized the significant role of consumer attitudes, with a positive attitude towards dairy products being strongly linked to higher purchase intentions. Health consciousness and taste preferences emerged as major drivers of consumer purchase behavior, with individuals who prioritized health and enjoyed the taste of dairy products showing a stronger inclination to buy. The regression analysis revealed that health consciousness, social contacts, and price perception had significant positive effects on purchase intentions, while attitude, product knowledge, and brand image, though positive, did not reach statistical significance. The research also highlighted the importance of external factors such as social networks, brand image, and product accessibility

in shaping consumer intentions in Kathmandu. These findings provide useful insights for dairy product marketers and policymakers seeking to align their strategies with local consumer preferences.

Firstly, informative marketing campaigns and educational initiatives are essential to enhance consumer awareness of dairy product quality and nutritional benefits, which positively impacts attitudes and purchase intentions. Moreover, dairy product marketing should emphasize their health benefits, highlighting nutritional value and positive health effects to appeal to health-conscious consumers effectively. Investing in brand development and management is crucial for dairy product marketers to cultivate positive brand perceptions, increase purchase intentions, and foster brand loyalty. Dairy product marketers can harness the influence of social contacts through word-of-mouth recommendations and endorsements on social media platforms, fostering communities of enthusiasts and leveraging social influence effectively. Affordable pricing and convenient access are imperative for dairy products, as they heavily influence purchase intentions, highlighting the necessity of making these items accessible and reasonably priced for local consumers. Tailoring marketing strategies to specific consumer segments based on demographic factors is also recommended.

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VALUE CHAIN ANALYSIS OF BROILER POULTRY PRODUCTION IN SINDHULI DISTRICT, NEPAL

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ABSTRACT

Poultry farming plays a crucial role in the economic and nutritional security of Nepal, with broiler production serving as a significant component of this sector. However, the broiler poultry value chain in Sindhuli District faces various challenges, including inefficiencies in production and marketing. This study aimed to analyze the value chain of broiler poultry production in Sindhuli District to identify key processes, challenges, and opportunities for improvement. The study was carried out during May-September 2023 through questionnaire format. Out of 55 respondents, 40 broiler poultry farms, 1 hatchery (broilers), 2 agro-vets and 10 retailers were surveyed where 5 core processes (input supply, production, collection, marketing, and consumption) were identified. Among the poultry farmers, 63% were male and 37% females. This study revealed a strong correlation between age and experience, emphasizing the pivotal role of experience in poultry farming. Educational backgrounds varied widely, with 27% respondents having only elementary education and only 3% respondents having attained a University-level education. Farm registration patterns followed distinct peaks in 2074, 2076, and 2077, reflecting the evolving landscape of poultry farming. Small-scale poultry operations, managing 500-1000 birds, dominated the sector. The intensive deep litter housing systems were found to be adopted by 100% of broiler framers at different scale and there was reliance on commercial feeds from sources outside the district. The respondents exhibited responsible antibiotic usage, with 90% farmers administering antibiotics therapeutically. A total of 70% farmers reported disease incidences on their farms, with Colibacillosis, Chronic Respiratory Disease (CRD), Infectious Bursal Disease (IBD), Newcastle Disease (ND), and Mycotoxicosis being the most encountered issues. This study identified challenges such as limited disease preparedness and biosecurity measures, small-scale poultry farming, restricted financial resources and opportunities for enhanced training, improving marketing channels and greater adoption of biosecurity practices.

Keywords: Commercial broiler, input supply, marketing channels, Sindhuli, value chain

INTRODUCTION

Nepal stands as a predominantly agricultural nation, with the agricultural sector constituting 23.9% of its GDP and employing 60.4% of the total population (MoF, 2022). Livestock, including cattle, buffalo, goats, sheep, poultry, and pigs, collectively contribute around 11.5% of the total GDP (FAO, 2006; MoALD, 2017). The poultry industry independently contributes 4% to the overall GDP (FAO, 2014a; MoALD, 2020) and 8% to the agricultural GDP, showcasing its significant role in the country's economy.

Globally, Nepal holds the 92nd position in egg production and ranks 112th in poultry meat production. (FAO, 2014a; Singh, 2018), highlighting the poultry sector as an emerging agribusiness and a vital source of the cheapest animal protein. Nepal has witnessed significant growth in poultry investments and the market supply chain, resulting in the widespread accessibility of poultry meat and eggs in local markets nationwide. (CBS, 2016).The poultry industry has created employment opportunities for over 150,000 individuals while attracting investments of approximately Rs. 115 billion (US$1.1 billion) (CBS, 2016; MoALD, 2020). Modern farming practices have driven sectoral growth, with improved breeds introduced in 1959 marking a turning point for Nepal's poultry farming. Today, there are over 1,400 commercial layer farms and more than 20,000 commercial broiler farms, ensuring poultry products' availability in local markets across Nepal (CBS, 2016; FAO, 2014a).

In 2021, Nepal declared self-sufficiency in egg and meat production, with poultry dominating the animal protein supply chain. Chickens account for 99% of poultry meat and egg production, yielding approximately 1.61 billion eggs and 548,000 tons of meat annually (Prasain, 2021). In the year 2021/2022, the national fowl population exceeded 66 million, with Sindhuli District contributing over 1 million fowls, producing 3,540 metric tons of chicken meat and 8.3 million eggs (MoALD, 2023). Research on Nepal's poultry value chain highlights challenges such as limited market access, weak biosecurity measures, inadequate disease surveillance, and gender disparities in agricultural participation, alongside findings that smallholder farmers face barriers like poor technology access and insufficient veterinary services. Additionally, studies emphasize the need for vertical integration, better regulatory compliance, and increased productivity to address low per capita poultry consumption and improve efficiency and sustainability in the sector.

Poultry value chain studies in Nepal

Prior research has explored various aspects of the poultry value chain in Nepal, providing valuable insights into the industry. For instance, a study by Pant *et al*., (2017) examined the challenges faced by smallholder poultry farmers in Nepal, emphasizing the need for improved access to markets, technology, and veterinary services. Similarly, Dhakal *et al*., (2019) conducted a value chain analysis of the broiler industry in Nepal, highlighting the importance of vertical integration and contract farming in enhancing efficiency and quality control. Osti *et al*., (2017) in his study illustrated a significant statistical difference ($P<0.05$) in farmers' age and experience. A study by FAO ECTAD (2020) revealed that the poultry value chain in Nepal is intricately complex due to various factors, including traditional practices, socio-economic conditions, geographical features of the districts, and extensive open borders with neighboring countries, particularly India. In the study, several critical findings emerged. A study of Gompo, *et al.* (2019)aimed to identify the top ten poultry diseases in Nepal. The top ten diseases with highest to lowest incidence were: colibacillosis 26%.

The poultry industry in Nepal presents a unique challenge: per capita consumption of chicken meat and eggs significantly lags behind the global average, with Nepalese consumption at 5.7 kg chicken meat and 3.66 kg (i.e., around 61) eggs per year compared to the global averages of 14.1 kg meat and 8.9 kg eggs (Mottet & Tempio, 2017; Singh, 2018). The reviewed studies align closely with our findings.

MATERIALS AND METHODS

Selection of study area

This study was carried out in May 2023 in Kamalamai Municipality, the district headquarters of Sindhuli district. It covers an area of 482.57 sq. km and consists of 14 wards. It is situated in the center of the district. It borders Tinpatan municipality in the east, Marin municipality in the west, Golanjor, Sunkoshi & Ghanglekh municipalities in the north, and Mahottari district in the South at present (VHLSEC,2021). Out of the 14 wards in the Kamalamai municipality, two (ward#4, ward#5) were the major broiler poultry producing wards. So, these two wards were selected for the household survey for this study..

Sampling procedure and sample size

In the context of this research, a meticulous approach was undertaken to ensure the comprehensive representation of all relevant stakeholders within the poultry value chain. Recognizing every actor's pivotal role in this intricate network; a deliberate and systematic sampling strategy was employed. Simultaneously, recognizing the limited numbers of certain key stakeholders, a different approach was adopted. Actors such as hatchery operators, input suppliers, distributors, and

retailers, although fewer in number compared to farmers, were no less significant in the value chain. To encompass their perspectives, a snowball sampling technique was applied.

Firstly, to capture the diversity and nuances within different administrative units, a judicious decision was made to include all actors associated with the poultry value chain. This inclusive stance was critical as it allowed for a holistic understanding of the dynamics at play. The study population consisted of all registered poultry farmers within the administrative units under study, totaling approximately forty-eight broiler poultry farms and a single hatchery . A subset of twenty poultry farmers was meticulously chosen from each administrative unit. This methodical selection process ensured that a substantial cross-section of the farming community was represented, ultimately totaling forty poultry farmers. The selection of these farmers was purposive, a decision rooted in the pragmatic realm of convenience. Purposive sampling was used to select farmers actively engaged in broiler production and willing to participate in the study. Although this method introduces potential bias, it was chosen due to logistical constraints and the need to gather data from knowledgeable respondents

1.1 Table 1. Types of key informants interviewed

SN.	Stakeholders of the value chain	Sample selection
1.	Poultry Farmers	40
2.	Hatchery Operators	1
3.	Input Suppliers	2
4.	Distributors	2
5.	Retailers	10

Sources of data

Primary data were gathered through the utilization of semi-structured questionnaires that were tailored to the research objectives. This involved conducting in-depth interviews with various stakeholders in the poultry value chain. These surveys aimed to gather quantitative data on resource flow, value addition, and challenges faced by each stakeholder.

Questionnaire Survey

Surveys were conducted among various stakeholders in the poultry value chain, including poultry farmers, hatchery operators, input suppliers, distributors, and

retailers using a semi structured questionnaire. These surveys aimed to gather quantitative data on resource flow, value addition, and challenges faced by each stakeholder.

Key informants

In-depth interviews were conducted with key informants, including representatives from local government agencies, agricultural cooperatives, and poultry industry associations. These interviews provided qualitative insights into the challenges and opportunities within the value chain.

Public interaction: Increasing the communications with new people, more or less information and data were collected.

Secondary data collection: Secondary data were obtained from various sources, including published and unpublished books, journals, newspapers, research papers, magazines, annual publications, reports, and related documents published by MoALD, VHLSEC, CBS, etc. These secondary sources were referred to in order to supplement and corroborate the primary data collected through the interviews.

Analysis and interpretation of data

The data analysis and interpretation activity were followed after the completion of field works. The collected data were analyzed using a combination of quantitative and qualitative methods. Quantitative data were analyzed using statistical software to calculate descriptive statistics, while qualitative data were subjected to content analysis to identify recurring themes and patterns.

RESULTS AND DISCUSSION

Marketing Channel of broiler poultry in Kamalamai municipality

In the study area, the research identified five distinct marketing channels. Notably, a significant role was played by agro-vets, who functioned as versatile market actors. These agro-vets often served as input suppliers, distributors, and even traders in numerous cases, demonstrating their multifaceted involvement in the poultry industry.

Parent Stock Farms → Hatchery (DOCs) → Distributors → Producers → Wholesalers → Retailers → Consumers

Farmers Participating in this Channel: 10 farmers (25%)

Product Flow through this Channel: 35% (30% of the total broiler production)

Producers → Wholesalers → Retailers → Consumers

Farmers Participating in this Channel: 14 farmers (35%)
Product Flow through this Channel: 30% (30% of the total broiler production)

Hatchery (DOCs) → Producers → Distributors → Wholesalers → Consumers

Farmers Participating in this Channel: 6 farmers (15%)
Product Flow through this Channel: 20% (20% of the total broiler production)

Producers → Retailers → Consumers

Farmers Participating in this Channel: 4 farmers (10%)
Product Flow through this Channel: 5% (5% of the total broiler production)

Producers → Consumers

Farmers Participating in this Channel: 6 farmers (15%)
Product Flow through this Channel: 10% (10% of the total broiler production)

Most Efficient Channel (as per respondents): Producers → Wholesalers → Retailers → Consumers

Farmers Participating: 14 farmers (35%)
Product Flow: 30%

Most Dominant Channel: Parent Stock Farms → Hatchery (DOCs) → Distributors → Producers → Wholesalers → Retailers → Consumers

Farmers Participating: 10 farmers (25%)
Product Flow: 35%

Value Chain map of broiler poultry in Kamalamai municipality

Value chain mapping for broilers involves creating a visual representation of the connections between different participants and enterprises within the value chain. This map illustrates the flow of broilers from producers (farmers) to end consumers and demonstrates the relationships among various stakeholders in the broiler industry in graphical form. The accompanying figure (figure 81) depicts the primary actors in the Broiler Value Chain (BVC). According to the figure, the

five key actors are input supply, production, collectors, marketing, and consumers. This finding aligns with the findings of Oloso *et al*., (2019) and with FAO. Additionally, these primary actors receive essential support services from feed suppliers, veterinary professionals, hatchery operators, and processing plant suppliers, all of which are also indicated on the map (Figure 1).

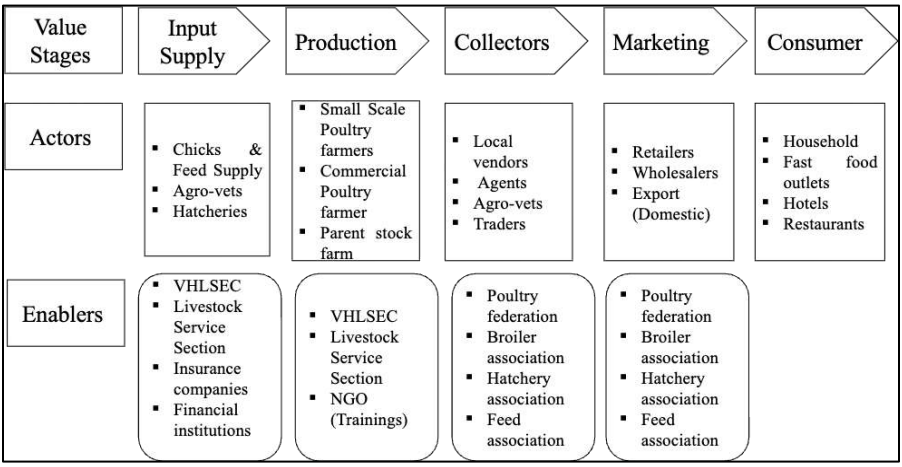

Figure 1. Value chain map of broiler poultry in Sindhuli district

Input supplier: Input suppliers are the individuals or institutions, responsible for provisioning producers with essential resources such as day-old chicks, vaccines, medicines, feeds, and essential equipment for chick rearing. In Sindhuli, agro-vets serve as primary sources for a range of these inputs. In larger-scale operations, hatchery dealers and feed industry distributors play pivotal roles in the supply of chicks and feed, respectively.

Producers:

Parent stock farmer

In Sindhuli District, the Singul hatchery and parent stock farm follow a specific process. They obtain Parent Stock Day-Old Chicks (PS DOCs) from GPS (Grandparent Stock) farms or import nationally and internationally. Additionally, they procure essential items like feed, feed ingredients, feeders, drinkers, medications, vaccines, and other inputs from their suppliers. The parent DOCs are raised for approximately 1.5 years under the supervision of a veterinary doctor and eggs are transferred weekly to the hatchery for a 21-day incubation period. Subsequently, the resulting commercial Day-Old Chicks (DOCs) are exclusively distributed to local commercial farmers, and DOC distributors within the district and exported to Kathmandu.

Commercial broiler farmers

The farmers procure commercial Day-Old Chicks (DOCs) from local hatcheries or distributors. Similar to Parent Stock (PS) farmers, they also source various inputs. The broiler birds undergo a growth period lasting approximately 42-46 days, during which they attain an average weight of 2 kg or above. This rearing process may or may not involve the supervision of a Veterinary Doctor. Subsequently, the mature broiler birds are either collected by distributors or directly sold to local consumers, live broiler marketers, wholesalers, or retailers.

Collectors: The collectors, encompassing agro-vets, local vendors, commission agents, and traders, serve as critical intermediaries. The two major agro-vets of the district supply essential inputs like day-old chicks and medicines while offering technical guidance to the majority of the farms as well as collecting the mature live birds to sell off in the markets. Local vendors act as points of sale for live birds and eggs, connecting producers with local consumers. Commission agents facilitate transactions between farmers and buyers, ensuring fair market value. Traders expand the reach of Sindhuli's poultry products beyond the district, transporting them to regional and national markets. Collectively, these collectors streamline the flow of resources and products, contributing significantly to the district's poultry industry's sustainability and growth.

Marketing: In the poultry value chain of Sindhuli District, marketing is facilitated by wholesalers and retailers. Wholesalers procure, process, and distribute poultry products, serving both local and broader regional markets. They efficiently handle bulk quantities, ensuring a steady supply of poultry products in the district.
Retailers, operating at the local levels, directly connect producers with consumers by offering a diverse range of fresh poultry products. They play a vital role in food security and cater to specific consumer preferences. Collectively, wholesalers and retailers bridge the gap between producers and consumers, ensuring the economic sustainability of the poultry value chain and contributing significantly to local food security.

Processors: The category of meat processors is characterized by a limited number of participants, and it was observed that the majority of birds were supplied directly to consumers without undergoing any processing functions that enhance the product's farm utility. Retailers took on the responsibility of slaughtering, cleaning, and packaging the birds before selling them to consumers. Notably, the Sinhuli District lacked dedicated processing agents within its poultry value chain.

Consumers: Consumers, encompassing households, hotels, and restaurants, play a pivotal role in the poultry value chain of Sindhuli District. They typically procure fresh broiler meat from local markets, retailers, and fresh houses. Broiler meat, due to its affordability and favored taste, constitutes a significant portion of their consumption, serving as a key protein source in the local diet. Additionally, hotels and restaurants regularly source poultry products to meet the demands of their patrons, further stimulating the poultry market. Overall, consumers play a central role in shaping demand patterns and influencing the dynamics of the local poultry industry.

Enablers: Enablers or facilitators, including both agencies and individuals, provide support and assistance to actors from input supply to consumption, focusing on enhancing product value rather than directly adding value to the products themselves. They are government sectors, poultry federations, VHLSEC, NGOs, and related organizations integral to the poultry value chain in Sindhuli District. They actively contribute to policy formulation, disease control, advocacy, training, and knowledge dissemination. Government sectors regulate and support the industry, while poultry federations foster cooperation among stakeholders. VHLSEC ensures poultry health, and NGOs empower smallholder farmers through capacity building. These enablers collectively create an environment conducive to the growth and sustainability of the local poultry sector.

Range of value-added available poultry products

In the scenario of Sindhuli District, Nepal, where meat processors are absent, the poultry value chain predominantly offers value-added products through fresh houses. These fresh houses undertake critical functions such as slaughtering, dressing, and preparing chicken meat for sale in local markets. The packaged value-added products such as sausages and meatballs are imported from Kathmandu and found in few marts and shops.

Among the value-added products in this context:

- Chicken Cuts: Various cuts of chicken, including thigh pieces and wings, are processed and made available for local consumption, with hotels and restaurants being major consumers.
- Chicken Organs: Various poultry organs, such as gizzards, livers, and hearts, are popular among local households. These organ meats are valued for their unique flavors and are used in traditional and contemporary Nepali dishes.
- Chicken Legs and Bones: Chicken legs and bones are often preferred by households with dogs as pets. These parts provide a source of protein

and nutrition for pets in cheap; minimizing waste in the poultry value chain.

- Boneless Meat: Some households and restaurants prefer boneless chicken meat for its convenience in cooking and serving. This processed product is especially popular in urban areas and among those who seek hassle-free meal preparation.
- Minced meat: Minced chicken meat, finely ground and versatile in culinary applications, serves as a popular choice for preparing a wide range of local delicacies and specially used in small local restaurants and hotels.
- Feathers and By-products: Poultry feathers are collected and processed into feather meal, which is used as a protein supplement in animal feed production. This not only reduces waste but also adds value to the poultry value chain.

These value-added products not only enhance the poultry sector's economic significance but also cater to the varied needs and preferences of the local population, contributing to food security and livelihoods in the region.

Constraints and opportunities in broiler poultry value chain

Constraints

1. Escalating Production Costs: The cost of poultry production in the Nepal is on the rise, primarily due to the increasing prices of feed ingredients. This surge significantly contributes to the overall cost of production, accounting for over 75% of expenses, as the production of essential feed ingredients, particularly maize, meets only a fraction of (40-50%) demand (Sharma,2010).
2. Inconsistent Supply of Quality Chicks: The availability of reliable, high-quality chicks at competitive prices is a critical determinant of poultry enterprise success. Unfortunately, in Sindhuli district, the absence of appropriate legal standards for chick quality assurance poses a substantial concern in this sector.
3. Bio-Security Neglect: Bio-security lapses, including bacterial and viral threats, as well as theft, undermine the poultry farming landscape in Nepal. In the study area, inefficient disease diagnosis, treatment, and prevention exacerbate these issues, with a significant proportion of small-scale poultry entrepreneurs lacking formal training in farm management (Acharya *et al.,*2015).
4. Slaughterhouse and Processing Plant Accessibility: The absence of meat processing plants in a district's poultry system restricts efficient processing and value addition, impacting food safety and the sector's

profitability. Additionally, it limits market reach, potentially reducing incomes for local poultry farmers.

5. Disease Outbreaks: Nepal grapples with recurring outbreaks of various diseases, including Avian Influenza, and H1N1 which inflicts substantial annual losses. Other prevalent infectious diseases include Infectious Bursal Disease, New Castle disease, coccidiosis, and pullorum.
6. Limited Poultry Production Knowledge: The poultry industry demands meticulous care and management for optimal results. However, there is a noticeable gap in comprehensive knowledge regarding successful poultry production, hindering progress.
7. Meat Price Volatility: Price fluctuations in poultry meat throughout the year present an additional challenge. These erratic shifts in unit prices create instability and difficulties for poultry enterprises.
8. Absence of Grandparent Stock Farms: The lack of grandparent stock farms in Nepal disrupts chicken production, contributing to elevated chicken costs. Furthermore, the underdevelopment of grandparent stock and hatchery farms in the country exacerbates the scarcity of quality chicks (MOAD,2013).

These challenges collectively impact the poultry industry in the study area necessitating comprehensive strategies and interventions for sustainable and efficient poultry production.

Opportunities

1. Growing Poultry Industry in Sindhuli: Sindhuli's transformation into a poultry hub offers significant economic potential, boosting national GDP. The increasing preference for poultry over red meat due to its affordability and health benefits presents a major opportunity for the sector. However, challenges remain in reducing production costs and ensuring product quality through effective regulations, training, and biosecurity**.**
2. Rising Demand in Urban Areas: The urban demand for poultry meat and eggs is growing substantially at annual rates of 25% and 10%, respectively. This demand provides a major opportunity for expanding poultry production to meet consumer needs. The annual growth rate of poultry bird production stands at a comparatively modest 2.38% (Acharya.et al.2015).
3. Employment Opportunities for Youth: The growing poultry sector is creating employment opportunities, especially for young people. This trend is contributing to both local and national economic development.

4. Increased Competition and Consumer Benefits: The rise of competition in the poultry sector is benefiting consumers through lower prices and improved product quality, spurring further industry growth

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CONCLUSION

Our research in Sindhuli District's poultry sector highlighted several important insights. Age and experience were closely linked among farmers, underscoring the value of accumulated knowledge in poultry management. While practical training in vaccination and rearing was common, there is a need for improvement in disease identification.

Biosecurity practices and disease history showed mixed results. Although intensive deep litter housing systems were widely used, which effectively control disease, there is still room to improve biosecurity measures and reduce antibiotic prophylaxis.

Agro-vets emerged as key players in Sindhuli's poultry ecosystem, serving as input suppliers, distributors, and traders. Their significant role in the local market underscores the importance of their presence in the poultry value chain.

To address the constraints in Nepal's poultry industry, especially in Sindhuli, a multifaceted approach is required. Research into alternative, cost-effective feed sources is necessary to combat rising production costs linked to feed prices. Establishing legal standards for chick quality will ensure a reliable supply of high-quality chicks at competitive prices. Enhancing training programs, particularly for small-scale farmers, is essential to bridge the knowledge gap and optimize production. Strengthening biosecurity measures and providing formal farm management training can help mitigate disease risks. Implementing price stabilization mechanisms can manage meat price volatility. Additionally, promoting the development of grandparent stock farms and hatcheries will ensure a consistent supply of quality chicks

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ANTIBACTERIAL ACTIVITIES OF METHANOLIC BARK EXTRACTS OF *BERBERIS ARISTATA* AND *BERBERIS ASIATICA* FROM DIFFERENT ELEVATIONS OF CHAMPADEVI HILL, NEPAL

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ABSTRACT

Berberis is the largest genus of the family Berberidaceae which grows in almost all vegetation type throughout Nepal from 1000-4600 m. Most of the *Berberis* species found in Nepal have medicinal uses. Methanolic extracts of *B. aristata* collected from two elevations (1900 and 2400 m) and *B. asiatica* from three different elevations (1400 m, 1900 m and 2400 m) were analyzed for antibacterial activities against four bacterial strains (ATCC). Agar well diffusion technique was used for antibacterial screening and inhibition was observed for plant extracts of different concentrations ranged from 6.25 mg/ml to 100 mg/ml, Gentamycin (+ve control), and DSMO (-ve control). Methanolic extracts from both species from different elevations showed antibacterial activity against gram positive (*Staphylococcus aureus* and *Staphylococcus epidermidis*) as well as gram negative bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*). Antibacterial activity was found decreased with increase of elevation for almost all concentrations of bark extracts from both *Berberis* species. However, comparison between antibacterial activities of bark extracts from two elevations (1900m and 2400m) against all bacterial strains except *E. coli* showed higher ZOI for *B. asiatica.* In case of *E. coli*, the higher ZOI was obtained for *B. aristata*. The results of the present study supported the idea that production of secondary metabolites in plants against microbes depends on possibility of infection which is more or less high in lower elevations in comparison to higher elevations.

Key words: Antibacterial activity, *Berberis*, elevation, nutrient broth, *Staphylococcus*

INTRODUCTION

The planet hosts a vast diversity of plant species distributed across various geographic regions. Approximately 391,000 vascular plant species are currently

recognized, including 369,000 angiosperms, as reported by the Royal Botanical Gardens, Kew, UK (Kew, 2016). Of these, about 75,000 species are used in medicinal systems, with over 20,000 higher plant species specifically utilized in traditional treatments by indigenous cultures worldwide (Prakash, 1998). The Nepal Himalaya, known for its exceptional biodiversity, harbors around 10,167 plant species, including 7,000 flowering plants (Shrestha et al., 2000).

Berberis, an angiosperm, is known to use for the cure of different ailments. Every part of the plant such as root, bark, stem and fruits are used in various ayurvedic preparations (Bhattacharjee, 1990). Among the plant parts, stem and root were studied more for their Asian species viz. *B. aristata*, *B. lycium* and *B. asiatica* (Bhardwaj and Kaushik, 2012). Extracts of *Berberis* are used in ophthalmic problems, to treat jaundice, malarial fever, diarrhoea and peptic ulcers (Manandhar, 2002). It also has febrifugal, hypotensive, immuno-stimulating, anti-inflammatory, antimicrobial properties (Musumeci *et al*., 2003). Experimental observation declared that the methanolic as well as ethanolic extracts from stem and root of *B. aristata* respectively, were effective against various bacterial and fungal strains (Lamichhane *et al*., 2014; Mazumder *et al*., 2011; Sharma *et al.*, 2008; Shahid *et al*., 2009; Kumar *et al*., 2007; Dar *et al*., 2014). More specifically, berberine compound (alkaloid) isolated from the stem extract of four *Berberis* species (*B. aristata, B. asiatica, B. chitria and B. lycium*) were found effective against different bacterial and fungal strains (Singh *et al*., 2009; Okunade *et al*., 1994).

Antimicrobial activity in plants is primarily attributed to secondary metabolites such as alkaloids, phenolics, and flavonoids (Zaynab et al., 2018). The production of these metabolites varies significantly, often influenced by environmental factors such as elevation and soil properties (Zargoosh et al., 2019). This study hypothesizes that methanolic bark extracts of *Berberis aristata* and *Berberis asiatica*, collected from different elevations, may exhibit distinct antibacterial potentials. Consequently, the primary objective of this research was to evaluate and compare the antibacterial efficacy of these extracts against selected bacterial strains.

MATERIALS AND METHODS

Collection and preparation of plant material

Two species of *Berberis*, *B. asiatica* and *B. aristata*, were collected from different elevations on Chandragiri Hill, Kathmandu, Nepal. *B. aristata* was obtained from elevations ranging between 1900m and 2400m, while *B. asiatica* was collected from three distinct elevations: 1400m, 1900m, and 2400m. The collected specimens were prepared as herbarium samples and deposited in the Tribhuvan University Central Herbarium (TUCH). The bark of the plants was peeled, dried in the shade for three weeks, and then ground into a fine powder for subsequent extraction.

Extract preparation and dilution

Ten grams of powdered bark from each sample were mixed with 100 ml of methanol in a vial and subjected to sonication (UC-7240BDT, E-Chrome Tech, Taiwan) for 2 hours. The mixture was then filtered through Whatman No. 1 filter paper. The filtrate was left to evaporate at room temperature, following the sonication method. The resulting crude extract was subsequently diluted, with 100 mg of each sample dissolved in 1 mL of dimethyl sulfoxide (DMSO). This stock solution was stored at 4°C and used for antimicrobial screening.

Antimicrobial Activity

Preparation of Culture media

Nutrient Broth media (HI-media laboratories Pvt. Ltd., Mumbai India) was prepared by dissolving 12.5 gram of NB powder in 500 mL distilled water. The media was transferred to the screw capped bottles and sterilized by autoclaving at 15 lbs and 121ºC for 15 minutes. Finally, the suspension media was cooled and used for bacterial culture. Similarly, Mueller Hinton Agar (MHA) media was prepared by using 19 gram of MHA powder (HiMedia Laboratories Pvt. Ltd, Mumbai, India) suspended in 500 mL distilled water. The content was heated to boiling to make media dissolve completely. The media was sterilized by autoclaving at 15 lbs and 121ºC for 15 minutes. The media was poured on sterile petridishes under aseptic conditions for further purposes.

Microorganisms

Two gram positive bacteria (*Staphylococcus aureus* ATCC 25923 and *Staphylococcus epidermidis* ATCC 12228) and two gram negative bacteria (*Escherichia coli* ATCC 25922 and *Pseudomonas aeruginosa* ATCC 27853) were used for antibacterial assay. Three bacterial strains namely *S. aureus, E. coli and P. aeruginosa* were acquired from Sukra Raj Tropical & Infectious Disease Hospital, Teku, Kathmandu while *S. epidermidis* was acquired from City Hospital, Kalanki, Kathmandu.

Preparation of the standard culture inoculums

The individual pure ATCC cultures of bacteria were streaked on the different nutrient agar plates. Those plates were incubated at 37º C for about 24 hours to obtain pure and isolated colonies. Each distant colony was aseptically transferred to the Nutrient broth for the suspension culture with the help of sterilized inoculating loop. The inoculated bottles were kept on the shaking incubator at 37º C and 150 ppm for overnight. The turbidity of the bacterial suspension was adjusted at the 0.5 McFarland standards for the antibacterial test. These inoculums were used for the swapping of the plates to test the antimicrobial effects of the plant extracts.

Transfer of bacteria on petriplates

The agar plates for the assay were prepared by labeling them with the date, name of bacteria, name code of plant samples and the concentration of plant samples. The inoculums of bacteria were transferred into Petri dish containing solid nutrient media of MHA using sterile cotton swab. The sterile cotton swab was dipped into well mixed saline test cultures and removed excess inoculums by passing the saturated swab against the inner wall of the culture tube. The swab was used to spread the bacteria on the media in a confluent lawn. One swab was used for one species of bacteria. The culture plates were allowed to dry for few minutes.

Antibacterial screening via agar well diffusion technique

The antibacterial test was performed by modified agar well diffusion method as suggested by Perez *et al*., (1990) with slight modification. Six wells were prepared on the solid MHA media with the help of sterile corkborer (5 mm diameter) and labeled properly with sterile marker pen. Five different concentrations (100 mg/mL, 50 mg/mL, 25 mg/mL, 12.5 mg/mL and 6.25 mg/mL) of the plant samples were prepared in the DMSO. With the help of sterile micropipette 25 µL of each individual plant extract was poured in the above prepared well. The DMSO was taken as the negative control while the gentamycin disc at concentration of 10 µg was taken as the positive control. The plates were incubated overnight at 37º C and zone of inhibition was observed and noted for individual plant extract of individual bacteria for different concentrations. A triplicate of each sample for each bacterial strain was taken for assurance of unbiased data.

Data analysis

All the experiments were performed in triplicates for each sample and values were reported as mean ± S.D. All the statistical analysis was done using Microsoft Excel 2013.

RESULTS AND DISCUSSION

Antibacterial activities of the methanolic bark extracts of *Berberis* aristata and *B. asiatica* from different elevations were tested against four ATCC pathogenic bacteria namely *E. coli, P. aeruginosa, S. aureus,* and *S. epidermidis*. Dimethyl sulphoxide (DMSO) was used as negative control and Gentamycin (10µg) as positive control. The bark extract of both species of *Berberis* from different elevations against four bacterial strains showed quite a good inhibition zone.

Measured zone of inhibition for both gram positive and gram negative bacteria were expressed in terms of mm including 5mm diameter of well (Fig. 1-4). Increased zone of inhibition was observed relatively with increase in concentration of the extract. Five concentrations of 100µg/mL, 50µg/mL, 25µg/mL, 12.5µg/mL, 6.25µg/mL were used during the test. Positive control (Gentamycin) showed highest inhibition zone (22mm) against *E. coli* while lowest inhibition zone (19mm) against *S. aureus*. DMSO doesn't showed inhibition zone against all the bacteria confirming it has no antibacterial activity against those bacteria. Thus, the inhibition zone showed by different concentration of extract was taken as due to the virtue of extract alone (Supple. Table 1 and 2).

More specifically, methanolic bark extracts of *B. aristata* and *B. asiatica* showed the zone of inhibition (ZOI) against *E. coli* in all concentration ranged from 6.25mg/mL to 100 mg/mL. Antibacterial activity was found decreased with increase of elevation for almost all concentrations of both bark extracts. However, a comparison between the antibacterial activities of both species at two elevations (1900 m and 2400 m) showed higher values of ZOI for *B. asiatica* (Figure 1).

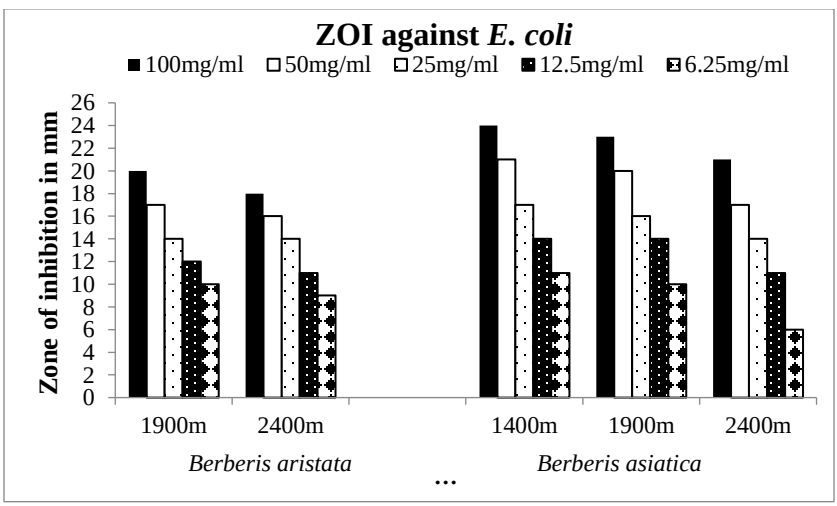

Figure 1. Zone of inhibition of *Berberis aristata* and *B. asiatica* methanolic bark extracts from different elevations against the bacterial strain *E. coli*

Similarly, both extracts showed the zone of inhibition against *P. aeruginosa* in all concentration types except 6.25mg/mL. Antibacterial activity was found decreased with increase of elevation for both bark extracts. In contrast to *E. coli*, higher antibacterial activity was recorded for *Berberis aristata* at three concentrations (25 mg/mL to 100 mg/mL) in two similar elevations (1900m and 2400m) (Figure 2).

In case of gram positive bacteria *S. aureus*, bark extract of *B. aristata* showed zone of inhibition in all concentrations except 6.25 mg/mL which was found decreased in higher elevation at different concentrations. However, the response of bark extract of *B. asiatica* showed almost similar range of ZOI in different elevations except for 100 mg/mL where it showed decrease in ZOI from lower to higher elevations (Figure 3). In case of lowest extract concentration (6.25 mg/mL) ZOI was only recorded from lower elevation (1400m) for *B. asiatica* (Figure 3). The bark extracts of *B. aristata* and *B. asiatica* collected from different elevations showed ZOI against *S. epidermidis* in all concentration ranged except 6.25mg/mL. Bark extract of *B. asiatica* from middle elevation (1900m) showed antibacterial activity even at lowest concentration (6.25mg/mL). Both extracts from lower elevation were found to show higher antibacterial activity, although, *B. asiatica* seemed to have greater antibacterial potential than that of *B. aristata* (Figure 4).

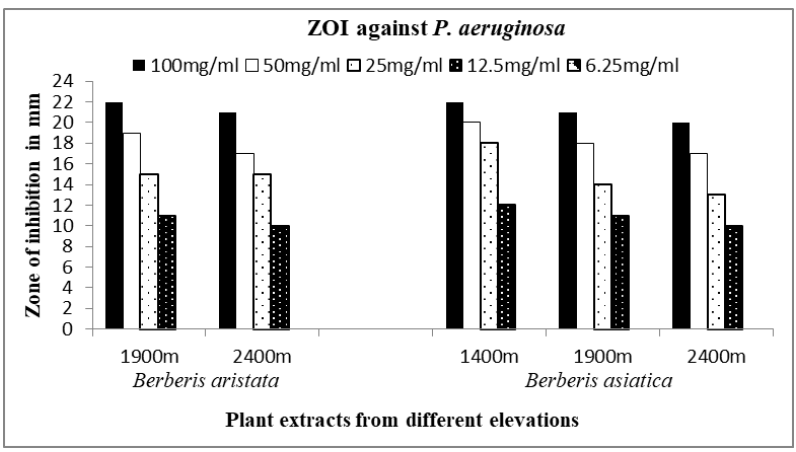

Figure 2. Zone of inhibition of *Berberis aristata* and *B. asiatica* methanolic bark extracts from different elevations against the bacterial strain *P. aeruginosa*

Angiospermic plants produce secondary metabolites, especially antimicrobial compounds to act like a defense mechanism against microorganisms. On the contrary, microorganisms have the genetic ability to mutate and acquire resistance to antibiotics and have become a major global health problem. This compelled the scientists to search out new drugs from plant origin (Khoobchandani *et al*., 2010). Flavonoid compounds exhibit inhibitory effects against Bacteria. Flavonoids, hydroxyl group on their ß- rings are more active against microorganisms and have also been found that the more hydroxylation, more the antimicrobial activity (Sato *et al*., 1996). The hydroalcoholic extract of *Berberis* and alkaloid (Berberine) has stronger and broader spectrum as compared to fungal strain (Singh *et al*., 2007).

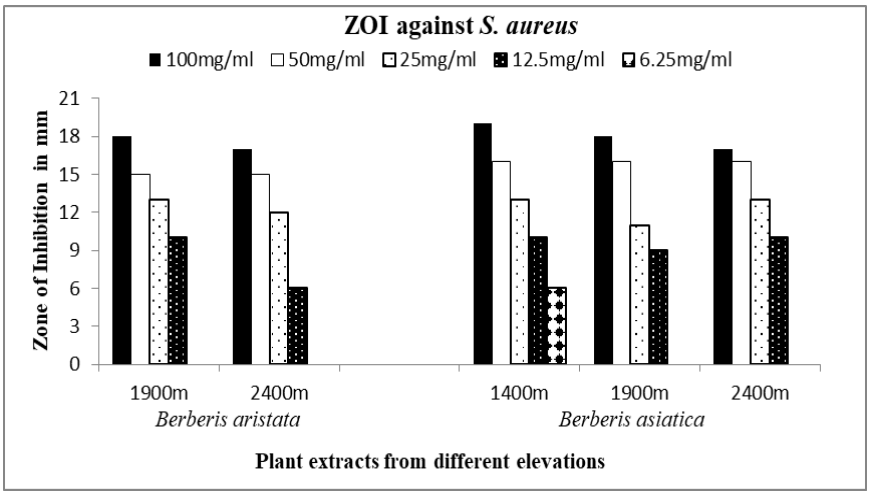

Figure 3. Zone of inhibition of *Berberis aristata* and *B. asiatica* methanolic bark extracts from different elevations against the bacterial strain *S. aureus*

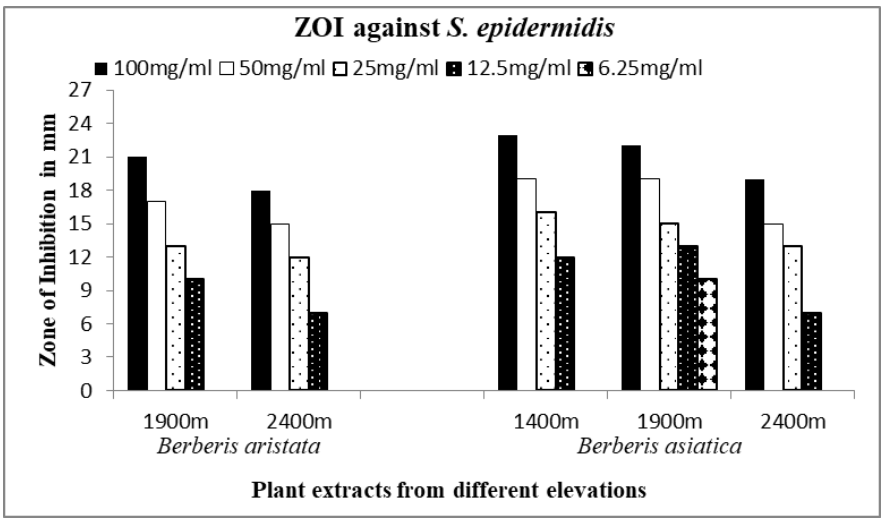

Figure 4. Zone of inhibition of *Berberis aristata* and *B. asiatica* methanolic bark extracts from different elevations against the bacterial strain *S. epidermidis*

Stem bark extract of selected species *Berberis* under study showed potential antibacterial activity against the gram positive (*Staphylococcus aureus* and *Staphylococcus epidermidis*) as well as gram negative bacteria (*Esterichia coli* and *Pseudomonas aeruginosa*). Thus, present outcome shows similarity with the outcome of Dar *et al*. (2014) that the methanolic extract of *Berberis aristata* stem is highly active against both Gram positive and Gram negative bacteria.

Experimental observation declared that the *Berberis aristata* stem extract was sensitive against *Candida albicans, Salmonella typhii, Pseudomonas aeruginosa* and *Escherich coli*, while it didn't show any activity against *Klebsiella pneumoniae*, *S. aureus* (Lamichhane *et al*., 2014) which is quite similar to the present result however inhibition zone was also obtained against *S. aureus* in present study. The high inhibition zone was obtained against *Esterichia coli* while low inhibition zone was obtained against *Staphylococcus aureus*. Difference in the area of collection of plant along with maturity of plant, collection time, extraction set up, extraction time might have contributed to this varied result.

Stem extract of *Berberis asiatica* tested against the Gram-negative bacteria, *Escherichia coli, Klebsiella pneumoniae, Serratia marcescens, Proteus mirabilis, P. vulgaris, Salmonella paratyphi-A, Shigella dysenteriae-1* and *Pseudomonas aeruginosa* showed zone of inhibition. *Pseudomonas aeruginosa*, however, had a considerably large zone of inhibition (Bhandari *et al*., 2000) which is comparable to result from this study. Alcoholic root extract of *Berberis aristata* was effective against *Staphylococcus aureus, Staphylococcus epidermidis* and *Esterichia coli* while ineffective against *Pseudomonas aeruginosa* (Shahid *et al.*, 2009) which is similar to result of this study however bark extract used in present study also shows effectiveness against *Peudomonas aeruginosa*. This variation may arise due to use of different plant parts and moreover other factors mentioned earlier may also affect the result.

CONCLUSION

The study highlights the antibacterial potential of methanolic bark extracts of *Berberis aristata* and *Berberis asiatica* collected from varying elevations of Champadevi Hill, Nepal. The findings suggest a negative correlation between antibacterial activity and elevations, as extracts from lower elevations exhibited stronger antibacterial effects. This trend may be attributed to the higher production of secondary metabolites, such as flavonoids and alkaloids, in plants growing at lower altitudes, where warmer conditions and higher microbial activity might drive the need for enhanced chemical defenses. Among the two species, *B. asiatica* generally outperformed *B. aristata* in antibacterial efficacy, except against *E. coli*, where *B. aristata* showed better performance. These results underscore the influence of environmental factors on the bioactive properties of medicinal plants and their potential as sources of natural antibacterial agents.

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Supplementary Tables

Supplementary Table 1. Antibacterial activity of *Berberis asiatica* and *B. aristata* from different elevations against two gram negative bacterial strains

Samples*	Tested organism	Zone of inhibition in mm (with diameter of well 5 mm)						
		100 mg/mL	50 mg/mL	25 mg/mL	12.5 mg/mL	6.25 mg/mL	+Ve control	-Ve control
BAS-1400m	*E. coli*	24.3±1.1	20.6±0.5	15.0±3.0	12.6±2.0	10.0±1.0	22	0
	P. aeruginosa	22±2.6	19.6±2.5	18.3±3.0	13.6±1.1	11.3±0.5	21	0
BAS-1900m	*E. coli*	22.6±1.1	20.0±2.0	16.0±1.7	13.6±2.0	10.3±2.5	22	0
	P. aeruginosa	21.0±1.7	17.6±1.5	13.6±2.5	10.0±0.0	0.0±0.0	21	0
BAS-2400m	*E. coli*	19.6±1.5	17.3±1.1	14.3±1.1	11.0±1.0	6.0±5.2	22	0
	P. aeruginosa	20.3±1.1	17.3±0.5	13.0±0.0	11.0±1.0	0.0±0.0	21	0
BAR-1900m	*E. coli*	19.6±1.5	17.3±1.5	14.3±1.5	11.6±1.1	10.0±1.0	22	0
	P.aeruginosa	22.0±2.6	19.3±3.0	15.3±3.5	11.0±2.0	2.6±4.6	21	0
BAR-2400m)	*E. coli*	17.6±0.5	16.0±1.0	14.3±1.5	11.6±1.1	10.0±1.0	21	0
	P. aeruginosa	21.0±2.6	17.0±3.2	15.3±3.2	9.6±1.5	0.0±0.0	21	0

* BAS: *Berberis asiatica*, BAR: *Berberis aristata*

Supplementary Table 2. Antibacterial activity of *Berberis asiatica* and *B. aristata* from different elevations against two gram positive bacterial strains

Samples	Tested organism	Zone of inhibition in mm (with diameter of well 5 mm)						
		100 mg/mL	50 mg/mL	25 mg/mL	12.5 mg/mL	6.25 mg/mL	+Ve control	-Ve control
	SAU	19.3±0.5	15.3±1.1	12.3±1.5	10.3±1.5	0±0.0	22	0
BAS-1400m	*SEP*	23.3±0.5	19.3±0.5	16.0±0.0	12.6±0.5	8±0.0	21	0
	SAU	18.6±1.1	15.0±1.0	11.0±0.0	9.0±1.7	0±0.0	22	0
BAS-1900m	*SEP*	22.0±1.7	19.3±1.5	15.3±1.5	12.3±1.1	9.3±1.0	21	0
	SAU	17.3±0.5	15.3±1.1	12.6±1.5	10.0±0.0	0±0.00	21	0
BAS-2400m	*SEP*	18.0±0.0	15.0±2.0	12.6±2.0	9.3±1.5	0±0.00	22	0
	SAU	18.3±1.1	15.6±1.1	12.3±1.1	9.3±1.1	0±0.00	21	0
BAR-1900m	*SEP*	20.6±0.5	16.6±1.1	13.3±0.5	10.3±0.5	2.6±4.6	21	0
	SAU	17.0±1.0	15.3±0.5	12.0±2.0	9.0±2.0	0±0.0	21	0
BAR-2400m	*SEP*	18.0±0.0	15.0±2.0	11.6±0.5	9.3±1.5	0±0.0	21	0

* BAS: *Berberis asiatica*, BAR: *Berberis aristata*

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AN ASSESSMENT OF PUBLIC POLICY CAPACITY DETERMINERS AND PARAMETERS

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ABSTRACT

Policy making is a complex and dynamic process involving various actors and stages, such as formulation, implementation, and evaluation. The effectiveness of public policy depends on the capacity of actors and institutions primarily to formulate, communicate, execute, and assess policies in a comprehensive manner. This study explored the determinants and parameters of policy capacity, identifies critical gaps, such as evidence base, enforcement, and stakeholder engagement. A qualitative approach was used, including literature reviews, field observations, key informant interviews (KIIs), stakeholder consultations, and focus group discussions (FGDs) in five cross reference countries viz. Nepal, India, China, Bhutan and Rwanda. The research identified major key determinants (knowledge, policy skills, political abilities, systemic ability, institutional abilities, leadership skills), and 31 parameters essential for enhancing policy capacity. These findings provide a practical framework to strengthen the capacity of policy actors, ultimately improving the agricultural system and contributing to sustainable development goals through well-informed, evidence-based policy recommendations.

Keywords: Determiners, Parameters, Policy capacity, Policy process

INTRODUCTION

A policy is a comprehensive statement that outlines future goals and aspirations, providing guidelines for achieving those goals. Hill (2014) defined policy as the outcome of political influence, which dictates and sets boundaries for the actions of the state. Public policy refers to a government's decision or action to solve a

social problem, implementing a specific strategy for planning and implementation (Arfina Osman, 2017).

Public policy making is not merely a technical function of government rather it is a complex interactive process influenced by the diverse nature of socio-political and other environmental factors. Policy making is a complex process that involves negotiation, bargaining, and accommodation of various interests, giving it a political flavor (Enserink *et al.*, 2022; Brovina & Arifi, 2023). It is a dynamic process that involves various groups with different interests at different stages. It involves several processes such as problem assessment, agenda setting, policy drafting, adoption, implementation and evaluation (Enserink *et al.*, 2022).

The people involved in the policy making are termed policy actors. These includes individuals, groups, or organizations involved in the formulation, implementation, or evaluation of policies within a governmental or institutional framework (Turnbull, 2008). These actors play crucial roles in shaping public policies that impact societies and economies. Anderson (1979) categorized policy actors as official and non-official actors influencing policy decision-making process. In the policy process, official actors hold legal authority to create and enforce public policies. These include legislators, who have the power to draft, review, and amend policies as necessary; executives, who provide technical assistance and institutional knowledge in policy formulation, with elected officials making the final decisions; and the judiciary, which ensures that policies align with constitutional principles. Non-official policy actors include individuals, interest groups, think tanks, civil society organizations, universities, political parties, NGOs, and the media. Although they lack formal roles, these actors influence policy through educating, advocating, lobbying, and exerting pressure on policy decision-makers (Enserink et al., 2022; Guo *et al.,* 2021).

Policy capacity encompasses the ability of governments and organizations to proficiently formulate, execute, and assess policies. It is the ability to predict and affect change and to acquire and apply knowledge to make intelligent decisions about policy; establish programs to implement the policy; attract and absorb resources; manage resources; and evaluate present policies to guide future action. (Karo & Kattel, 2018). There are several issues and gaps on policy capacity in developing nations, including policy coherence, no policy works habits, lack of information, poor enforcement, accountability systems, insufficient policy capacity research and intervention, and inadequate funding for policy implementation (Mugwagwa et al., 2015). Consequently, poor implementation policies have produced inferior outcomes. It is crucial to analyze government policies, including legal and institutional provisions, identify gaps and restrictions, and connect directly to the policy formulation process, including the

ability of policy actors and institutions (Mukherjee *et al.*, (2021); Karo & Kattel (2018). Policy effectiveness and capacity are directly connected. Actors represented individuals, organizations, and systems/structures who are involved in policy formulation, and implementation processes. Policy actors' credentials, experiences, and inherent abilities promote the success and relevance of any policy, which are often measured by policy outcomes as policy effectiveness. Policy actors need comprehensive expertise, skill sets, and competencies through research and development (Wu *et al.*, 2015). Only capable actors can develop public policy with scientific prediction. Finally, such qualified policy actors support strengthening administrative and governing capacities and certainly support to scale up of the state capacity (Gleeson *et al.*, 2011).

A policy capacity gap occurs when there is a difference between the intended goals of a policy and the actual outcomes. Policy gaps can manifest in several ways. Gap of Knowledge, information and precision data for issues selection. A **capacity gap on policy design** reflects issues within the policy itself, such as unclear objectives or unrealistic expectations, which hinder effective implementation (Weible *et al.,* 2012). A **capacity gap on communication, negotiation and stakeholders' engagement in policy process** arises when policies are not effectively communicated to those responsible for their implementation, leading to misunderstandings and inconsistent practices (Bardach, 2012). A **capacity gap on compliance** arises when there is a failure to adhere to policy requirements, often due to lack of awareness or conflicting interests (Müller, 2015). A **capacity gap** on policy implementation occurs when policies are not effectively put into practice due to resource constraints or poor management (Hill & Hupe, n.d.). A capacity gap on **monitoring and evaluation** occurs when there is insufficient monitoring and evaluation to ensure policies are followed and to measure their impact, making it challenging to identify and address implementation issues effectively.

The main objective of this research was to identify and analyze policy capacity determinants and parameters, thereby providing actionable insights for policymakers, researchers, and development practitioners. Ultimately, this study also aimed to contribute to sustainable development goals through evidence-based policy recommendations tailored to local needs and challenges.

MATERIALS AND METHODS

This study adopted a qualitative research approach to examine the agricultural policy processes and policy capacity of five cross reference countries; Rwanda,

Bhutan, India, China and Nepal. Data collection included an extensive review of academic literature, governments' documents, and policy reports to develop a robust conceptual framework. Field observations in these cross-reference countries were conducted to evaluate the practical implications of their policy processes. Semi-structured interviews and key informant interviews (KII) were held with representative policymakers, government officials, subject experts, members of cooperatives, leading farmers, central government ministers, senior officials of various ministries, foreign experts, and representatives of development partners.

The Rwandan field study was done with close facilitation and coordination of Ministry of Agriculture and Animal Resources- MINAGIR and Centre for Tropical Agriculture, CIAT team Rwanda in June 2024. We specially performed KII with National farmers leaders and field research team of CIAT for Northern Province Musanze district; discussed and visited with local agriculture technician, cooperative group and farmers; senior staffs in Kivu Tilapia fishery farm Eastern province Kayonza district Bymana cell, Kabeza village. Chief Planning division with senior staffs in Ministry of Agriculture and Aanimal Resources, Kigali. We have participated three days seminar in Kigali named "Global Dialogue Kigali-2023" with the experts of twenty more countries and veterans think tank from Rwanda. In that seminar we discussed with Foreign Minister, Chairman of Rwandan Development Board, and foreign representatives from development partners. Similarly, we had visited Bhutan for field study which was closely facilitated and coordinated by the Ministry of Agriculture, and Rotary club of Bhutan. Five KII and FGDs were conducted in Bhutan with the planning section of the Ministry of Agriculture; experts from the Royal Bhutan University, civil society and private entrepreneurs, parliamentarians and politicians, and senior staffs of National Centre for Organic Agriculture, Yusipang, Thimpu. We participated three days seminar in Bhutan with the experts of various countries and renowned think tank from Bhutan in May and June 2024. Short meeting with Prime minister of Bhutan, opposition leader and former minister, NGO partner of Bhutan government and international development partners were also done to understand the policy process. Similarly, a visit to India was done with close facilitation and coordination of Centre for Policy Studies, India. Five KII and FGDs were conducted in India with the experts of public policies, University Professors, and Indian thinktanks; planning section of the Ministry of Agriculture, experts from the JNU, Delhi University and IIT Mumbai civil society and private entrepreneurs, parliamentarians and politicians, and senior staffs of Indian present and former bureaucrats. We had also participated the three days seminar in India- "Policy Process in Global South; 5th India Public Policy Network Conference

December 2024. Similarly, In Nepal an observational visit to all seven province was done along which comprehensive KII with policymakers, government officials, members of cooperatives, leading farmers, local elected leaders, Provincial leaders, Parliamentarians, Provincial Ministers, Agriculture committee from provincial assemblies, central government ministers, senior officials of various Ministries, foreign experts, and representatives of development partners. A policy dialogue workshop was organized in Annapurna Rural Municipality; Senior bureaucrats in ministry of Agriculture and Land Management and Agriculture Ministers and Parliamentarians in Gandaki Province. Policy dialogue program was also conducted with association of fishery farmers and other stakeholders in Chitwan, Bagmati Province. Workshop with deputy chair of local bodies in Nawalpur district was conducted. Policy dialogue meeting with agriculture sub-committee, Sudurpaschim Provincial Assembly, Dhangadi was done. Agriculture sector stakeholders meeting in Biratnagar and Surket were also well organized. Similarly, Policy dialogue on *Raithane* (indigenous) crops was accomplished in Nepal, and public policy dialogue was also co-organized with Rotery club and Public Policy Hub at a national level seminar in Kathmandu. In our study period we reached almost same type of nature of Key Informants among five countries. Specially, in China we deeply analyzed agriculture and public policy process related literatures. We reached all types of policy actors like state actors and non-state actors among cross references country including Nepal. By using those collected qualitative data, the common framework of policy capacity parameters and determiners was drawn and synthesized.

RESULTS AND DISCUSSION

This study findings highlights the effect of capacity of policy actors directly influencing the quality of the policies they produce. The findings revealed that policy processes often lack comprehensive integration of essential factors, such as knowledge, skills, political abilities, ethical standards, systemic abilities, institutional capacities, and leadership skills. These gaps hinder the ability of both official and non-official policy actors to design, implement, and sustain impactful policies. Furthermore, the study findings underscored that non-official policy actors, such as civil society organizations and advocacy groups, often face barriers in influencing the policy process due to limited access to institutional platforms, inadequate knowledge, and insufficient lobbying, or advocacy capabilities. Therefore, this study has identified seven major determiners of policy capacity: Forms of knowledge, set of policy skills, political abilities, ethical standards, systemic ability, Institutional abilities, and policy leadership.

Knowledge as a determinant of policy capacity

The findings of our study has underscored the knowledge as the most important determinant of capacity of policy actor in the policy-making process across all five countries analyzed. The country-specific insights revealed distinct patterns in how knowledge influences policy formulation:

- **Rwanda**: Emphasized indigenous knowledge and contextual perspectives, such as traditional Imihigo practices, which are deeply embedded in the policy process and reflect a commitment to community-driven goals.
- **India**: Prioritized professional and scientific knowledge, aligning policies with global standards to strengthen its competitive position on the world stage.
- **China**: Focused primarily on scientific knowledge while incorporating indigenous and contextual knowledge to complement its policy framework base on their policy related literatures.
- **Bhutan**: Placed significant importance on indigenous knowledge, particularly in exploring the concept of happiness, which serves as a central pillar in their policy-making efforts.
- **Nepal**: Leaned towards modernization, emphasizing scientific and professional knowledge to guide its policy transition into a contemporary framework.

Across all respondents, the consensus highlights that knowledge is the cornerstone of policy capacity. Four dimensions—scientific, professional, contextual, and local knowledge—emerged as the key parameters essential for robust policy development. By integrating these dimensions policymakers can ensure their decisions are well-informed, comprehensive, and effective. The absence or imbalance of these dimensions in any policy results in inefficiencies and undermines the state's ability to progress on developmental indices and achieve its aspirational goals.

Wu *et al.,* (2015) also reported knowledge as a fundamental determinant of policy capacity encompassing a broad spectrum that includes contextual, indigenous, professional, and scientific insights. In recent decades, there has been a growing emphasis on evidence-based policy worldwide, recognizing that evidence is knowledge derived from research, indigenous insights, and various other sources (Capano & Malandrino, 2022). Contextual knowledge ensures that policies are tailored to specific environments and circumstances (Schmitt et al., 2024) , enhancing their relevance and effectiveness. Mielke *et al.,* (2022) AND Schmitt *et al.,* (2024) mentioned that policymakers should possess contextual knowledge, a critical aspect of policy capacity. Indigenous knowledge incorporates traditional wisdom and practices (Zidny *et al.,* 2020), providing valuable perspectives that

are often overlooked. By integrating indigenous knowledge into policymaking, policymakers can develop more comprehensive and culturally sensitive policies (Zurba & Papadopoulos, 2023) that respect and preserve traditional practices. This approach not only enhances policy relevance and effectiveness (Raychelle *et al.*, 2022) but also empowers indigenous communities by recognizing their contributions and promoting inclusivity. Scientific knowledge contributes evidence-based information and innovative approaches, grounding policies in robust research and data (Edler *et al*., 2022a). Policymakers with a strong grasp of scientific knowledge can identify policy issues based on empirical evidence, logical reasoning, and peer review (Edler *et al*., 2022b). The finding of our study resonates with the scholars that identifies different forms of knowledge as one of the major determiners of policy capacity.

Set of policy skills as a determinant of policy capacity

Based on insights from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) across five countries, the findings revealed that a diverse set of skills among policy actors significantly influences the success of policy processes. Respondents emphasized four key skills: negotiation and communication, policy problem analysis, application of contemporary policy theories and perspectives, and policy drafting skills. Rwanda demonstrated remarkable progress in utilizing these skills, contributing to consistent improvements in development indicators. Similarly, India's strength lies in the negotiation and communication abilities of its policy actors, while China's focus on policy problem analysis and drafting ensures effective implementation. Bhutan prioritizes applying contemporary policy theories to address contextual challenges, and Nepal's respondents at all levels of government stressed the importance of integrating these skill-related components into policy processes.

These findings collectively highlight that policy actors' skills are universally essential for robust policy-making and effective governance. The ability to negotiate and communicate fosters consensus-building, while strong problem analysis and drafting skills ensure precision and coherence in policy design. Applying modern policy theories enables adaptation to emerging challenges and fosters innovative solutions. Manazir (2023), also argued that the ability to apply theory and perspectives in policymaking leads to more effective, sustainable, and responsive policies that can address complex challenges in a holistic manner.
Across all countries, respondents agree that prioritizing these skills is integral to achieving effective policy formulation and implementation.

Political abilities as a determinant of policy capacity

Our study highlights the pivotal role of political abilities among policymakers as a critical determinant of policy capacity. Across the four political systems analyzed—Nepal and India's democratic prime ministerial systems, China's communist regime, Rwanda's democratic presidential system, and Bhutan's constitutional kingship—strong political abilities consistently emerged as a key factor influencing policy effectiveness. Respondents widely acknowledged that without the political abilities of policymakers, achieving actual policy goals becomes unattainable. Four core abilities were identified as crucial for a merit-based policy process and timely achievement of policy objectives: the ability to synthesize public policy preferences, make policy decisions, handle political risks and crises, and manage readiness for policy inaction. Policymakers must identify potential political risks associated with policy initiatives, including opposition from powerful interest groups, public backlash, and unintended consequences (Hood *et al*., 2001).

Comparative findings reveal distinct priorities across the political systems. Respondents emphasized that in the communist regime of China and the democratic presidential regime of Rwanda, the focus is on decision-making abilities, crisis handling, and policy inaction readiness. In contrast, the democratic regimes of India and Nepal prioritize synthesizing public policy preferences and handling political risks and crises. Bhutan's constitutional kingship emphasizes synthesizing public preferences and policy inaction readiness. Across all systems, respondents stressed that political abilities are indispensable to policy capacity and critical to achieving effective governance. These abilities enable policymakers to navigate diverse challenges, align policies with public interests, and ensure resilience and adaptability in dynamic political landscapes.

Ethical abilities as a determinant of policy capacity

This study identifies the pivotal role of ethical abilities among policymakers as a critical determinant of policy capacity. Policymaking, as highlighted by respondents, is a highly sensitive and impactful task directly tied to the welfare of people and the enhancement of a state's developmental progress. Ethical standards among policy actors are instrumental in shaping policies that not only improve a nation's global standing but also ensure the equitable and sustainable growth of its citizens. Across the five countries studied, respondents unanimously acknowledged the significant influence of ethical abilities on policy effectiveness. Respondents identified four essential parameters for upholding ethical standards in policymaking: (1) General ethical maturity, including principles like "no harm," "no misconduct," "no conflict of interest," and "no violence"; **(**2)

Cognizance and social responsibility; (3) Sustainability and consciousness-driven thought; and (4) Patriotism. These abilities equip policymakers to address complex challenges with integrity and foresight. Respondents highlighted leaders such as President Paul Kagame of Rwanda, Prime Minister Narendra Modi of India, King Jigme Khesar Namgyel Wangchuck of Bhutan, and President Xi Jinping of China as exemplary ethical leaders who have significantly contributed to nation-building through their ethical leadership. The study concludes that all policymakers should strive to emulate these leaders, fostering ethical maturity as a cornerstone of effective and responsible governance. This argument has been put forward by other scholars as well; Ethics is a fundamental determiner of policy capacity, ensuring that policymaking is conducted with fairness, integrity, and equity (Mukherjee *et al.*, 2021b). Policymakers must demonstrate ethical maturity (Charo *et al*., 2021) by adhering to principles that prevent harm, misconduct, conflict of interest, and violence.

Systemic abilities as a determinant of policy capacity

Our study highlights the critical role of systemic abilities among policymakers as a key determinant of policy capacity. Respondents from all five countries consistently emphasized that a systemic approach—defined as an automated chain of input, process, and output—is essential for ensuring policy sustainability, impartiality, and efficiency. They argued that policies become more merit-based and effective when the system drives the policy process. In contrast, a lack of systemic intervention in policy processes increases the risk of monopolization by individuals, leading to inefficiencies and potential policy failures. Respondents identified four essential parameters for managing a systemic chain in policy processes: (1) Comprehensive systemic provisions for policy processes, (2) Backward systemic linkages to ensure continuity with past policies, (3) Forward systemic linkages to guide future actions, and (4) Performance automation to enhance efficiency and accountability. P anticipation of different stakeholders before policy formation helps in building consensus, increasing the legitimacy of the policy, and ensuring that it addresses the needs of those affected (Bryson, 2011).

The responded successful examples of systemic abilities include Rwanda's Imihigo system for performance assessment and its digital agriculture system, and international development partner mobilization in agriculture which have created great outcomes. Similarly, the public policy process in Kerala, India, stands out as a model of systemic ability in governance, Strong bureaucratic intervention of India is great part of systemic abilities. China's achievements in corporate sector development and the cooperative movement in agriculture, and land management

is further illustrating the importance of systemic interventions. Education system of Bhutan showed a similar better systemic example. These examples underline the significance of systemic abilities in fostering robust, sustainable, and effective policy frameworks, providing valuable lessons for policymakers worldwide (Figure 1 and 2).

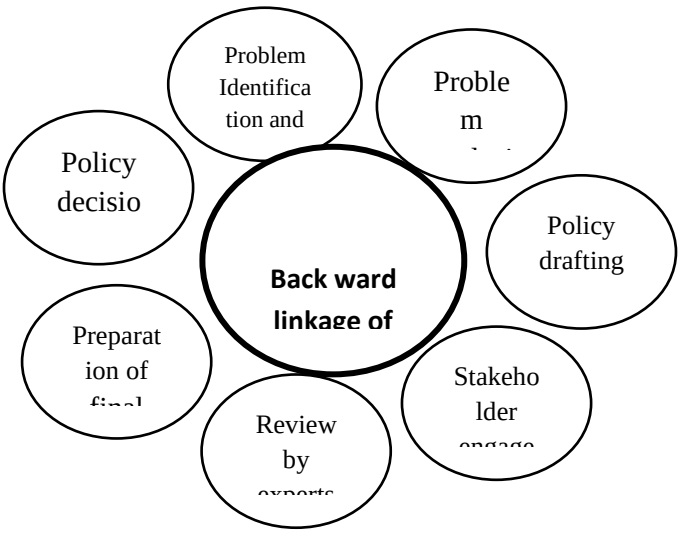

Figure 1. Backward linkage of policy preparatory stage

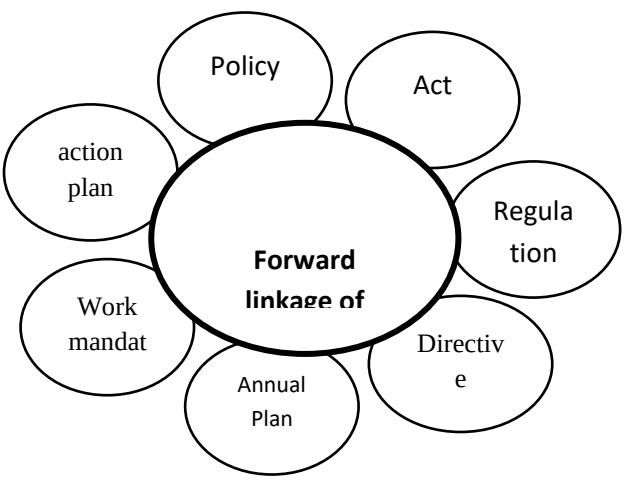

Figure 2. Forward linkage of policy implementation stage

Backwards systemic linkage involves reviewing and integrating past experiences and lessons learned into the current policy formation process. This requires thorough stakeholder engagement, consultation, and coordination, ensuring that all relevant parties are involved before policy formation, whereas forward systemic linkage involves essential steps After policy formation. It is crucial to maintain open lines of communication with all relevant stakeholders to monitor the policy's impact and make necessary adjustments. Stakeholder engagement during policy implementation helps in identifying any issues early on and addressing them promptly (Bryson, 2011). Therefore, forward and backward systemic linkage is identified one of key parameter of policy capacity among the policy actors.

Institutional abilities as a determinant of policy capacity

Our study underscores the critical role of strong institutional abilities in policy process. Institutional abilities as a fundamental determinant of policy capacity. Respondents from all five countries consistently emphasized that strong institutions are essential for states to perform effectively and fulfill their responsibilities toward citizens. A majority of respondents from diverse sectors agreed that every action within the policy process must be institutionalized to ensure sustainability, impartiality, and efficiency. They highlighted that systemic approaches to policymaking must be anchored in robust institutions, as only strong institutions can ensure the successful implementation of whole policy process.

Field study findings revealed four essential parameters for enhancing institutional abilities in the policy process: (1) Comprehensive organizational **structures** that support the policy process, (2) Adequate and uncompromised allocation of required resources, (3) Effective corporate governance to uphold transparency and accountability, and **(**4) Strong coordination, collaboration, and implementation mechanisms. Perception of respondent found divided, however, majorities are acknowledged their institutional capacity of the Communist Party of China (CPC) has been ruling since 1949; Ruling party of Rwanda Rwandan Patriotic Front ruling from 1994**,** Bharatiya Janata Party (BJP) has been continuous ruling since 2014; the policy actors learn their long-term institutional abilities. Respondents emphasized that these institutional abilities are pivotal for fostering policy sustainability and delivering impactful governance outcomes. The findings highlight the need for a firm commitment to building resilient institutions to achieve policy goals and enhance overall state performance.

Policy leadership abilities as a determinant of policy capacity

Our study highlights the pivotal role of leadership abilities among policymakers as a cornerstone of policy capacity and nation-building. Respondents consistently emphasized that leadership is an inherently sensitive and impactful task, directly tied to the welfare of citizens and the advancement of a state's developmental trajectory. Leadership abilities serve as an ideological instrument, shaping policies that elevate a nation's global standing while ensuring equitable and sustainable growth for its people. Across the five countries studied, respondents unanimously recognized the profound influence of leadership abilities on policy effectiveness and governance.

The study identified five essential parameters for effective leadership in policymaking: (1) Ideology setting as a guiding principle for policy direction, (2) Developing competency as a foundational trait of policy leadership, (3) Building courage to navigate challenges and drive transformative decisions, (4) Demonstrating commitment to achieving policy goals, and (5) Fostering leading maturity for responsible governance. Leaders such as President Paul Kagame of Rwanda, Prime Minister Narendra Modi of India, King Jigme Khesar Namgyel Wangchuck of Bhutan, and President Xi Jinping of China were highlighted as exemplary figures who have significantly advanced nation-building through their visionary leadership. The findings underscore that policymakers worldwide should strive to cultivate these leadership abilities, as they are integral to fostering effective governance, addressing complex challenges, and driving sustainable progress.

CONCLUSION

This study presents a clear framework for understanding and enhancing policy capacity, identified seven key determiners for effective policy processes. Furthermore outlined 31 parameters that play a crucial role in strengthening policy implementation and achieving sustainable, impactful outcomes of the policy. The seven determiners—knowledge, set of policy skills, political abilities, ethical standards, systemic ability, institutional abilities, and leadership skills—offer a comprehensive view of the multifaceted nature of policy capacity. Each of these determiners is broken down into specific parameters, covering both technical and non-technical aspects, official and non-official actors of policy development and execution.

Policy actors grouped in two categories official and non-official, for official policy actors, these parameters and determiners continuously strengthened through different ways and means. However, for non-official policy actors, having the proper knowledge, skill sets, and political and institutional influence is crucial

and difficult to strengthen in short term. Only once these elements are in place can they play a meaningful role in the policy process, contributing through education, advocacy, lobbying, and pressure.By identifying these critical areas, our study offers valuable insights into the determiners policymakers need to enhance in order to effectively address both current and emerging challenges.

Strengthening these determiners and parameters will not only improve policy effectiveness but also help in the creation of policies that are inclusive, adaptive, resilient and implementable in the face of both local and global dynamics. The effectiveness of non-state actors in the policy-making process is pivotal for ensuring well-informed and inclusive outcomes. Their roles in educating the public, providing expert counsel, advocating for marginalized voices, and lobbying for change are integral to creating equitable policies. Weak performance in these areas undermines the foundation of merit-based policy development. Consequently, assessing their capacity through clear benchmarks becomes essential. Civil society organizations, political parties, and universities must demonstrate strong competencies in these areas to fulfill their critical roles in shaping impactful and sustainable policy frameworks. The findings from this study provide a strong foundation for future research and practice in the field of policy capacity. They offer policymakers, institutions, and scholars a clear framework for evaluating and improving their capacity to achieve better governance and meet policy goals.

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REVIEW ARTICLES

EVALUATING THE ECONOMIC FEASIBILITY OF HYDROPONICS IN URBAN AGRICULTURE AT KATHMANDU, NEPAL

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ABSTRACT

This review paper explores hydroponics as a progressive method of urban agriculture, addressing challenges of confined land availability, food security, and environmental worries resulting from urbanization. Hydroponics, a soilless agricultural technique, emerges as a sustainable response to the urban challenges of limited arable land and water scarcity. Overall, this review synthesizes the study's insights into setup costs, operational challenges, and profitability, aligning them with global trends and local constraints. Recommendations for strategic interventions, including subsidies, training, and urban planning integration, highlight pathways to foster the adoption of hydroponic farming in urban contexts.

Keywords: Economic feasibility, Hydroponic farming, Soil-less agriculture, Sustainability, Urban agriculture

INTRODUCTION

Hydroponic farming is a transformative method in urban agriculture that is increasingly vital for food security in densely populated areas, mainly like Kathmandu Valley. As a soilless farming technique, hydroponics provides a possible answer to the challenges posed by urbanization, which includes developing vegetation in a water-based, nutrient-rich solution offering higher productivity per unit area by utilizing the resources available. However, the economic viability of such systems in resource-constrained settings like Kathmandu Valley remains complex, necessitating comprehensive evaluation.

In Kathmandu Valley, a place in an urban area with less space and scarcity of water is a growing concern; adapting hydroponic farming could significantly

enhance urban food security and sustainability. However, the economic feasibility of hydroponic systems remains uncertain due to high initial setup costs, ongoing maintenance requirements, and the need for specific technical expertise. Additionally, the market for hydroponically grown vegetables is still developing, with varying levels of consumer acceptance and market demand.

IMPORTANCE AND RELEVANCE TO URBAN AGRICULTURE IN KATHMANDU VALLEY

The adoption of hydroponic farming in city areas, such as Kathmandu Valley, affords a sustainable answer to the challenges posed by using fast urbanization and restrained agricultural land. Hydroponics requires extensively much less house and water in contrast to common farming methods, making it perfect for densely populated city environments the place land and water sources are scarce (Kumar et al., 2023). In Kathmandu Valley, hydroponic farming has the plausible to beautify city meal protection via enabling the neighborhood manufacturing of clean veggies and herbs. This reduces dependency on imported produce and shortens the grant chain, main to more energizing produce with fewer transportation-related carbon emissions (Wagh et al., 2020).

Moreover, the managed surroundings of hydroponic structures can mitigate the outcomes of detrimental climate prerequisites and soil degradation, which are big challenges for ordinary farming in the place (Sela Saldinger et al., 2023). In Kathmandu, research has proven that hydroponics, particularly in rooftop settings, can furnish tremendous inexperienced cover, supporting minimizing the city's warm island impact and merchandising nearby meal production (Shrestha et al., 2021).

By integrating hydroponic farming into city planning, Kathmandu Valley can tackle several city sustainability goals, consisting of decreasing city warmness island effects, bettering inexperienced spaces, and promoting sustainable agricultural practices (Khan et al., 2020). This revolutionary strategy can additionally create new monetary possibilities by way of fostering the improvement of nearby agribusinesses and aiding city farmers with current agricultural strategies (Cifuentes-Torres et al., 2020). Furthermore, the possibility for aquaponics, an aggregate of aquaculture and hydroponics, is being explored in Kathmandu, demonstrating the feasibility of integrating these structures into city settings (Khadka & Maharjan, 2019).

COMPARATIVE ANALYSIS WITH LITERATURE

This review included studies from various regions in Nepal and globally, providing a broader context for understanding hydroponic farming practices and investment costs.

Initial Investment Costs

The scatter plot shows a positive linear relationship between the scale of operation and the initial investment cost, as indicated by the equation y=68068.33x+86173 with an R2=0.5. Larger-scale operations, particularly in locations like the USA and Western Greece (Alder et al., 2000; Michalis et al., 2023), exhibit significantly higher initial investment costs compared to smaller-scale operations in other regions. The observed trend suggests that larger-scale hydroponic systems require more substantial initial investments, possibly due to the need for more advanced technology and infrastructure. However, the moderate R2 value indicates that while the scale is an important factor, other variables such as local economic conditions and technology costs also significantly influence initial investment requirements across different regions.

Operational Costs

The operational costs vary significantly across different regions, with the USA showing the highest costs at approximately $289,760 per year (Alder et al., 2000), followed by Western Greece with costs around $35,491 per year (Michalis et al., 2023). Other regions, such as Australia and Germany, have notably lower operational costs, with values closer to $10,000 and $6,213 per year, respectively (Filho et al., 2017; Souza et al., 2023).

The disparity in operational costs reflects the varying levels of resource availability, labor costs, and technological sophistication across these regions. Higher costs in the USA and Western Greece may be attributed to the scale of operations and the inclusion of labor and variable capital costs (Alder et al., 2000; Michalis et al.,2023), while lower costs in regions like Australia and Germany suggest more efficient resource utilization and smaller-scale operations (Filho et al., 2017; Souza et al.,2023).

The profitability metrics across different hydroponic farming locations reveal varied economic outcomes, with Kathmandu showing a strong B/C ratio of 2.32 and a positive NPV (Thapa, 2021), while locations like the USA and Germany demonstrate favorable NPVs and reasonable payback periods (Alder et al., 2000,

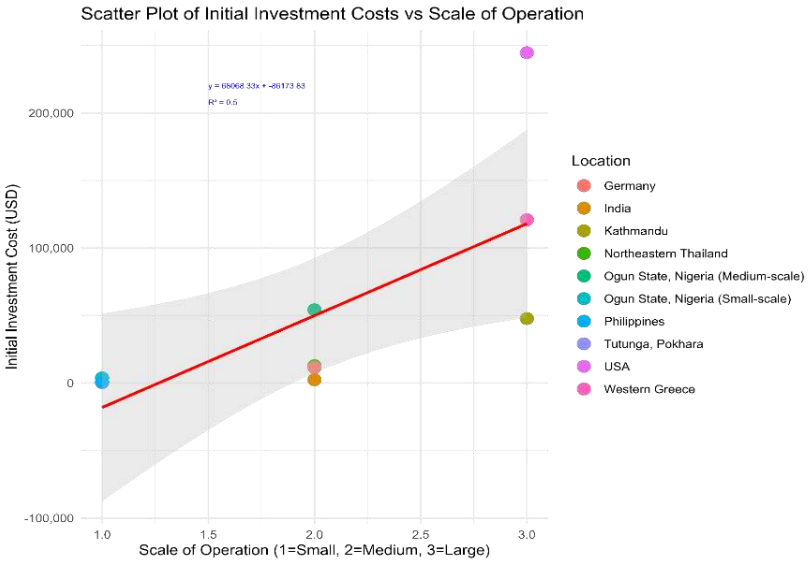

Figure 1. Scatter plot for initial investment costs vs scale of operation

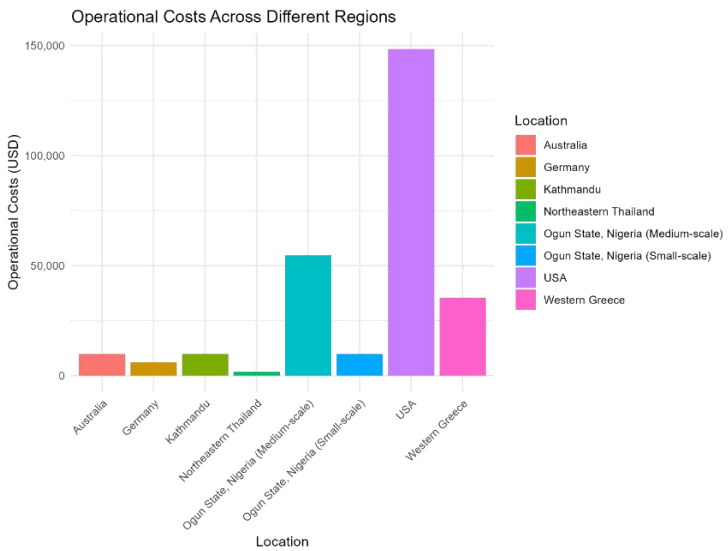

Figure 2. Operational Costs across different regions

Table 1. Revenue and Profitability Analysis

Location	B/C Ratio	NPV	IRR (%)	Payback Period (Years)
Kathmandu (Thapa,2021)	2.32	Positive	0.27	-
Pokhara		Positive	-	Quick payback periods
India (Mishra et al., 2024)	-	-	-	INR 1,05,000 profit; Higher profitability compared to traditional farming
USA (Alder et al., 2000)	-	Potential 12.5% return	-	7.5 years
Australia (Filho et al., 2017)	-	-	-	Highest annual profit of $18,880 using Furlani's mineral solution
Northeastern Thailand (Urayama et al., 2015)	-	57% higher profit in the rainy season	95% higher in the dry season compared to open-field cultivation	-
Germany (Souza et al.., 2023)	-	15575.63	0.3287	3.69 years
Western Greece (Michalis et al., 2023)	-	EUR 25,270.67	0.13	5 years
Ogun State, Nigeria (Folorunso et al., 2023)	-	€42,895 (Small-scale), €331,465 (Medium-scale)	0.83	-
Philippines (Sace et al., 2024)	1.56	Ph P 129,084.05	-	2.1 years

Souza et al., 2023). Notably, Northeastern Thailand exhibits significant profitability with up to 95% higher returns in the dry season compared to open-field cultivation (Urayama et al., 2017). The positive NPVs and relatively short payback periods in several locations suggest that hydroponic farming can be a viable investment, particularly when optimized for local conditions.

CHALLENGES AND SOLUTIONS

Operational Challenges

The most frequently reported operational challenge in hydroponic farming is the high initial investment/setup costs, mentioned 11 times, followed by dependency on energy/electricity and market price fluctuations/volatility, reported 5 and 4 times, respectively.

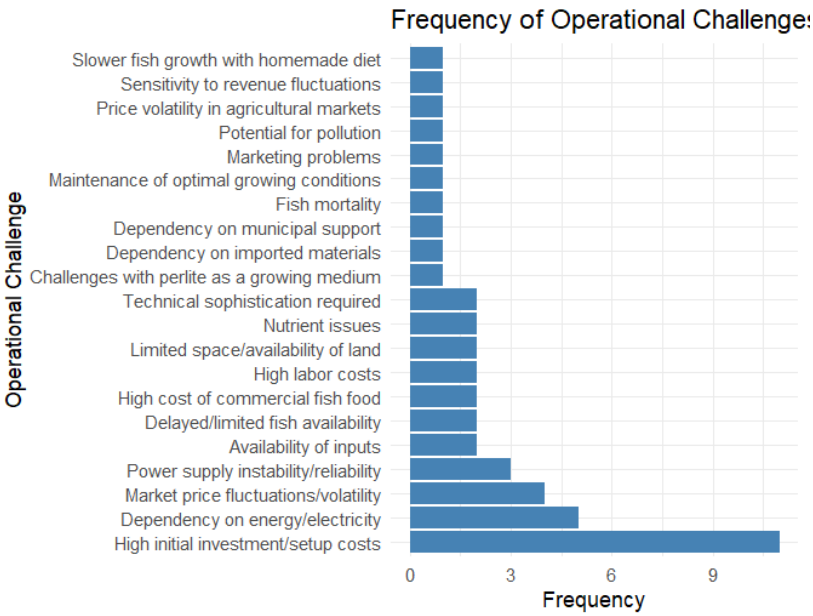

Figure 3. Operational challenge in hydroponic farming

The high frequency of challenges related to initial investment/setup costs indicates that capital intensity is a significant barrier to entry or scaling in hydroponic farming. The dependency on energy/electricity and market price fluctuations further emphasizes the need for reliable infrastructure and stable economic conditions to maintain profitability and operational stability. Addressing these challenges could enhance the viability and sustainability of hydroponic farming operations, potentially lowering entry barriers and operational risks.

Mitigation Strategies

The most frequently cited mitigation strategies include the use of local resources/materials (6 mentions), renewable/alternative energy sources (5 mentions), and advanced technology/innovation (4 mentions). Less frequently mentioned strategies involve public-private partnerships (2 mentions), agricultural insurance (1 mention), and the utilization of small urban spaces (1 mention).

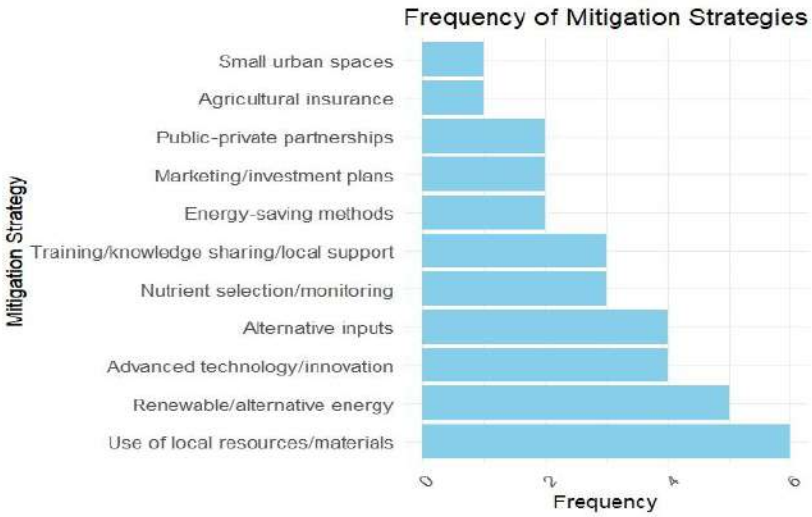

Figure 4. Mitigation strategies

MARKET TRENDS AND CONSUMER PREFERENCES IN LITERATURE

The bar chart shows that local markets are the most frequently used market channel, with a total frequency of 8. Self-consumption is the second most common market channel, with a frequency of 4. Although local markets and direct restaurant sales dominate distribution channels, reflecting consumer preferences for fresh, locally sourced produce. However, challenges persist in expanding these networks, with online sales and wholesale underutilized.

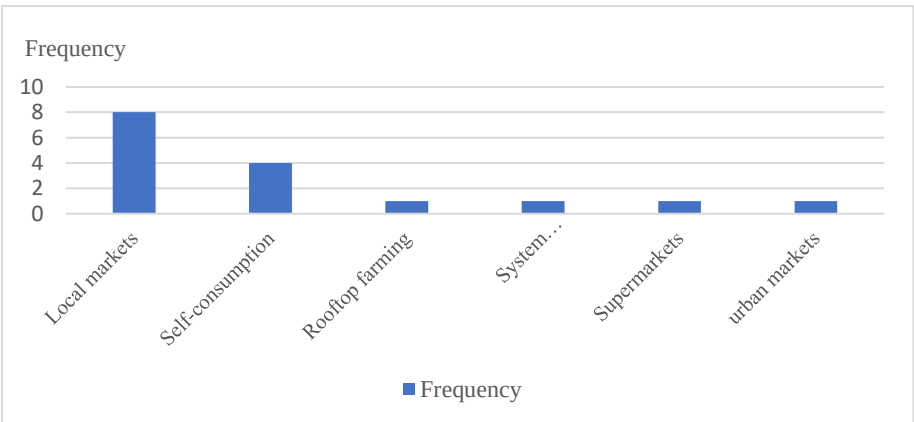

Figure 5. Different marketing channels

Consumer Preferences

The primary consumer preference for hydroponic produce is "Fresh, locally grown," highlighted 8 times, demonstrating the importance of freshness and local sourcing. There is growing demand for hydroponic produce, perceived as high-quality, pesticide-free, and sustainable. These attributes align with global consumer trends prioritizing health and environmental considerations.

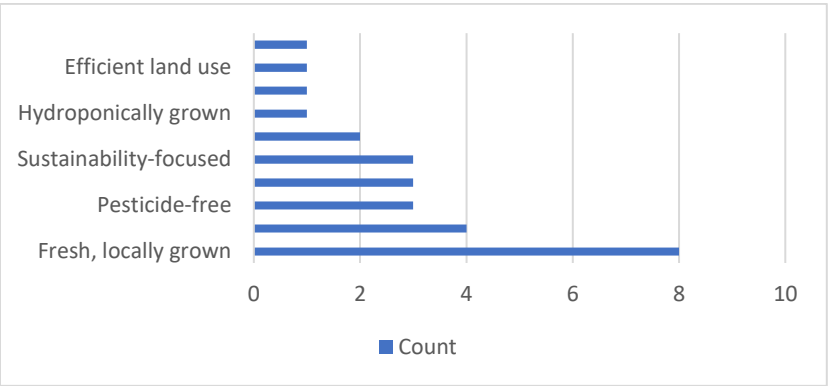

Figure 6. Consumer preference for hydroponic produce

CONCLUSION

The study aligns with global trend, where hydroponic farming faces similar economic and operational hurdles. Yet, specific to Kathmandu are localized challenges such as limited technical capacity and unique market conditions, which affect feasibility. Global success stories emphasize the role of government support and technological innovation in overcoming these barriers.

The study also highlights significant initial setup cost (NPR 1,000,000-20,000,000), deterring widespread adoption. The costs align with global findings, where scalability often dictates profitability. Ongoing operational costs, driven by energy, nutrient solutions, and maintenance, further challenge small-scale farmers. Hydroponics systems, despite high costs, demonstrate long-term profitability through efficient resource use and higher crop yields. Lettuce, identified as the most productive crop in Kathmandu, showcases the system's capability for generating consistent revenue streams. Despite of shortage in skilled labor, seasonal water scarcity, and lack of financial incentives hydroponic farming presents a promising avenue for sustainable urban agriculture in Kathmandu Valley. While economic and operational challenges persist, strategic interventions can unlock its potential, contributing to food security and environmental sustainability.

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ENVIRONMENTAL, SOCIAL, AND ECONOMIC BENEFITS OF ROOFTOP FARMING

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ABSTRACT

Rooftop farming has emerged as a transformative solution to address pressing urban challenges in Kathmandu, Nepal, amidst rapid urbanization and population growth. This paper explores the historical roots, types, benefits, and economic insights of rooftop farming, focusing on its significance in Kathmandu's urban landscape. Drawing on historical examples and contemporary initiatives, the study highlights the multifaceted benefits of rooftop farming, including environmental sustainability, food security, community resilience, and economic empowerment. By examining the successes and challenges of rooftop farming in Kathmandu, this paper underscores its potential as a sustainable urban agricultural practice and calls for concerted efforts to mainstream and scale up rooftop farming initiatives in Kathmandu and beyond.

Key Words: Community resilience, Environmental Conservation, Green roofs, Urban agriculture

INTRODUCTION

The burgeoning population and rapid urbanization worldwide have compounded existing challenges, particularly in developing countries where urban populations are swelling. As cities burgeon, so does the number of low-income consumers, amplifying the strain on resources. Projections indicate that urbanization will surge to 69% by 2050, with urban residents comprising 86% of the population in more developed regions and 66% in less developed ones (Deelstra and Girardet, 1999). This demographic shift disrupts ecological equilibrium, deepening the interplay between nature and human society. Unprecedented urbanization and population growth have thrust the world's cities into the spotlight, confronting them with critical issues like food security and climate change. Studies suggest that urban populations will nearly double from 2010 to 2050, exacerbating the demand for essential resources, including food and supplies (Swilling *et al.*, 2018).

According to the Central Bureau Statistics (2024) Nepal consumer spending has been persistently increasing (Table 1). During the Last one decade the consumer spending has increased by two-times. Consumers preferences have been increasing towards fresh and organic vegetables and fruits. That may be one reason that rooftop gardening has been increasing in the urban areas.

Table 1. Nepal Consumer Spending - Historical Data (CBS, 2024)

Year	Spending	Per Capita	Growth Rate
2023	$35.16B	$956	0.70%
2022	$35.01B	$960	6.83%
2021	$31.52B	$914	7.97%
2020	$28.49B	$866	3.60%
2019	$26.18B	$851	8.14%
2018	$25.54B	$796	6.17%
2017	$22.74B	$758	0.79%
2016	$21.69B	$761	4.16%
2015	$20.36B	$737	2.58%
2014	$18.78B	$723	3.04%
2013	$18.68B	$703	2.65%

Many urban cities in the world are trying to enhance sustainability by improving greenery and promoting urban farming. Following a promotional “Go Green” campaign, rooftop farming has become an important factor in urban planning. An investigation based on an urban ecological assessment proved the significance of green roofs for modern town planning strategies, it showed that the extent of the area with a high environmental load could be reduced. Innovative forms of green urban architecture aim to combine food, production, and design to produce food on a larger scale and promise environmental benefits resulting from the saving and recycling of resources and reduced food miles. Social advantages include improving community food security, the provision of educational facilities, linking consumers to food production, and serving as a design inspiration. In economic terms, it provides potential public benefits and commodity outputs.

As worries about food security become more pressing, rooftop gardening has become a practical alternative in urban areas, providing fresh crop production and

supporting sustainable farming methods at the same time. Rooftop gardens are located atop buildings and offer a multitude of functional benefits, such as temperature regulation, food provisioning, hydrological management, architectural enhancement, and the creation of wildlife habitats or corridors that support biodiversity conservation within urban landscapes. Rooftop gardens are also visually pleasing.

In burgeoning cities like Kathmandu Valley, rooftop farming emerges as a creative solution to utilize wasted spaces. Known as "*Kausi Kheti*," this initiative promotes greening the city and addresses the rising vegetable prices and concerns over produce quality. The growing interest in rooftop gardening reflects a modern commitment to sustainability, community resilience, and food self-sufficiency. It embodies an effort to align human living with natural ecosystems, emphasizing the interconnectedness of sustainability, community well-being, and food security. Examining the historical roots of rooftop farming provides insights into its contemporary relevance in tackling urban challenges.

HISTORICAL NOTE OF ROOFTOP FARMING

Rooftop farming has a rich history that spans centuries and continents, showcasing humanity's ingenuity in utilizing elevated spaces for agricultural purposes. Ancient Mesopotamia provides some of the earliest documented instances of rooftop gardens, with the legendary Hanging Gardens of Babylon believed to have been constructed around 600 BCE. These gardens, though debated among historians, are often cited as early examples of rooftop farming. During medieval Europe, rooftop gardens flourished in monasteries and convents, where monks and nuns cultivated herbs, vegetables, and medicinal plants for sustenance and healing. The Victorian era witnessed a resurgence of rooftop gardens, particularly in urban centers like London and New York City, where ornamental rooftop gardens adorned buildings, adding to the aesthetic appeal of the skyline. World War II saw rooftop gardening gain prominence as part of the war effort, with citizens urged to grow their food on rooftops to supplement rationed supplies. This initiative, known as "victory gardens," played a pivotal role in ensuring food security during the times of scarcity. In more recent decades, rooftop farming has experienced a modern revival driven by urbanization, environmental concerns, and a focus on sustainable agriculture. Germany emerged as a pioneer in modern green roof technology, with the concept of "Begriming" originating in the early 20th century. The Saxon State Chancellery building in Dresden, Germany, constructed with a green roof in 1915, is often credited as the first modern green roof. Switzerland also played a significant role

in advancing green roof development and adoption, with a notable portion of apartment roofs being greened by the mid-1990s. These early innovations underscore the role of Germany and Switzerland as leaders in sustainable urban development strategies, with green roofs serving as a tangible manifestation of their commitment to environmental stewardship (Bertschinger *et al.*, 1996).

BENEFITS OF ROOF-TOP FARMING

Rooftops, often considered spaces of fantasy and imagination, offer unique opportunities for agricultural innovation and ecological engagement. With three primary options for rooftop farming - container gardening, intensive rooftop planting, and hydroponics - each approach presents distinct advantages and considerations. Container gardening, characterized by its simplicity and affordability, involves minimal modifications to existing roof structures, making it accessible to many urban dwellers. Conversely, intensive rooftop planting, where the rooftop serves as the planting medium, requires more substantial investments but offers benefits such as enhanced storm-water retention, building insulation, and the creation of urban ecosystems that facilitate biodiversity conservation and ecological resilience.

Benefits of Roof-Top Farming

Environmental benefits

Rooftop farming offers a plethora of benefits, aligning with the growing global momentum towards sustainable living. Amidst the rapid urbanization and modernization in Kathmandu Valley, Nepal, traditional agricultural practices have faced significant challenges due to the conversion of arable land into urban infrastructure. This transition has heightened concerns over food security, environmental degradation, and sustainable development, necessitating innovative solutions (Sharma and Nepal, 2020).

Rooftop farming has emerged as a promising avenue to address various challenges including food security, environmental sustainability, and community resilience. By utilizing underutilized rooftop spaces, urban dwellers can cultivate fresh and organic produce, thereby reducing dependency on imported food items and mitigating the environmental impact associated with long-distance food transportation (Shrestha, 2023). The environmental benefits of rooftop farming are substantial. Rooftop farms act as natural filters, absorbing rainwater and reducing storm runoff, thus mitigating the risk of flooding and soil erosion. Additionally, the vegetation on rooftops helps cool buildings, counteracting the

urban heat island effect and improving overall air quality. Organic farming practices further contribute to healthy soil and biodiversity, fostering a harmonious ecosystem that supports pollinators like bees and butterflies (Sharma and Nepal, 2020).

Social Benefits

Beyond environmental advantages, rooftop farming brings significant social benefits to urban communities. By engaging residents in rooftop gardening, it fosters a sense of community and connection to nature. Participants can grow fresh, nutritious produce for themselves and their families, thereby improving access to healthy food options, particularly in underserved areas. Moreover, rooftop farming initiatives create local job opportunities, especially in urban regions with high unemployment rates, and educational programs can be integrated to educate children about sustainable food production and environmental stewardship (Gurung, 2019). Furthermore, rooftop farming initiatives demonstrate a commitment to environmental, social, and governance (ESG) principles, which are increasingly valued by cities worldwide. Cities with robust rooftop farming programs showcase their dedication to environmental responsibility and social well-being, attracting environmentally conscious businesses and residents. Through incentives and streamlined regulations, local governments can further encourage the development of rooftop farms, fostering collaboration between public and private entities to ensure their success (Thapa and Subedi, 2021). Despite facing challenges such as limited awareness, technical knowledge, and logistical constraints, the future of rooftop farming is bright. Technological advancements, such as lightweight growing mediums and automated irrigation systems, are making rooftop farming more accessible and efficient. With growing public awareness of sustainability issues and government support, rooftop farming is poised to become a mainstream practice, contributing to a more sustainable and resilient urban future (Khan and Akram, 2020).

Economic Benefits

One compelling example of the economic importance of rooftop farming in Kathmandu lies in its role in providing supplementary income for urban residents. Consider a family residing in an apartment building in the heart of Kathmandu, where traditional agricultural pursuits are constrained by limited space. Turning to their rooftop as a fertile ground for cultivation, they meticulously plan and employ innovative techniques to establish a garden abundant with high-value crops such as tomatoes, bell peppers, and herbs.

As their rooftop garden flourishes, the family begins harvesting a bountiful yield of fresh produce. Not only do they satisfy their own dietary needs with homegrown vegetables, but they also find themselves with surplus crops to sell at local markets or directly to neighbors and restaurants. The premium quality and organic nature of their rooftop-grown produce command a higher price compared to mass-produced, commercially available alternatives. The income generated from the sale of rooftop-farmed produce serves as a valuable supplement to the family's finances, easing financial strain and enhancing their overall economic well-being. Furthermore, as the demand for locally sourced, organic produce continues to rise in Kathmandu, the economic viability of rooftop farming becomes increasingly apparent.

An economic analysis of rooftop gardening in Kathmandu Valley (Wasti and Bhusal, 2019) provides intriguing insights into its financial viability. The total cost of operation averaged NRs. 35,519.40, with expenses varying across different inputs, notably higher expenditure on manure compared to oil cake. Conversely, the total income from rooftop gardening amounted to NRs. 44,032.17, with green leaves emerging as the primary income generator among all garden components. The benefit-cost ratio (B/C ratio) further underscores the economic prospects, with the average B/C ratio per household calculated at 1.24. This suggests that for every unit invested in rooftop vegetable production, the return was approximately 1.24 times, affirming rooftop gardening as a profitable venture worth pursuing.

SUITABLE CROPS FOR ROOF TOP FARMING

In the vibrant landscape of rooftop farming in Kathmandu, an array of crops thrives under the open sky, transforming urban rooftops into verdant oases. From the familiar solanaceous delights of tomatoes and bell peppers to the robust brassicas of cabbage and broccoli, the diversity of cultivars mirrors the rich tapestry of Kathmandu's culinary heritage. Yet, within this mosaic of greenery, variation abounds as rooftop farmers tailor their crops to the unique capabilities of their rooftop spaces. Some opt for the delicate allure of herbs like parsley and dill, infusing their dishes with aromatic freshness, while others venture into the realm of woody plants, nurturing fruit-bearing trees like apples and pears. This dynamic spectrum of cultivation reflects not only the ingenuity of urban farmers but also the adaptability of rooftop farming to meet the diverse needs and preferences of Kathmandu's inhabitants. Reasons for adapting rooftop gardening: The major reasons for adapting the rooftop gardening were for the sustainable production with 0.54 index value followed by minimize side effects of health,

healthy soil and environments with rank value 0.48 and 0.44, respectively (Wasti and Bhusal, 2019).

Unveiling Kathmandu's Rooftop Eden: A Paradigm Shift in Urban Agriculture

In today's global landscape, rooftops are transforming into multifunctional spaces, heralding a new era of sustainability and innovation. From Singapore's cooling rooftops to Berlin's urban greenhouses, cities worldwide are harnessing the potential of elevated spaces for environmental, social, and economic benefits (Khan and Akram, 2020). In Kathmandu, a city grappling with rapid urbanization and a surge in rural migrants seeking better prospects, rooftops offer a promising solution to address pressing challenges while nurturing a greener future.

With over 3 million residents in Kathmandu Valley alone, the burgeoning population density strains the city's resources and infrastructure. Rooftop gardens emerge as a beacon of hope, promising to alleviate urban pressures and enhance the quality of life for its inhabitants. These elevated sanctuaries not only contribute to ambient and home temperature regulation but also reduce heating and cooling requirements, thereby curbing emissions and cutting costs (Shakya and Shrestha, 2017).

Rooftop farming (RTF) emerged as a transformative practice, pioneered by the Kathmandu Metropolitan City (KMC) with support from development agencies like the Environment and Public Health Organization (ENPHO) and the Institute for Social and Environmental Transformation Nepal (ISET Nepal). Encouraged by its success, the KMC envisions RTF as a cornerstone of urban waste management, utilizing organic waste and greywater to nurture thriving ecosystems above the concrete jungle (Shakya and Shrestha, 2017).

The exponential growth of Kathmandu's urban landscape underscores the urgency of sustainable urban agriculture initiatives. With an estimated one million new houses added to the capital in recent years, the KMC recognizes the pivotal role of rooftop farming in ensuring food security and fostering self-reliance (CBS, 2017). Empowering residents to embrace rooftop gardening, the KMC initiates training programs and provides support to 500 households annually, aiming to cultivate a culture of self-sufficiency and environmental stewardship (CBS,2017). The integration of rooftop farming into government policies reflects a concerted effort to mainstream sustainable agricultural practices. While challenges persist in defining and implementing rooftop farming initiatives, governmental support

and grassroots enthusiasm pave the way for a greener, more resilient Kathmandu. As the Ministry of Agriculture and Livestock Development prepares to formalize the concept of rooftop farming, the stage is set for Kathmandu to emerge as a beacon of urban agricultural innovation, inspiring cities worldwide to cultivate their rooftops and harvest the sky.

Table 2. Species and families of vegetables grown on roof top gardens at Kathmandu

Solanaceae	Brassicaceae	Cucurbitaceae
• Tomato • Bell Pepper • Chili • Eggplant • Potato	• Mustard • Turnip • Radish • Cabbage • Cauliflower • Broccoli • Kale	• Zucchini • Bottle gourd • Bitter Gourd • Cucumber • Squash • Pumpkin • Melons
Fabaceae	Poaceae	Apiaceae
• Lentils • Chickpeas • Beans • Peas	• Corn • Wheat • Barley • Oats • Lemon grass	• Carrots • Celery • Parsley • Dill
Amaranthaceae	Amaryllidaceae	Rosaceae
• Spinach • Swiss Chard • Beetroot • Quinoa	• Onion • Garlic • Leeks Chives	• Raspberry • Blackberry
Asteraceae	Lamiaceae	Rutaceae
• Lettuce • Arugula • Chicory • Sunflower	• Mint • Basil • Lavender • Oregano • Rosemary	• Grapefruit • Tangerine • Citrus (e.g., Lemon, Orange, mandarin)
Rosaceae	Others	
• Strawberries • Apples • Pears • Cherries	• Herbs (e.g., Thyme, Cilantro), Flowers	

Source: Observation of various rooftop gardens, 2024

CONCLUSION

Rooftop farming in Kathmandu is not merely a horticultural endeavor; it represents a transformative shift towards sustainable urban development. As Kathmandu grapples with the challenges of rapid urbanization and burgeoning population growth, rooftop farming offers a beacon of hope, addressing critical issues such as food security, environmental sustainability, and community

resilience. Through innovative approaches and collaborative efforts between government bodies, development agencies, and local communities, rooftop farming has emerged as a viable solution to utilize underutilized spaces and promote self-sufficiency.

The historical roots of rooftop farming, spanning centuries and continents, underscore its resilience and adaptability to diverse urban landscapes. From ancient Mesopotamia to modern-day Kathmandu, rooftop farming has evolved to meet the changing needs of urban dwellers, reflecting humanity's ingenuity in harnessing elevated spaces for agricultural purposes. Today, Kathmandu's rooftop gardens not only provide fresh produce but also contribute to environmental conservation, social cohesion, and economic empowerment.

As rooftop farming gains momentum in Kathmandu, it is imperative to address challenges such as limited awareness, technical knowledge, and logistical constraints. By leveraging technological advancements, government support, and community engagement, Kathmandu can unlock the full potential of rooftop farming, paving the way for a more sustainable and resilient urban future. With concerted efforts and collective action, Kathmandu has the opportunity to emerge as a global leader in urban agricultural innovation, inspiring cities worldwide to cultivate their rooftops and harvest the sky.

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