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ASSESSMENT OF FOOD SAFETY KNOWLEDGE AMONG FRESH PRODUCE GROWERS AND EXTENSION WORKERS BEFORE AND AFTER TRAINING IN NEPAL

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ABSTRACT

Access to safe food, including safe fresh produce, is essential to ensure healthy food and diets for the households and communities. However, there is limited awareness of food safety at household levels in Nepal. Food safety educational programs bridge the knowledge gap in addressing food safety. A pre- and post- assessment study was conducted during food safety trainings in five cities of Nepal to understand and evaluate the effectiveness of the trainings. Data from 102 fresh produce growers and 100 extension workers was collected through pre- and post- training responses. Questionnaires featuring 15 food safety statements were administered to the participants before and after the training. Then subsequent comparative analysis was done using the Wilcoxon signed ranks test, Mann Whitney test and Kruskal-Wallis test. The scores across subgroups: gender, age, respondent type and location were evaluated to test the significant differences. We found that the median knowledge score (indication of the knowledge or awareness level) elevated from 9.00 to 11.00 after the training. Our analysis suggested a statistically significant increase in food safety knowledge following the trainings ($p<0.001$). We found significant differences in the pre- and post- knowledge scores by gender ($p<0.001$), respondent type ($p=0.005$) and location ($p<0.001$). Our findings suggest that the targeted trainings to growers and extension workers could be an effective tool in enhancing food safety knowledge.

Keywords: Food safety, Interventions, Risk, Stakeholders, Vegetables

1. INTRODUCTION

Food safety is a critical aspect of sustainable food systems, ensuring access to safe and nutritious food for consumers (WHO, 2023). The widespread concern for food safety in fresh produce is attributed to the global surge in production, distribution, and consumption, coupled with inconsistent adherence to good agricultural practices (Olaimat & Holley 2012; Machado-Moreira et al., 2019). The World Health Organization (WHO) has emphasized the importance of food safety practices in ensuring healthy lives in Nepal (WHO, 2023).

Unsafe fresh produce consumption is associated with an increasing number of foodborne illnesses (Callejon, 2015). Studies have unveiled contamination of vegetables with several categories of microorganisms like Bacteria including *Bacillus*, *Staphylococcus*, *Salmonella*, *Shigella* and *Pseudomonas* spp, *Giardia* cysts, Hookworms, Coliforms (Ghimire et al., 2020; Shrestha & Rai, 2014; Ankita & Shrivastava, 2012). Microbial contamination of the fresh

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produce results from unsafe production and handling methods, like using polluted water for irrigation and unhygienic handling practices (Khadka et al., 2017). In Nepal, unsafe handling of fresh produce put consumers' health at risk for food-borne illnesses (Ghimire et al., 2020). This embarks the collaborative responsibility of the government agencies, agriculture extension agents and farmers to enhance food safety and promote a sustainable and healthy food supply chain benefitting both farmers and consumers alike.

Gaining food safety knowledge is essential as it could potentially minimize the outbreak of food-borne diseases (Jianu & Golet, 2014). Targeted food safety educational programs are an effective tool to address food safety challenges (Chen et al., 2022; Scott et al., 2009). Accelerating educational program among diverse stakeholders in the production system should be a priority for Nepal (Khanal et al., 2023). In this context, Nepal has started to take steps toward food safety management practices but it is still in infant stage.

To ensure the safety of agricultural products and a safe food supply, good agricultural practices (GAP) has been suggested as an effective tool for implementation during the on-farm production as well as post-production processes (FAO, 2016). Food handlers should understand the safe handling of the fresh produce before selling at local markets (WHO, 2023). However, there is limited awareness on food safety practices in Nepal, particularly among women suggesting their greater participation in outreach and extension activities including training programs (Khanal et al., 2023). Moreover, at farm level, there is seldom use of food safety precautions in Nepal (Bagale, 2023). To equip farmers with the knowledge and skills necessary to reduce contamination risks a food safety training program was delivered in five major cities of Nepal. A survey was administered on the training participants to assess knowledge on pre- and post-training. This comparative evaluation seeks to understand the transformative potential of the educational program.

2. METHODOLOGY

2.1. STUDY DESIGN AND SITES

This study was carried out from September 15 to October 8, 2023 across five cities of Nepal. Itahari, Kohalpur, Bharatpur, Pokhara, and Kathmandu were the selected location of the trainings.

The structured approach employed in the project titled "Market-Led Food Safety in Nepal: Harnessing Production Incentives and Consumer Awareness", implemented in Nepal by Agriculture and Forestry University as a part of a project from Feed the Future Innovation Lab for Food Safety in Nepal led by Tennessee State University with funding from the United States Agency for International Development (USAID) was outlined for this study. Prior to the commencement of the training, formal letters were dispatched to government and private organizations, urging the participation of agriculture extension agents and fresh produce growers to represent their respective locations. Government organization included Prime Minister Agriculture Modernization Project (PMAMP), Agriculture Knowledge Center (AKC), agricultural offices under municipalities and private organizations included private farms involved in fresh produce production.

Targeted organizations were informed about the objectives of the food safety-training program. Government offices in close geographic proximity to each training site were strategically chosen during the selection process based on their convenience and access to training site. Additionally, farmers representing diverse locations within each training site were selected by respective offices. The food safety training program for fresh produce growers was subsequently delivered during distinct time periods. This approach not only ensured that stakeholders in agriculture would participate in a representative manner, but it also improved the training effectiveness and coverage.

2.2. SELECTION OF THE PARTICIPANTS

Organizations were requested to send one agricultural extension agent and one fresh produce grower as participants for the training. From the response of the formal requests, we finalized the total number of respondents from each location (Table 1).

Table 1. Location specific number of participants in the food safety training

Location of the training site	Number of participants (n=202)
Itahari	39 (19.3)
Kohalpur	38 (18.8)
Chitwan	39 (19.3)
Pokhara	44 (21.8)
Kathamandu	42 (20.8)

Note: Figure in the parenthesis indicate percentage.

2.3. DESCRIPTION OF THE TRAINING

The training included five different sessions where each session comprised an hour-long presentation on different aspects of food safety. Display of posters and question answer discussion were incorporated in between the sessions. The poster session focused on important information and issues regarding the food safety in Nepalese context.

2.4. SURVEY

A set of questionnaires consisting of the same question set was assigned to the participant before and after the training to the same individual. The questionnaire was collected separately before and after the training sessions.

2.5. SCORING SYSTEM USED

There were 15 statements regarding the food safety on fresh produce for assessing food safety knowledge with a maximum possible score of 15. One mark was assigned for each correct answer and zero mark was assigned for wrong answers. The total scores before and after the module was obtained by adding the score of fifteen statements. Similar approach was applied by Jha et al. (2013). The topics to be included in the questionnaire were developed based on food safety issues in Nepal. Inputs were also obtained from experts of the respective field. Knowledge scores were compared before and after the training. Knowledge level of the respondents was categorized as poor, moderate and high based on the mean and standard deviation (S.D). Score less than six were categorized as poor (<Mean - S.D), score between 6 and 12 were categorized as moderate (Mean - S.D to Mean + S.D) and scores above 12 were categorized high level knowledge (>Mean + S.D).

2.6. STATISTICAL ANALYSIS

After the training, knowledge scores were again measured using the same questionnaire. The collected data were analyzed using SPSS (Statistical package for the social sciences) version 20 for Windows. The knowledge scores before and after the training was tested for normality of distribution using Shapiro Wilk test. The score distributions were not found to follow a normal distribution and hence non-parametric tests were used to compare subgroups of respondents. Median was calculated as a measure of central tendency, difference of pre and post training knowledge scores was analyzed using Wilcoxon signed ranks test whereas relation between difference on pre and post knowledge score with gender, age, and participant type were compared using Mann Whitney test and difference on pre and post knowledge score and training location were compared using Kruskal-Wallis test.

3. RESULTS AND DISCUSSION

3.1. RESPONDENT DEMOGRAPHICS

Out of the 202 participants 50.5% were fresh produce growers and 49.5% were agricultural extension agents. The majority (68.8%) of the participants were female. Most of the participants (69.3%) were from the adult group category of 30 years or above and 30.7% belongs to the age category of below 30 years. Furthermore, 44% participants were participated in the Pokhara training followed by Kathmandu (20.8%), Itahari (19.3), Chitwan (19.3) and Kohalpur (18.8%) training. Table 2 shows the demographic characteristics of the respondents.

Table 2. Demographic characteristics of the respondents

Sub groups	Number (n=202)
Gender	
Male	63 (31.2)
Female	139 (68.8)
Age (years)	
Below 30	62 (30.7)
30 or above 30	140 (69.3)
Respondent type	
Fresh produce growers	102 (50.5)
Agricultural extension agent	100 (49.5)
Location of the training site	
Itahari	39 (19.3)
Kohalpur	38 (18.8)
Chitwan	39 (19.3)
Pokhara	44 (21.8)
Kathamandu	42 (20.8)

Note: Figure in the parenthesis indicate percentage.

3.2. KNOWLEDGE SCORE

The knowledge scores before and after the training is depicted in the Table 3. The median knowledge score obtained by participants before and after training was 9.00 and 11.00, respectively. The scores before and after the intervention were compared using Wilcoxon signed ranks test. The knowledge score obtained during the two different phase was significantly different at 1% level of significance (alpha value 0.001). This signifies the effectiveness of the training as participants have higher knowledge on food safety after the attainment of the training.

Table 3. Knowledge score of the participants before and after training

Knowledge score	Median knowledge score	Wilcoxon p value
Before training	9.00	0.001
After training	11.00	

3.3. THE KNOWLEDGE SCORES OF RESPONDENTS OF DIFFERENT SUBGROUPS BEFORE AND AFTER TRAINING

Knowledge score of the respondents based on the gender, age, type of the respondents and location is depicted in Table 4.

Table 4. Comparison of median scores among different subgroups of respondents before and after training

Characteristics	Median score		Median score difference	p value
	Before	After		
Gender				Mann Whitney U test
Male	10.00	11.00	1.00	0.113
Female	9.00	11.00	2.00	
Age (Years)				Mann Whitney U test
Below 30	10.00	12.50	2.50	0.547
30 or above 30	9.00	11.00	2.00	
Respondent Type				Mann Whitney U test
Fresh produce growers	8.00	11.00	3.00	0.078
Extension workers	10.00	12.00	2.00	
Location				Kruskal-Wallis test
Itahari	10.00	12.00	2.00	0.214
Kohalpur	10.00	11.50	1.50	
Chitwan	8.00	11.00	3.00	
Pokhara	8.00	10.50	2.50	
Kathamandu	10.00	11.00	1.00	

Gender

The scores for knowledge were higher for male (11.00) as compared to the female (9.00) before training but the difference was not statistically significant. The low level of knowledge of female before training compared to their counterpart may be due to the fact that females are not familiar with the food safety information in their day to day life. This finding aligns with the broader context of Nepal's patriarchal social structure, where men typically have greater mobility and higher educational attainment compared to women. This is reflected in nationwide literacy rates, standing at 83.6% and 69.4% for males and females, respectively (Atreya, 2007; GoN, 2023). There is no significant difference on pre and post training knowledge score in relation to gender. Similar findings observed in study of Aditya et al. (2023) where female were less aware about food safety as compare to male, suggesting the efficacy of a gender-responsive approaches in outreach programs. The scores improved from 9 to 11 for female and from 10 to 11 for male. This finding is similar with the study of Sakore et al. (2023) where gender has no significance difference on food safety knowledge. But this finding contradict with the study of Pokhrel et al. (2015) where significant gender difference in food safety practices was observed.

Age

The knowledge score was higher among the age group of below 30 respondents (10.00) before training as compared to the above 30-age group (9.00). Same was the case for post training knowledge score where knowledge scores increased among lower age group (12.50) as compared to higher age group respondents (11.00) but the change was not significant. This finding is similar with the study of Sakore et al. (2023).

Type of the respondents

The knowledge score was higher among the agricultural extension workers (10.00) before training as compared to the fresh producer growers (8.00). Same was the case for post training knowledge score where knowledge scores improved significantly among fresh producer growers (11.00) as compared to extension agent (12.00). The observed improvement in knowledge scores among fresh produce growers emphasized the critical role of targeted outreach activities. It suggests that tailored training initiatives specifically designed for individuals engaged in agriculture, like fresh produce growers, can be instrumental in bridging knowledge gaps.

Location

Before training there was significant difference on participants' knowledge score on food safety with respect to training (p-value =0.023). Participants from Chitwan and Pokhara possess low level of knowledge on food safety before the training with scores of 8.00 each. However, participants' from Itahari, Kohalpur and Kathmandu possess more knowledge than that of the Pokhara and Chitwan with knowledge score of 10.00 each. But after training there was no significance difference on knowledge score among the participants with respect to training sites. After training, participants knowledge score of the Pokhara and Chitwan improved significantly with the score of 11.00 and 10.50, respectively. Knowledge score of the participants from Kathmandu valley was found highest after the training with score of 12.00 followed by participants from Kohalpur (11.50).

3.4. KNOWLEDGE LEVEL OF THE RESPONDENTS AFTER TRAINING

The food safety knowledge level of the respondents after the training is depicted in the table (5). The mean and standard deviation of knowledge score of the respondent after training were 11.08 and 2.30, respectively. Majority of the respondent (72.3%) possess average level of knowledge on food safety followed by good level (14.9%), and poor (12.9%). This indicates that there is still room to improve the stakeholders' understanding of food safety in the fresh produce systems. Similar food safety interventions are required to enhance the food safety knowledge among the respondents to ensure continuous improvement in food safety knowledge among farmers and extension workers. These findings contradict with the study of Sakore et al. (2023) and Kubde et al. (2016). Similar findings depicted in the Takalkar and Kumavat (2011) study where majority of the respondent possess average food safety knowledge.

Table 5. Food safety knowledge level of respondents after training

Knowledge level (Score)	Frequency
Poor (<6)	26 (12.9)
Moderate (6 to 12)	146 (72.3)
High level (>12)	30 (14.9)
Total	202 (100)

Note: Figure in the parenthesis indicate percentage.

4. CONCLUSION

Food safety training and outreach interventions seem to be an effective tool to enhance the knowledge of the fresh produce growers and extension workers. The overall improvement in the median knowledge score after the trainings suggest that the outreach interventions are valuable. However, there is still a room for improvement in food safety knowledge among fresh produce growers and extension agents as majority of the participants reached an average level of food safety knowledge after the training.

DECLARATION

The authors declare no conflict of interest.

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EFFECT OF DIFFERENT SUBSTRATES AND SUPPLEMENTS IN PRODUCTION OF *Pleurotus ostreatus* IN DANG, NEPAL

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ABSTRACT

An investigation was laid out to evaluate the production of Pleurotus ostreatus on different substrates and supplements in inner Terai of Nepal, Dang, Deukhuri. Ten different treatments with different substrates and supplements were tested in completely randomized design, replicated four times during the spring season with an average daily temperatureof 20-27^{0}C and relative humidity ranging from 80-95 %. The parameters taken for the observation during the experiment were spawn run period, length of stalk, diameter of stalk, diameter of pileus, thickness of pileus, fresh weight of mushroom, ash content, moisture content and biological efficiency of treatments. The research revealed that there were statistically significant yield differences associated with rice straw + banana leaves + rice bran (2.46 kg/ball), followed by rice straw + chickpea flour (2.35 kg/ball). The spawn run duration (23 days) was shortest in banana leaves with highest stipe length (5.01cm). The biological efficiency of various mixtures was found between 40 to 159%, the highest being in treatment rice straw + banana leaves + rice bran and followed by rice straw + chickpea flour. Highest moisture percentage (89.4%) was recorded in rice straw + maize flour . It was accomplished that rice straw + banana leaves whenever abundantly present, can be reasonably used in mixtures with rice bran supplement for better mushroom cultivation. Thus, its use is suggested to farmers in this country where large volumes of rice bran and dry banana leaves are discarded as agricultural residue.

Keywords: Banana leaves, Chickpea flour, Maize flour, Rice bran, Rice straw

1. INTRODUCTION

Oyster mushroom (*Pleurotus* spp) is an efficient decomposer of wood with an amazing flavor and taste (Motlhalamme, 2019). According to Kong (2004) there are altogether 18 species Oyster mushroom under genus *Pleurotus* that are edible as well as commercially cultivated. In Nepal, three species of oyster mushrooms are cultivated. They are *Pleurotus sajor-kaju, P. ostreatus* and *P. florida* (Neupane et al., 2018). Among them, *P. ostreatus* is the most economical with high productivity, promising to eat and most preferred by farmers (Kong, 2004). Also, it requires less environmental control and exhibits resistance to diseases and pests compared to other mushroom species (Sharma et al., 2013). Oyster mushrooms are also excellent lignin degraders and can be cultivated using various agro-based residues (Jandaik & Goyal, 1995). Consequently, oyster mushroom cultivation is burgeoning in Nepal and worldwide (Raut, 2019). The proper growth and development of oyster mushroom entails substrate containing lower content of nitrogen but high carbon nutrient source (Sharma et al., 2013). Therefore, many organic matters containing cellulose, hemi-cellulose and lignin like

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rice straw, wheat straw, cottonseed hulls, corncob, sugarcane bagasse, sawdust, waste paper, leaves and pseudo stem of banana, water hyacinth, duck weed, etc on simple processing can be used as a substrate for oyster mushroom (Sharma et al., 2013; Sitaula et al., 2018).

It has already been reported that for the economical cultivation of oyster mushrooms, the quality and nutrient content of the substrate are major concerns (Ibekwe et al., 2008). In Nepal, rice straw is commonly used as a substrate for mushroom cultivation, but its availability, quality, and increasing prices present challenges to farmers (Raut, 2019). There are numerous locally available organic materials that can be used as supplements to enhance the growth and production capacity of mushroom substrates. However, many farmers in Nepal are unaware of these alternatives, and the organic matter is often either burned or fed to livestock (Sanjel et al., 2021) leading to reduced profits and environmental pollution.

Developing countries like Nepal still continue to suffer from nutrient deficiency and food security. Mushroom cultivation, particularly oyster mushrooms, offers a promising solution to address issues of nutrient deficiency, food security, and rural economy improvement (Pokhrel, 2016). Oyster mushroom cultivation can be successfully cultivated using a wide range of ligno-cellulose containing plant by-products (Mondal et al., 2010). Dry banana leaves can be the best alternative to rice straw as it contains high amounts of ligno-cellulose (Reddy, 2001) and is economical than rice straw. Furthermore, use of dry banana leaves as substrate can also prevent banana plant from unwanted disease source and lower environmental problem. Supplementing substrates with organic matter such as rice bran, chickpea flour, and maize flour can further enhance mushroom growth and yield. The present study focuses on determining the most economical substrate and supplement combination for the enhanced production of *Pleurotus ostreatus* in the inner Terai region of Nepal. The objective is to improve the socio-economic status of mushroom farmers through increased production at a low input cost.

This study was conducted using two locally available substrates supplemented with three types of organic matter, which are easily found in the study area as agricultural byproducts. The study examined rice straw, banana leaves, and their combination along with different types of supplements, to determine the most economical substrate and supplement combination that yields the best performance for the cultivation of *P. ostreatus*. Mushroom mycelium requires specific nutrients in the substrate for proper growth and development, so supplementing the substrate enhances mushroom yield (Sinha & Chourasia, 2021). Both organic and inorganic supplements added to the substrate can increase the yield of oyster mushroom (Kumar et al., 2020). Therefore, this study aims to identify the optimal substrate and supplement combination to improve the socio-economic status of mushroom farmers in Nepal by increasing production at a lower input cost.

2. MATERIALS AND METHODS

2.1 SITE OF STUDY

The experiment was conducted at Lamahi, Dang at the site of the Prithu Technical College during January to May 2022 for the determination of effect of different substrates and supplements on the performance of *P. ostreatus*. The research was carried out under the poly house to provide sufficient darkness for the spawn-run.

2.2 TREATMENT DETAILS

The substrates selected for the cultivation of oyster mushroom were rice straw and banana leaves whereas the supplements used during the experiment were rice bran, chickpea flour and maize flour. The experimental design was laid in a single factorial completely randomized design. Twelve treatments were replicated four times thus making a total of forty-eight bags. A distance of 60 cm and 20 cm were kept between row-to-row distance and ball to ball distance respectively. The details of each treatment are given in the Table 1.

Table 1. Details of the treatment used in the experiment

Treatments number	Treatment details
T1	Rice straw only
T2	Rice straw + Maize flour (5%)
T3	Rice straw + Chickpea flour (5%)
T4	Rice straw + Rice bran (5%)
T5	Rice straw + Banana leaves (1:1)
T6	Rice straw + Banana leaves (1:1) + Maize flour (5%)
T7	Rice straw + Banana leaves (1:1) + Chickpea flour (5%)
T8	Rice straw + Banana leaves (1:1) + Rice bran (5%)
T9	Banana leaves only
T10	Banana leaves + Maize flour (5%)
T11	Banana leaves + Chickpea flour (5%)
T12	Banana leaves + Rice bran (5%)

2.3 SUBSTRATE COLLECTION

Paddy straw and dry banana leaves were collected from the nearest local farmers field. Similarly, chickpea and maize flour were brought from the market and sun-dried for 16 hours for milling. Rice bran was bought from the nearest rice mill.

2.4 PREPARATION OF SUBSTRATES AND SUPPLEMENT

A rough estimation of substrates was made. Paddy straw was chopped to 1.5” to 2” long pieces and dry banana leaves were chopped to 2” to 3” long pieces with the help of the knives. The paddy straw was washed and soaked in water for 12 hours to retain the appropriate moisture level whereas banana leaves were only washed but not soaked. The next day all these wet substrates were pulled out from the water tank and excess red black water was drained by spreading over a meshed sieve. The moisture level in the substrates was reduced to such a level so that the water didn’t ooze out when squeezed by hand. Similarly, for the supplement chickpea and maize flour were brought from the market and sun dried for 16 hours for milling. Rice bran was also taken from the nearest rice mill.

2.5 SANITIZING THE MUSHROOM HOUSE

The mushroom polyhouse was sterilized with formalin solution (100 ml formalin in 1 liter of water) and fumigated with potassium permanganate (15 g with 60 ml formalin in 2 different places) and was kept for 48 hours.

2.6 STERILIZATION

A stainless metal drum of 34.5” × 23” size was used for the steam sterilization of substrate and supplement. Water was poured up to a height of 6”- 7” in the bottom of the drum, above inside of which a perforated round net sieve was placed supported by a stand. Clean moist substrate after washing for 3-4 times was filled into the drum in such a way that the base of the substrate rested on the net but did not touch the water level. A polypropylene plastic filled with supplements was also placed at the side. Substrate level was maintained 2”- 3’ above the actual height of the drum. Opening of the drum was sealed with a plastic sheet and tied with a rubber on the rim, so that the steam will not escape for the proper sterilization. Sterilization process continued for 30 minutes after the steam started leaking from the covered plastic sheet. After the steam sterilization completed, substrates were taken to the mushroom house and spread over a sterilized canvas for cooling.

2.7 FILLING OF SUBSTRATES IN PLASTIC BAGS

Transparent polythene bags of 16” × 24” size were used with flat-shaped-base that result in circular shape after filling them it with the substrate and supplement. The readiness of substrate for filling in the plastic bag was confirmed by squeezing the sterilized substrate with two hands and at that point it was ready to inoculate when no drops of water came out with only getting our palm wet. For the preparation of one mushroom bag 5 kg of wet substrate with 5% supplement (250g) on wet substrate basis was thoroughly mixed.

2.8 INOCULATION / SPAWNING

The substrate mixtures in the bags were inoculated with grain spawn of *Pleurotus ostreatus* aseptically. Bottom layer of plastic was filled with a 2-3cm thick layer of substrate and the spawn was placed at each layer (5-6cm) of substrate along the border line in a plastic bag but the top most layers was broadcasted on the whole surface and covered with thin layer of substrate. After inoculation of the spawn the bag was tightly pressed with both hands and the mouth was secured compactly with nylon thread. For the proper aeration 30-40 small holes were made with sterilized needle throughout the bag.

2.9 INCUBATION

The packed bags were then hung on a rope in a cool, dark area to prevent direct contact with the ground. The poly-house room was well ventilated until the entire substrate was colonized by mycelium of the oyster mushroom, which typically took approximately 23-34 days. The temperature was maintained at around 20 to 27°C during the incubation period.

2.10 GROWING AND WATERING

After the spawn-run of the whole substrate was complete, the bags were cut with the help of a sterilized blade from the two opposite sides. As the first harvest was made subsequent cuts were made to other opposite part. Primordial growth of mushroom was observed within 5-7 days of plastic cutting. With the first watering, the poly-house was exposed to diffuse light by making the proper arrangement of the ventilation. Watering was done twice a day with the help of mister and to maintain the proper relative humidity the wall and the floor of the room was also irrigated. Wet jute sacks were used to cover the racks in the mushroom house so that the humidity level was maintained.

2.11 HARVESTING

This mushroom was harvested when the cap began to fold and the edges turned brown. Harvesting was done after 5-6 days of pin head formation when the cap diameter reached to 6-7 cm. Picking was carried out by twisting the mushroom gently so that it is pulled out without leaving any stub. The periodical harvests from each treatment and their replications were weighed on an electronic balance and recorded.

2.12 PEST, DISEASE AND RODENT CONTROL

Sciarid flies and green mould were the two main issues encountered during the trial. The problem of the sciarid flies was managed by keeping yellow sticky trap at four different places and later it was controlled by spraying the neem oil at a concentration of 2 ml in 1 liter of water. To control green mould and prevent infestation in other balls, rectified spirit and formalin were used. Infected balls were transferred to the next room to avoid further contamination.

2.13 DATA COLLECTION AND ANALYSIS

The relevant data on growth parameters such as time to spawn-run (days), pinhead formation (days), first harvest (days), mushroom cap (pileus) diameter (cm), mushroom stipe length (cm), total yield (kg), biological efficiency (%) and quality parameters including moisture and ash contents were collected during the experimental period. These parameters were taken from five samples of each treatment periodically during 1st harvest, 2nd harvest and 3rd harvest. The final weight of the total harvest was also recorded.

To calculate the spawn run period, time interval between incubation and full colonization of each bag in the treatment was recorded. After the full colonization, the date of pinhead formation was noted for each replication in each treatment. Stipe length, stipe diameter, pileus diameter and pileus thickness were measured by randomly selecting five samples of different sizes from each fruiting body. Vernier calliper was used to measure dimension in centimetres (cm). Average was calculated from five readings and this process was repeated for every harvest. The biological efficiency, which represents the total yield of mushrooms per kilogram of substrate on a dry weight basis, was calculated using the formula provided by Chang et al. (1981).

$$\text{Biological efficiency (\%)} = \frac{\text{Fresh weight of mushroom (kg)}}{\text{Dry weight of substrate (kg)}} = 100$$

The moisture content was calculated by drying a 15g fresh mushroom sample in an oven at 80°C for 48 hours. The loss in weight before and after drying was recorded; the moisture content was calculated using the formula (AOAC, 1990).

$$\text{Moisture content (\%)} = \frac{\text{Fresh mushroom weight (gm)}}{\text{Dried mushroom weight (gm)}} = 100$$

Ash content was calculated by keeping 2g sample from each treatment into muffle furnace at 550 - 600°C for 5 hours to convert it into ash (Das et al., 2014) and ash content was calculated by using formulae:

Ash content (g/100 g sample) = weight of ash × 100/weight of sample taken (Raghuramulu et al., 2003).

The data were processed to fit into R-studio and analysis was conducted using R Studio 3.5.2. Based on the ANOVA result, Duncan's multiple range test (DMRT) was performed and the means were separated using least significant difference (LSD), at the 5% level of significance.

3 RESULTS AND DISCUSSION

Two different types of substrates along with three supplements were compared with respect to production of oyster mushroom. The substrates used in these studies exhibited variation in spawn-run period, pinhead formation, harvesting days, number of fruiting bodies, stipe length and diameter, pileus diameter and thickness, total weight, moisture content and biological efficiency.

3.1 SPAWN-RUN PERIOD AND PINHEAD FORMATION

The fastest spawn-run period (23 days) was observed in banana leaves, banana leaves + chickpea flour, banana leaves + rice bran followed by banana leaves + maize flour (23.25 days) and slowest colonization was observed in banana leaves + rice straw (1:1) (34 days) shown in Table 2.This finding is in line with the finding of Mondal et al. (2010) outcome for colonization was comparatively similar to the findings of due to the presence of right proportion of alpha-cellulose, hemi-cellulose and lignin was the probable cause of higher rate of mycelium running in banana leaves and rice straw. Pokhrel et al. (2013) also found a minimum spawn-run period on banana leaves supplemented with rice bran and stated that pinhead formation and harvest date are positively correlated. USDA (2011) had also reported that bananas are a substantial source of many vitamins and minerals that could be important for pinhead formation.

The fastest pinhead formation (31 days) was observed in banana leaves alone substrate followed by banana leaves + chickpea flour (31.25 days), rice straw + banana leaves + rice bran (31.75 days), rice straw alone (32 days), and slowest pinhead formation was observed in banana leaves + rice straw (1:1) (66.5 days). This finding is in line with the finding of Silva et al. (2018) as they have also found the fastest pinhead formation in banana source and concluded that it is due to the nutrient composition of banana fruits. Moreover, USDA (2011) has also reported that bananas are a substantial source of many vitamins and minerals that could be important for pinhead formation. However, this finding contradicts the findings of Mondal et al. (2010) because they have found the fastest pinhead formation in rice straw + banana leaves (1:1) than other substrate treatments.

Table 2. Effect of different substrates and supplements on spawn-run period and pinhead formation of *Pleurotus ostreatus*

Treatments	Spawn run period (days)	Pinhead Formation (days)
Rice straw only	25^{de}	32^{ef}
Rice straw + Maize flour (5%)	23.75^{ef}	43.75^{b}
Rice straw + Chickpea flour (5%)	27.75^{c}	35.25^{cdef}
Rice straw + Rice bran (5%)	28^{c}	39.75^{bc}
Rice straw + Banana leaves (1:1)	34^{a}	66.5^{a}
Rice straw + Banana leaves (1:1) + Maize flour (5%)	28^{c}	39^{bcd}
Rice straw + Banana leaves (1:1) + Chickpea flour (5%)	26^{cd}	33.75^{cdef}
Rice straw + Banana leaves (1:1) + Rice bran (5%)	30^{b}	31.75^{ef}
Banana leaves only	23^{f}	31^{f}
Banana leaves + Maize flour (5%)	23.25^{ef}	38^{bcde}
Banana leaves + Chickpea flour (5%)	23^{f}	31.25^{f}
Banana leaves + Rice bran (5%)	23^{f}	32.5^{def}
Grand Mean	26.27	37.875
SEM (±)	1.369	4.6
F-test	***	***
LSD (5%)	1.969	6.62
CV (%)	5.21	12.16

Note: Means with same letter in column are not significantly different at $p = 0.05$. LSD = Least significant difference, and CV = Coefficient of variance. *, **, *** represent significant at 5%, 1%, and 0.1% level of significance, respectively.

3.2 DAYS TO FIRST HARVEST DAYS, NUMBER OF FRUITING BODIES AND TOTAL WEIGHT

Shortest time to first harvest (36.5 days) was observed in banana leaves alone substrate followed by banana leaves + chickpea flour (37 days), rice straw + banana leaves + rice bran, banana leaves + rice bran, rice straw only (37.25 days), and longest time to first harvest (72 days) was observed in rice straw + banana leaves (1:1). This finding is in line with the finding of Silva et al. (2018) as they have also found fastest harvesting days in banana source concluded that it is due to the nutrient composition of banana fruits. Moreover, USDA (2011) has also reported that bananas are a substantial source of many vitamins and minerals that could be important for pinhead formation.

The total yield was highest from treatment rice straw + banana leaves + rice bran (2.465 kg) which was at par with the rice straw + chickpea flour (2.34 kg) followed by banana leaves only (1.795 kg), banana leaves + rice bran (1.75 kg), rice straw + banana leaves + maize flour (1.592), rice straw + rice bran(1.55 kg), rice straw + maize flour (1.242 kg), banana leaves + chickpea flour (1.177 kg), rice straw only (1.147 kg), banana leaves + maize flour (1.077 kg) and lowest was observed in rice straw+ banana leaves (0.625 kg). This finding was similar with the findings of Mamiro and Mamiro (2011) as they have also found high yield of *Pleurotus ostreatus* on rice straw and banana leaves (1:1) substrate because of the high-water holding properties of banana leaves makes it beneficial nutrient substrate. Peng et al. (2000) has also found that high yield of oyster mushroom in substrate supplemented with rice bran and concluded that high yield is due to nutrient supplied by bran for fruiting bodies of mushroom species. Adenipekun and Omolaso (2015) as they have also found highest total yield in rice straw supplemented by 30% rice bran than other banana leaves supplementation and rice straw only. The study revealed that the addition of rice bran to substrates could be beneficial as a nutrient supplement and promoter to growth and yield.

Table 3. Effect of different substrates and supplements on days to first harvest days, number of fruiting bodies and total weight of *Pleurotus ostreatus*

Treatments	**Days to first harvest (days)**	**Number of fruiting bodies**	**Total Weight (kg)**
Rice straw only	37.25[de]	122.25[cd]	1.15[bcd]
Rice straw + Maize flour (5%)	46.25[b]	171[bcd]	1.24[bcd]
Rice straw + Chickpea flour (5%)	41.25[bcde]	345[a]	2.35[a]
Rice straw + Rice bran (5%)	44[bc]	202.5[bcd]	1.55[bc]
Rice straw + Banana leaves (1:1)	72[a]	115.5[d]	0.625[d]
Rice straw + Banana leaves (1:1) + Maize flour (5%)	44.25[bc]	231.75[b]	1.59[bc]
Rice straw + Banana leaves (1:1) + Chickpea flour (5%)	39.5[cde]	233.25[b]	1.86[ab]
Rice straw + Banana leaves (1:1) + Rice bran (5%)	37.25[de]	370[a]	2.46[a]
Banana leaves only	36.5[e]	215.25[bc]	1.79[abc]
Banana leaves + Maize flour (5%)	43.5[bcd]	190.25[bcd]	1.07[cd]
Banana leaves + Chickpea flour (5%)	37[de]	244.5[b]	1.77[bcd]
Banana leaves + Rice bran (5%)	37.25[de]	242.75[b]	1.75[abc]
Grand Mean	43	223.67	1.55
SEM (±)	4.525461	65.75	0.51
F-test	***	***	***
LSD (5%)	6.510417	94.59	0.73
CV (%)	10.52433	29.4	32.4

Note: Means with same letter in column are not significantly different at p = 0.05. LSD = Least significant difference, and CV = Coefficient of variance. *, ** and *** represent significant at 5%, 1%, and 0.1% level of significance, respectively.

3.3 STRIPE DIAMETER, STRIPE LENGTH, PILEUS DIAMETER AND PILEUS THICKNESS

Although there was slightly high stipe diameter of mushroom from rice straw + banana leaves + maize flour (0.79 cm) followed by rice straw +banana leaves + chickpea flour (0.73 cm) and lowest in rice straw + banana leaves + chickpea flour (0.65 cm). Analysis of variance of stipe length shows that there was no significant difference obtained among the tested substrates ($p \leq 0.05$). The highest stipe length (5.01 cm) was observed in banana leaves substrate followed by rice Straw + banana leaves + maize flour (4.62 cm), rice straw + banana leaves + rice bran (4.31 cm), banana leaves + rice bran (4.28 cm) and lowest stipe length on rice straw + banana leaves (1:1) substrate (3.46 cm). Mondel et al. (2010) have also reported lowest stipe length in rice straw + banana leaves (1:1) substrates which is statically similar to our findings. Furthermore, it has been also reported that the quality of mushroom decreases with the increase in oyster mushroom stipe length (Zadrazil, 1978). The quality of oyster mushroom *P. florida* depends on the length of stalk, the higher the length of stalk, the poorer the quality of mushroom (Zadrazil, 1978).

The highest pileus thickness was observed in rice straw + banana leaves + maize flour (0.425 cm) followed by rice straw + chickpea flour (5%) (0.42 cm), rice straw + banana leaves + chickpea flour (0.38 cm), rice straw + banana leaves + chickpea flour (0.38 cm) and lowest in rice straw + banana leaves (1:1) (0.28 cm). This finding is in line with the finding of Mondal et al. (2010) as they have also found lowest pileus thickness in rice straw + banana leaves (1:1) substrate. It can be also concluded that the pileus thickness can be high due to presence of adequate nutrients in the substrates and it is a yield attributing character in which the thickness of pileus increases with increase in yield (Mondal et al., 2010). Analysis of variance of pileus diameter shows that there was no significant difference obtained among the tested substrates ($p \leq 0.05$). The highest pileus diameter was observed in rice straw + banana leaves + rice bran (7.03cm) and lowest on rice straw + banana leaves + chickpea flour (5.12cm).

Table 4. Effect of different substrates and supplements on stripe diameter, stripe length, pileus diameter and pileus thickness of *Pleurotus ostreatus*

Treatments	**Stripe Diameter (cm)**	**Stripe Length (cm)**	**Pileus Diameter (cm)**	**Pileus Thickness (cm)**
Rice straw only	0.66	3.63^{cd}	5.77	0.32^{cd}
Rice straw + Maize flour (5%)	0.69	4.22^{bc}	6.475	0.34^{cd}
Rice straw + Chickpea flour (5%)	0.72	3.98^{bcd}	6.18	0.42^{ab}
Rice straw + Rice bran (5%)	0.68	4.31^{abc}	5.86	0.36^{bc}
Rice straw + Banana leaves (1:1)	0.65	3.4575^{d}	5.37	0.28^{d}
Rice straw + Banana leaves (1:1) + Maize flour (5%)	0.79	4.62^{ab}	6.36	0.425^{a}
Rice straw + Banana leaves (1:1) + Chickpea flour (5%)	0.73	3.88^{bcd}	5.12	0.38^{abc}
Rice straw + Banana leaves (1:1) + Rice bran (5%)	0.72	4.49^{ab}	7.03	0.38^{abc}
Banana leaves only	0.72	5.01^{a}	6.51	0.35^{c}

Treatments	Stripe Diameter (cm)	Stripe Length (cm)	Pileus Diameter (cm)	Pileus Thickness (cm)
Banana leaves + Maize flour (5%)	0.69	3.95^{cd}	5.57	0.37^{abc}
Banana leaves + Chickpea flour (5%)	0.66	3.91^{cd}	5.9	0.35^{bc}
Banana leaves + Rice bran (5%)	0.72	4.28^{abc}	6.31	0.345^{c}
Grand Mean	0.71	4.145	6.04	0.36
SEM (±)	0.06	0.52	0.82	0.043
F-test	NS	*	NS	**
LSD (5%)	NS	0.74	NS	0.06
CV (%)	7.89	12.51	13.73	12.08

Note: Means with same letter in column are not significantly different at p = 0.05. LSD = Least significant difference, and CV = Coefficient of variance. *, **, and *** represent significant at 5%, 1%, and 0.1% level of significance respectively and NS = Non-significant.

3.4 BIOLOGICAL EFFICIENCY, MOISTURE CONTENT AND ASH CONTENT

Highest biological efficiency was found in rice straw + banana leaves + rice bran (159.03%), followed by rice straw + chickpea flour (156.33%), rice straw + banana leaves + chickpea flour (120.32%), banana leaves only (115.81%) and lowest was found in rice straw + banana leaves (40.32) as shown in figure 2. When 5% supplement is added, biological efficiency increases at the peak than with other different levels of supplement and without supplement (Mamiro & Mamiro, 2011).

Highest moisture content was found on rice straw + chickpea flour (89.49%) followed by rice straw + banana leaves + maize flour (89.3%), banana leaves + rice bran (89.1%), and lowest was found on banana leaves + chickpea flour (83.68%). Mushrooms are highly perishable because of their moisture content, fragile cell structure and susceptible to enzymatic browning (Kumar et al., 2013). So, high moisture content mushrooms are not desirable.

Highest ash content was found on rice straw + chickpea flour (13.41%) followed by rice straw + maize flour (13.26%), and lowest was found on banana leaves + chickpea flour (4.44%). The ash content denotes the minerals and inorganic substances that remain after subjecting the sample to intense heat, which eliminates moisture, volatile components, and organic matter. The primary minerals and inorganics typically found are calcium, magnesium, sodium, and potassium, while smaller amounts of manganese, zinc, iron, and other elements may also be detected (Monti et al., 2008).

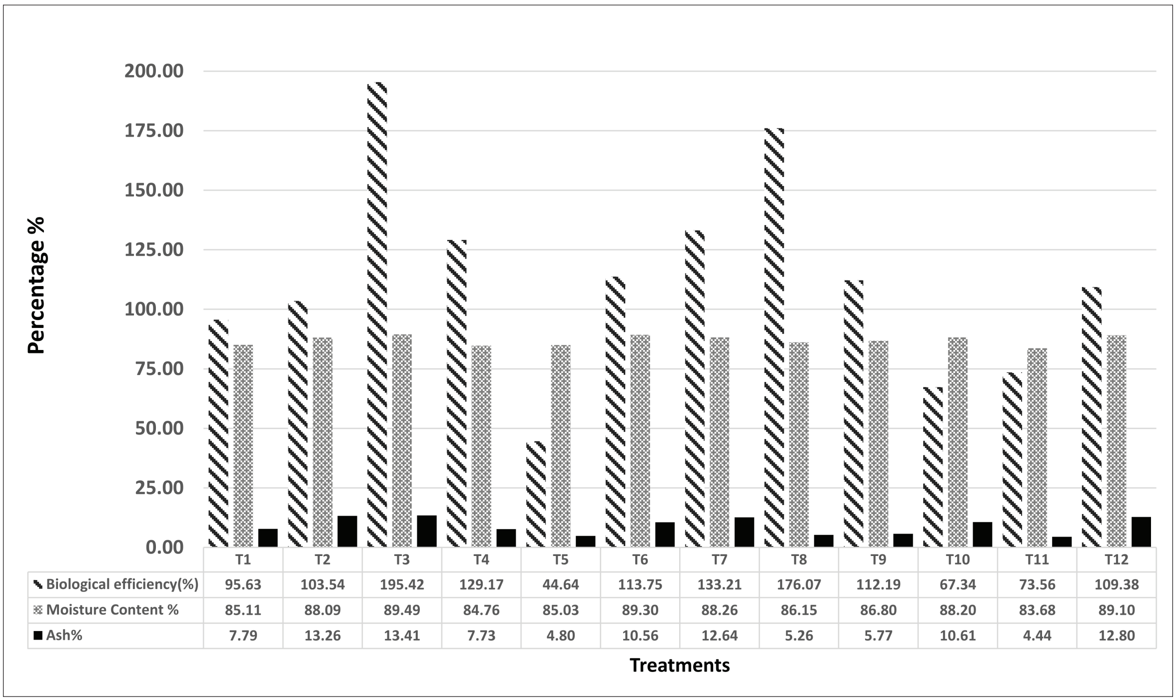

Figure 1. Effect of different substrates and supplements on biological efficiency, moisture content, and ash content

CONCLUSION

From the study it is concluded that the combination of rice straw, banana leaves, and rice bran exhibited the highest yield of 2.46 kg per ball, followed closely by rice straw supplemented with chickpea flour at 2.35 kg per ball. Banana leaves contributed to the shortest spawn run duration of 23 days, with mushrooms reaching a remarkable stipe length of 5.01 cm. Biological efficiency ranged from 40% to 159%, with the highest efficiency observed in the rice straw + banana leaves + rice bran treatment, followed by rice straw + chickpea flour. Additionally, rice straw supplemented with maize flour recorded the highest moisture content at 89.4%. The findings suggest that utilizing rice straw and banana leaves, in combination with supplements like rice bran, could enhance mushroom cultivation in Nepal. These findings underscore the potential of utilizing locally available agricultural byproducts for oyster mushroom cultivation, offering economic benefits to farmers and contributing to food security. Further research could explore optimized combinations to enhance productivity and quality while addressing nutrient deficiency challenges in developing regions like Nepal. Overall, mushroom cultivation presents a viable avenue for sustainable agriculture and rural livelihood improvement in such contexts.

DECLARATION

The authors declare no conflict of interest.

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UNDERSTANDING ALLOCATION AND FARMERS' ACCESS TO VARIED LEVEL OF AGRICULTURAL INPUT SUBSIDIES FROM DIFFERENT TIERS OF GOVERNMENT: A CASE STUDY IN KAVREPALANCHOWK DISTRICT, NEPAL

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ABSTRACT

Government support for essential agricultural services, such as agricultural input subsidies, is vital for empowering smallholder farmers. This study explores distribution and the factors affecting farmers access to varied level of government agricultural input subsidies in Kavrepalanchowk district, Nepal. The study relied on survey data from 219 randomly selected households. Results showed that 72 percent, 8 percent, and 20 percent of sampled households received less than NRs 15,000, NRs 15,000 to 30,000, and more than NRs 30,000 in input subsidies per year, respectively. Among the recipients of the input subsidy, the mean subsidy for electricity, chemical fertilizers, agricultural machinery, interest subsidy, and cash subsidy for the GI tunnel were NRs 4,061, 7,143, 35,633, 67,500, and 4,72,000, respectively. Results from a multinomial regression show that households with higher income, farms near roads, and registered farms receive a higher level of input subsidies. It is recommended that farmers register their farms either as a firm or company or as farmer's groups or cooperatives. To effectively perform their roles, there is a need to review the subsidy delivery mechanism, ensuring its reach to the most constrained farmers.

Keywords: Access, Delivery mechanism, Government subsidies, Multinomial regression, Subsidy recipients

1. INTRODUCTION

Agriculture support policies are implemented by the majority of the countries as a tool for agricultural and rural development (Chen et al., 2020). In the agricultural sector, input subsidies have been a popular policy instrument in both the developed and developing countries since the 1960s, and since then, subsidies have become an integral part of development policies (Dorward & Chirwa, 2011). Irrespective of the path of implementation, the aim of such policies is to increase efficiency of agricultural production, protect farmers, attain national food safety and security (Jelic et al., 2014) and ensure stable income for farming families (Daniel & Kilkenny, 2009).

Recent available data from the Organization for Economic Cooperation and Development (OECD) shows that the Chinese government in 2021 spent about $276 billion to support agriculture, while the European Union had support worth $96 billion in 2021. Meanwhile, during the same period, the US, Japan, and India spent about $107 billion, $36 billion, and $15 billion, respectively, in agricultural support (OECD, 2022). Government support can

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take several forms, such as price support programs, direct payments, and input support, to influence the cost and availability of farm inputs like credit, fertilizers, seeds, irrigation, water, etc. (Fan et al., 2008; Uddin & Dhar, 2018).

Though input subsidies are a contentious development strategy (Messina et al., 2017), Nepal's agricultural policies prioritize agricultural subsidies to improve agricultural production and productivity, improve food security, and reduce income poverty among smallholder farmers (Paudel & Crago, 2017). Agriculture is the mainstay of the Nepalese economy, employing 60.40 percent of the population and contributes about 24.10 percent to the national GDP (2021), but it is characterized by the dominance of small and marginal farmers following traditional and indigenous farming technology (GC & Hall, 2020). Such smallholder farmers have a low purchasing power of inputs (Bista et al., 2018), and cannot intensify the use of agricultural inputs on their own (Takeshima et al., 2017). But increased and improved use of agricultural inputs, viz. fertilizers, seed, irrigation, and mechanization, among others, is necessary for the transformation of subsistence agriculture to commercial agriculture (Houssou et al., 2017) and to bring agriculture-induced economic development (Hemming et al., 2018). So, the efforts of the government have always been directed towards the modernization and commercialization of agriculture through different approaches among which agricultural subsidy is the most notable. Three spheres of government (Central, Provincial, and Local), have brought subsidy packages for inputs subsidy for the promotion of the agriculture sector. The government of Nepal has spent nearly 17,000 million rupees in agricultural support in 2021 (MoF, 2023). Farmers are receiving input subsidies in chemical fertilizers, improved seeds, agricultural implements, irrigation technical backstopping, crop and livestock insurance premiums, business start-ups, interest, and mechanization.

Many needy farmers might be excluded from input subsidy services as they do not make efforts in seeking input subsidies. This might be because the technology supported might not meet their specific requirements (Anang & Asante, 2020). Smallholder farmers who do not have marketable produce might face difficulties in registering their farms or be a member of producer organization and therefore have problems in accessing input subsidy support (Wennink et al., 2007). Subsidy support can also end up favoring the large and influential farms rather than empowering smallholder farmers (Mustapha et al., 2016). Shrestha (2021) reported that there has not been a proper utilization of Nepalese agricultural subsidies and small farmers are not being benefitted from such policies owing to lack of proper information and higher political influence. There can be many factors influencing farmer's access to government input subsidies. Studies have reported gender roles in access to subsidies and found that male headed households were more likely to receive subsidized fertilizers in Ghana (Fisher & Kandiwa, 2014; Mustapha et al., 2016). The household with higher farming experience and more household income were more likely to receive agricultural subsidies as they were progressive farmers and early adopter of new agricultural technologies (Anang & Asante, 2020; Chibwana et al., 2012). Similarly, number of extension visits, political influence had positive impact on access to agricultural subsidies (Anderson et al., 2013; Dionne & Horowitz, 2016; Mustapha et al., 2016). Analyzing factors influencing access to agricultural input subsidies can provide valuable insights to policymakers about ways to improve the agricultural input subsidy programs.

It is important to understand how government support for agriculture is being allocated and its impact on agricultural growth. Most of the earlier studies on access to agricultural subsidies were limited to African nations (Anang & Asante, 2020; Chirwa et al., 2011; Mustapha et al., 2016). Nepalese studies were focused on access to agriculture extension services (Ghimire et al., 2015), access to mechanization (GC et al., 2019), access to credit (Upadhyay et al., 2020) and issues on subsidy policies in Nepal (Shrestha, 2021). These studies have not covered the factors affecting access to agricultural input subsidies in Nepal. On what agricultural inputs, the farmers are receiving subsidy in Nepal has not been studied at farm level. So, the study was done to address this gap in literature. Detail study at the farm level can provide valuable insights into the farmers access to government subsidies, as subsidies will continue to be important in the future. This research can be important step towards developing a stock of knowledge on assessment of agricultural input subsidies in Nepal.

This paper investigates the factors that influence household access to different agricultural input subsidies provided by the government of Nepal using field-level data from three municipalities in Kavrepalanchowk district in Central Nepal. The paper is organized into four sections. The next section outlines the study methodology and econometric model of the determinants of access and data used for analysis. Section three presents the results and discussion on the results. Finally, section four presents concluding remarks.

2. METHODOLOGY

2.1 STUDY AREA AND DATA COLLECTION

The study was conducted in Kavrepalanchwok district of Bagmati province. Kavrepalanchwok is a hilly district with the total cultivable land of 61,598 hectares (MoALD, 2021). The major cropping patterns of the district are: rice-potato, rice-vegetables, and maize-vegetables. Panchkhal, Panauti, and Banepa municipalities of the district were purposively selected as these are considered commercial areas of potato and tomato production and use subsidized inputs. Smallholder farmers were sampled from these three municipalities. The study site was visited and information on the subsidy recipients in the fiscal year 2075/76 and 2076/77 were obtained from the Agriculture Knowledge Centre, the Prime Minister Agriculture Modernization Project (PMAMP), the Vegetable Development Directorate (VDD), and concerned municipalities. All subsidy recipients' farmers constituted a sampling frame. Then, simple random sampling was done to collect data from the farming household. The sample size was (n) was estimated using Slovin's formula.

$$n=\frac{N}{1+Nxe^2} \quad [1]$$

Where, N = population size, n is the sample size to be estimated, and e is the margin of error (5 % for this study). Thus, sample size was calculated as $n=\frac{484}{1+484*(0.05)^2}$ = 219. A fairly representative sample of 219 farming households were chosen for the econometric analysis. Data collection was carried out from August to September 2021. The secondary information was collected from various sources, like journal articles, research papers, and reports prepared by the Agriculture Knowledge Centre, the Central Bureau of Statistics, Ministry of Agriculture and Livestock Development, and e-sources. The final data were analyzed using STATA 16.

2.2 MULTINOMIAL LOGISTIC REGRESSION MODEL

The multinomial logit model is used when there are more than two categories for the dummy dependent variable. The dependent variable may have ordered categories or unordered categories (Greene, 2012).

$E(Y_i^*) = \Sigma \beta_k X_{ki} = Z_i$, where Y_i is a dummy variable whose value equal to 1, 2, 3… [2]

A dummy variable with m categories requires the calculation of m-1 equations using a category with the highest frequency as a reference category.

$$In = \frac{P(y=m)}{P(y=1)} \beta_{mo} + \Sigma \beta_{mk} + X_{mk} = Z_m \quad [3]$$

Where, P (y = m) is the probability of the event happening,

P (y= 1) is the probability of the event not happening, or the reference category.

The observed household was classified into three groups by valuing the amount of subsidy they have received, including both the subsidy on capital cost and the variable costs. The household that received less than NRs 15000 were considered as low; NRs 15000 to 30000 were considered medium; and greater than NRs 30000 were considered high.The dependent variable, the level of agricultural input subsidy received by farmers, categorized as low, medium, or high, creates a categorical dependent variable with multiple unordered categories. In such a case, multinomial regression model is well-suited for analyzing factors influencing farmers' access to different level of subsidies.

The result of the multinomial regression calculates the odd ratio for all independent variables of both the subsidy groups, with an exception of the reference category. The exponential beta coefficients represent likelihood of a household receiving medium range of subsidy or higher range of subsidy with regard to the low subsidy for a unit change in the corresponding independent variables.

Subsidy class $(Y_i) = \beta_o + \beta_i X_i + v_i \ldots$ [4]

Where, Subsidy class = 1 low subsidy (reference group)

= 2 medium subsidy group

= 3 high subsidy group

Here the probability of getting a different amount of subsidy is specified as:

$$P(\text{high subsidy} = 3) = \frac{e^{Z3}}{1+\sum e^{Zh}} \qquad P(\text{medium subsidy} = 2) = \frac{e^{Z2}}{1+\sum e^{Zh}}$$

$$P(\text{low subsidy} = 1) = \frac{1}{1+\sum e^{Zh}}$$

Where, $\sum e^{Zh} = e^{Z2} + e^{Z3}$ and Z, denotes the logit values for the regressions.

The consistent estimates were obtained using the maximum likelihood estimation method. X_i denotes a vector of explanatory variables hypothesized to influence access to agricultural input subsidies namely respondents age, sex, education, household size, cooperative membership, farm size, household income, and location of the farm. The choice of the variables was made on the basis of existing literature and a priori expectation.

Literature indicates that a number of factors affect farmers' access to agricultural input subsidies. These factors include socio-economic, demographic, locational and institutional factors. The influential factors include respondents age, sex, (Fisher & Kandiwa, 2014; Mustapha et al., 2016) household income, farm size (Anang & Asante, 2020; Chirwa et al., 2011), farming experience, farmers group or cooperative membership and location of farm (Anang & Asante, 2020), and education of household head (Prakash et al., 2022).

3. RESULTS AND DISCUSSION

3.1 DESCRIPTIVE STATISTICS OF THE SAMPLE

Table 1 illustrates the socio-economic and demographic assessment of the respondents selected for the study area. The sample household head had an average age of 44.10 years. The average land holding was 0.33 ha. The mean farming experience of households in the study area was 11.28 years. On average, the farming area was at a distance of 0.37 km from the nearest road and 1.75 km from the nearest market (Table 1).

Table 1. Socio-economic characteristics of the sample household

Quantitative variables						
Variables	**Description**	**N**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Land	Available land area in hectares	219	0.33	0.22	0.03	1.22
Age	Age of the household head in years	219	44.1	12.28	20	76
Family size	Total family members	219	5.52	1.58	3	11
Distance to market	Distance from field to nearest market in km	219	1.75	1.13	0.1	6
Distance to road	Distance from field to nearest road in kms	219	0.37	0.38	0.01	2
Farming experience	Number of years family had involved in agriculture	219	11.28	7.5	1	35
Qualitative variables						
Variables	**Description**	**N**	**Frequency**		**Percentage**	
Ethnicity	Brahmin/Chhetri	219	162		73.97	
	Janajati		44		20.09	
	Others		13		5.04	
Gender	Male	219	161		73.52	
	Female		58		26.48	
Education	Uneducated	219	34		15.53	
	Primary		69		31.51	

Quantitative Variables	Description	N	Frequency	Percentage
	Secondary		77	35.16
	Higher		39	17.18
Farm size	Small (less than 0.5 ha)	219	173	78.99
	Medium (0.5 to 2 ha)		46	21.01
Farm registration	1= Yes	219	70	31.96
Extension visits	1= Yes	219	47	21.46
Cooperative membership	1=Yes	219	131	59.82
Income Group (Monthly income)	Low (< NRs 20000)	219	23	10.5
	Medium (NRs 20000-40000)		91	41.55
	High (> NRs 40000)		105	47.95
Subsidy group	Low (NRs <15000)	219	157	71.69
	Medium (NRs 15000 to 30000)		19	8.08
	High (> NRs 30000)		43	19.63

73.52 percent were male-headed households. The ethnicity of the respondents was categorized as Brahmin/Chhetri, Janajati, and others. Others included Dalits and ethnic minorities. 74 percent of the respondents belonged to Brahmin/Chhetri, which was followed by Janajati (20.09 percent). The others included only about 5 percent of the respondents. Even though subsidies were targeted to benefit the marginalized small farmers, but the distribution shows that the agricultural input subsidies are not reaching the intended groups. The education level of the household head shows that 15.53 percent were uneducated, 31.51 percent of the household head had primary education, and 35.16 percent had a secondary level education (Table 1).

Farms were classified into small (less than 0.5 ha) and medium farms (0.5 to 2 ha) based on the Agriculture Development Strategy (ADS) classification. The majority of the farms (79 percent) were small farms. Out of the total samples, only 70 (32 percent) farms were registered. The total respondents were classified into three groups based on their monthly income. The classification was made based on the national average monthly income of NRs. 30,121. The household with less income than NRs 20,000 a month were classified as low-income groups, whereas households with monthly income ranging from 20,000 to 40,000 were classified as a medium-income group and households with monthly income greater than 40,000 were classified as high-income groups. Only 10.50 percent of the respondents had low income, 41.55 percent had a medium range of income and 47.95 percent of the respondents had a high income. Similarly, based on the monetary value of the subsidy the household had received, 71.69 percent of the household had received a low subsidy (less than NRs. 15,000); 8.08 percent had received a medium range of subsidy (NRs. 15,000 to 30,000) and the remaining 19.63 percent had received high subsidy (greater than NRs. 30,000) (Table 1).

3.2 AGRICULTURAL INPUT SUBSIDIES AND THEIR SOURCES

Agricultural input subsidies provided by the government were classified in terms of the items and their sources. The source was classified into three tiers of government namely federal, provincial and local units. The input subsidy granted by the Prime Minister Agricultural Modernization Project (PMAMP), the Vegetable Development Directorate (VDD), subsidies on chemical fertilizers, interest subsidies, insurance, and electricity subsidies were included under the federal government. Input subsidies provided by Agriculture Knowledge Centre were included under the Provincial government, while input subsidies provided by municipalities were listed under the local government.

Table 2. Distribution of agricultural input subsidies and their sources

Items	Source of subsidy			Average amount (NRs)	Minimum (NRs)	Maximum (NRs)
	Federal	Provincial	Local			
Machinery (minitiller, leg operated thresher, power tiller)	4	22	4	35633.33 ± 21943.86	5000	75000
Other agricultural tools (Sprayer, protective garments, mulching plastic)	0	5	50	3178.94 ± 1622.22	1000	11000
Plastic for tunnel	0	9	23	6195.3 ± 3218.10	1750	14000
Interest subsidy	15	0	0	67500 ± 27648.60	10000	131250
Electricity subsidy (Krishi meter)	13	0	0	4061.54 ± 3126.04	1200	12000
Cash subsidy for GI tunnel	4	5	0	472000 ± 362854.11	200000	1450000
Soil test and agricultural lime	0	0	14	850.43 ± 181.57	400	1200
Chemical fertilizers	219	0	0	7143.07 ± 5537.66	726.10	32816.97
Irrigation (drip irrigation sets, irrigation motor pump, solar irrigation system)	3	3	0	52250 ± 67387.47	6000	200000

Source: Field survey, 2021

The result showed that high-cost items like agricultural machinery, GI tunnels for tomato production, and solar irrigation were subsidized by the federal and provincial governments, while subsidies on small items soil testing, sprayer, and mulching items, were provided by local government. The mean subsidy amount on agricultural machinery like power tiller, mini-tiller, leg operated thresher, etc. was NRs 35,633.33. The small agricultural tools like sprayers, mulching items, and protective garments were mostly subsidized by the local government for which the mean subsidy amount was NRs 3,178.49 (Table 2).

Only 15 respondents had received a subsidized loan, and the mean amount in interest subsidy was NRs 67,500 per year. Mostly, the provincial and local governments had subsidized plastic for tunnels, and the mean amount of subsidy for it was NRs 6,195.3, ranging from NRs 1,750 to 14,000 for each household. The study area also had a subsidy on electricity provided using the Krishi meter through the federal government. The mean amount of subsidy received by a household on electricity was NRs 4,061.54 per year. The mean cash subsidy provided by the federal government and provincial government on the GI tunnel was NRs 4,72,000. The mean amount of subsidy received by each household in chemical fertilizers was NRs 7,143.07 and it ranged from NRs 726.10 to 32,816.97. For irrigation mean amount of subsidy received by the farmer per year was NRs 52,250.00 (Table 2).

3.3 DETERMINANTS OF ACCESS TO AGRICULTURAL INPUT SUBSIDIES

As discussed in equation 3, thirteen explanatory variables, including socioeconomic variables and locational factors, were used to determine the probability of a household receiving a low, medium, or high range of subsidy. There was very less correlation among the independent variables as indicated by mean variance inflation factor (VIF) of 1.709 through the multicollinearity test.

Table 3. Results on multinomial regression to determine factors determining access to input subsidies

Subsidy class	Coeff.	S.E.	P>|Z|
Low- Less than 15000	**(Base outcome)**		
Medium- 15000 to 30000			
Monthly income	0.000021*	0.0001	0.0690
Training received	-0.3402	0.6073	0.5750
Farm registration	2.6194*	1.4370	0.0680
Household size	0.1514	0.1867	0.4170
Farming experience	0.0006	0.0452	0.9890
Distance to market (km)	0.5652	0.2442	0.8170
Distance to road (km)	-0.6886	0.7826	0.3790
Age	0.0107	0.3188	0.7380
Land (ha)	0.9120	1.3621	0.5030
Education			
Primary	-0.7764	0.8526	0.3630
Secondary	-0.3559	0.8682	0.6850
Higher	-0.9724	1.1619	0.4150
Ethnicity			
Janajati	-0.3968	0.7538	0.6010
Others	-13.3702	870.1029	0.9880
Cooperative membership	1.9061	1.4143	0.1630
Gender	-0.9959	0.6105	0.1100
Constant	-5.5303**	2.2169	0.0120
High (greater than 30000)			
Monthly income (NRs)	0.000263***	0.000008	0.0030
Training received	0.2867	0.4656	0.5380
Farm registration	2.4759**	1.0144	0.0150
Household size	0.0635	0.1520	0.6760
Farming experience (yrs)	-0.0089	0.0384	0.8150
Distance to market (km)	0.0593	0.2184	0.7860
Distance to road (km)	-1.2607*	0.7324	0.0850
Age (yrs)	0.0021	0.0252	0.9320
Land in ha	-0.2056	1.1522	0.8580

Subsidy class	Coeff.	S.E.	P>|Z|
Low- Less than 15000	**(Base outcome)**		
Education			
Primary	1.1003	0.9360	0.2400
Secondary	0.7351	0.9563	0.4420
Higher	1.5956	1.0428	0.1260
Ethnicity			
Janajati	-0.1416	0.6270	0.8210
Others	0.1501	0.9794	0.8780
Cooperative membership	0.8742	0.9920	0.3780
Gender	-0.1103	0.5543	0.8420
Constant	-5.3926***	1.7547	0.002
Log Likelihood	**-126.46**		
Likelihood ratio (Chi-square)	84.47		
Prob > chi square	0.0000		
Pseudo R squared	0.2504		
Number of observations	219		

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

Source: Field survey, 2021

The lowest subsidy group (less than NRs. 15,000) was used as a reference group. The first regression on a medium range of subsidy (NRs. 15,000 to 30,000) showed that two variables, namely income of the family and farm registration, were statistically significant. The monthly income was positive and statistically significant at a 10 percent level of significance. It means that households with more income relative to the low subsidy groups are more likely to receive a medium range of subsidies. Similarly, farm registration was statistically significant and positive at a 10 percent level of significance, which means that registered farms are more likely to receive a medium range of subsidies than unregistered farms.

The second regression on the high range of subsidy (more than NRs. 30,000) showed that income, farm registration, and distance to the road are statistically significant. The monthly income was positive and statistically significant at a 1 percent level of significance. It means that households with more income are more likely to get a high range of subsidies. The result is in accordance with Chibwana et al. (2012), Chirwa et al. (2011) and Lunduka et al. (2013), who found that poor and vulnerable households are less likely to receive fertilizer subsidy coupons in Malawi. The positive influence of household income on access to input subsidy was also observed in Ghana, where input subsidies were provided in the form of package of technologies, whose adoption was more in case of richer and progressive farmers (Anang & Asante, 2020). The reason for better access of wealthy household to agricultural services like input subsidies was their higher demand to services and financial strength to meet the cost of those agricultural services. However, in the context of farmers in the study area, there is obligatory provision of cofinancing by the farmers in major subsidy schemes as defined by the directives for the implementation of subsidy programs to agriculture related cooperatives and institutions for agriculture development, 2073 B.S. The poor farmers lack the financial muscles to meet the matching fund which might have limited their access to higher level of input subsidies. Similarly, registered farms were more likely to receive a high range of subsidies than unregistered farms. Registration of farms might have formed a strong basis for beneficiaries' identification for the subsidy program as the major subsidy programs require the recipient to have valid institutional documents (registration, renewal, tax clearance, audit report). The smallholder farmers with limited access to information and extension might be unable to meet all these requirements. Distance to the road from the farming area was negative and significant at a 10 percent level which means that the greater the distance of the farm from the road, the farms are less likely to receive a higher range of subsidies. The finding is consistent with the findings of Fisher and Kandiwa (2014), Mustapha et al. (2016) and Paudel and Crago (2017), who observed that the access and impact of fertilizer subsidy declines along with the increase in distance between the nearest road and the market. The other variables like land, age, gender, education, ethnicity, household size, and farming experience did not have a significant effect on the amount of subsidy received by the household. We expected that households with more cultivable land were more likely to receive higher subsidies, but no significant effect was observed which is in contrast to the findings of Chirwa et al. (2011) and Fisher and Kandiwa (2014).

Analyzing the determinants of access to agricultural input subsidy shows that farm registration, household income and distance from the road were significant factors. Mostly, a higher amount of subsidies was reaching richer farmers which is against the primary objective of subsidy policy to support poor and smallholder farmers. This can be an inefficient way of stimulating increased production and productivity as the economic rents are received by the farmers who benefit from subsidy when they would have purchased inputs anyway without subsidy. Similarly, registered farms were mostly receiving subsidies while farmers' involvement in cooperative or farmer groups did not affect the amount of subsidies received. So, the government subsidy should be equally channeled through farmers' associations or groups to reach the most constrained farmers. Input subsidies should though aim to support all the farmers equally, the farmers away from the roads are not getting enough input support.

Table 4. The marginal effect after multinomial logit

Three levels of outcome	**Probability**
Y = 1 = Pr (Receiving low subsidy)	0.716
Y = 2 = Pr (Receiving medium subsidy)	0.086
Y = 3 = Pr (Receiving high subsidy)	0.196

Source: Field survey, 2021

The marginal effect after multinomial logit shows that the probability of receiving low subsidy amount was around 71.60 percent, a medium subsidy amount was 8.60 percent, and the probability of receiving the high subsidy was around 19.60 percentage for the farmers of the three municipalities of the Kavrepalanchwok district. Agriculture subsidies are provided following the directives for implementation of subsidy programs to agriculture related cooperatives and institutions for agriculture development, 2073 drafted by Ministry of Agriculture and Livestock Development. The subsidy programs have broader aims and focus on commercialization, value chain development, risk minimization, agricultural infrastructure development, food security enhancement through increased production and productivity, social security, and conservation of local biodiversity. For achieving those aims, there are three ways of implementation: public subsidies which can benefit all (minimum support price, subsidy on insurance, tariff-free, electricity), targeted subsidies (for particular ethnic groups/caste, crop and livestock specific subsidies), and competitive subsidies that requires call for proposal, selection of the best, and agreement for subsidy (Shrestha, 2021). The low level of subsidy are particularly the public subsidies which are reachable to most of the farmers and constitutes smaller amount. So, the probability of receiving it is higher.

4. CONCLUSION

The three tiers of government in Nepal provide agriculture input subsidy support. The success of the input subsidies program depends on the delivery mechanism, the degree to which the most constrained farmers have access to it, and how they utilize it. This paper assessed what agricultural inputs farmers of Kavrepalanchowk are receiving subsidies and the factors determining farmers' access to agricultural input subsidies using multinomial regression models. Results revealed that farmers are receiving inputs on nine different agricultural inputs, including agricultural machineries and chemical fertilizers. Household income, farm registration and distance of farm from road were the main determinants of access to agricultural input subsidies in the study area. The input subsidies were being provided to the richer household rather than financially constrained poor households. It is suggested that farmers register their farms either as firm or company or as a farmer's groups or cooperatives to be eligible to receive higher level of input subsidies. The result also suggests that, to effectively perform their roles, there is a need to review the delivery mechanism to ensure the reach of subsidies to the most constrained farmers. Policymakers are also suggested to devise a mechanism to regulate agriculture input subsidy flow from different tiers of government.

DECLARATION

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EFFECTS OF GENOTYPES AND MULCHING ON GROWTH AND YIELD OF ONION

Susmita Ghimire[1,*], Raj Subedi[1], Gobinda Pandey[2]

ABSTRACT

Selection of the right genotype and optimizing management practices are essential for higher crop productivity. In the area of onion cultivation, the correlation between onion genotypes and mulching remains a relatively unexplored terrain. To identify this association, an experiment was conducted at the Horticulture Development Resource Centre, Kaski, from November to April 2023. Structured in two factorial randomized complete block designs, the experiment featured five genotypes—AVON 1052, AVON 1103, Khumal 1, Khumal 2, and Red Creole (check variety)—and two mulching levels, namely black plastic mulch and control, with four replications. Significant variations were found among genotypes in response to mulching. Red Creole, Khumal 1, and AVON 1103 exhibited a significant difference in plant height and leaf number. AVON 1052, Khumal 2, and Khumal 1 showed a substantial divergence in average total bulb diameter with and without mulching. Furthermore, with the exception of Red Creole, other genotypes demonstrated a significant difference in total bulb yield, favoring mulching with black plastic. Khumal 2, produced a yield of 11.7 t ha^{-1} without mulching, attributed its success to larger bulb diameter, more leaves (8), and taller plants (66.8 cm), while Khumal 2 (16 t ha^{-1}) under mulching showed similar yielding potential as Red Creole. Ultimately, the recommendation of mulching in Khumal 2 was given owing to the bulb-splitting problem in Red Creole and indifferent yield in Khumal 2 as compared to Red Creole. This research shows how better onion types and using mulch can enhance onion production and promote agricultural sustainability in Nepal.

Keywords: Black polythene mulch, Bulb diameter, Microclimate, Soil moisture, Yield

1. INTRODUCTION

In the Alliaceae family, onion (*Allium cepa L.*) is one of the most important vegetable worldwide, including Nepal. It is a rich source of phosphorus, calcium, and carbohydrate. Along with these minerals, onion has several antibacterial and anti-fungal properties, that's why it has been used to prevent infection in wounds and burn from the very beginning (Luitel et al., 2021). Similarly, the sulfur volatiles from onion have been found to control Asian citrus psyllid (Mann et al., 2011) and the intercropping of onion and garlic acts as a good method of pest control (Debra & Misheck, 2014).

As per the global review of the area and production of major vegetable crops, onion ranks third in area and production (Board, 2015). According to the current market price, 417,000 metric tons of onions worth more than Rs. 25 billion are consumed in Nepal in a year. As per the data of the National Center for Potato, Vegetable and Spice Crop Development, 289,000

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tons of onions were produced in Nepal in the fiscal year 2020/21, while 129,000 metric tons had to be imported from abroad to meet the demand. In the same year, 11.5 tons of onions were exported from Nepal. Similarly, as per MoALD (2023), the area of onion is 13,189 ha, with its overall production of 166,904 mt, and yield of 12.65 mt ha^{-1}. As a result, the onion's overall GDP contribution to agriculture is 0.9473% (MoALD, 2023).

Many factors, including low yield and a small number of varieties, the lack of high-quality seed at the necessary planting time and location, bulb splitting, cultivars' poor adaptation to low input management conditions, and others, contribute to Nepal's lower onion productivity (12.65 mt ha^{-1}) than the global average (19.7 mt ha^{-1}) and neighboring countries (India: 31.69 mt ha^{-1}) (Srivastva et al., 2022). It says a lot about the status of onion cultivation in Nepal. Farmers cannot afford to pay high prices for seed every year and high input costs because the majority of imported cultivars on the market are hybrids and receptive to heavy inputs (Gautam et al., 2019) that's why the Nepalese farmers depend upon traditional onion cultivars which produce less per acre of land, limiting harvesting and making it challenging for farmers to make a livelihood. They have higher disease and insect susceptibility, leading to poorer yields and increased pesticide use (Luitel et al., 2021). They spoil quickly, have a lower shelf life, and produce inconsistent quality (Gyawali et al., 2022) inadequate approach to market and seasonal fluctuation of available vegetable creates difficulties in commercialization of off-season production. The current paper describes about what opportunities and importance do off-season farming has in Nepal and the constraints it has to encounter with. The cheap availability of labour, increasing interest of the government, and climatic suitability provide an opportunity for the farmers to make profitable income due to high prices during the off-season period which reduces the risk of failure of the farm, marketing risk, and maintains market equilibrium. Nevertheless, this cultivation system faces challenges of high post-harvest loss, poor implementation of policies, hijacked subsidies, inadequate irrigation facilities, and high pest infestation on-farm side and scarcity of cold storage, high transact cost, unmanaged collection, and market centers on the market side. Commercialization of off-season vegetable production can create a better environment for income improvement and maintain market equilibrium.

Onions are sensitive to drought stress, requiring regular watering for seed yield (Zayton, 2007). Throughout the growing season, the crop needs 350-500mm of water (FAO, 2023). Therefore, ensuring sufficient moisture, potentially achieved through irrigation or other ways, plays a crucial role in onion production. As such, mulching is a valuable technique that lowers the amount of soil moisture lost through evaporation (Mahajan et al., 2007). It lessens the need for irrigation, fosters the growth of roots, speeds up the development of crops, decreases the risk of weeds taking over, and encourages an earlier harvest of the crops (Ngouajio et al., 2008; Vavrina & Roka, 2000). Using polythene mulch raises the temperature of the soil and improves the effectiveness of applied nitrogen fertilizer by decreasing the loss of nutrients through leaching and evaporation (Kashi et al., 2004; Roy et al., 1990). Similarly, the use of black polythene mulch have also found to show the higher bulb diameter and single bulb yield than in control which ultimately increases the total bulb yield in onion (Rachel et al., 2018).

Thus, the objective of this study is to determine the effect of mulches on various genotypes of onion regarding their growth and yield in Pokhara Valley.

2. METHODOLOGY

2.1 EXPERIMENTAL SITE

The field trial was conducted at Horticulture Development Resource Centre (HDRC), Pokhara, situated at the latitude of 28°16'0.80" N and longitude of 83°58'6.64" E during the month of November to May of 2022. The lab works were carried out in the Horticulture lab of the Centre.

2.2 EXPERIMENTAL MATERIALS, DESIGN AND CULTURAL PRACTICES

The seeds of four onion genotypes, AVON 1052, AVON 1103, Khumal 1 and Khumal 2 were obtained from Horticulture Research Division of Nepal Agriculture Research Council (NARC), Khumaltar, Lalitpur. A standard check variety, Red Creole was obtained from the nearby market. Two factorial experiment was designed in randomized complete block with five genotypes and two mulching levels: with and without mulching, replicated four times.

The nursery bed was plowed, harrowed, and levelled before seed was sown on November 27, 2022. The field was ploughed three days before transplanting, and weeds and stubbles were incorporated. Transplantation was done on January 20, 2023, in forty plots with a hundred plant population in each plot and spacing 20×15 cm. FYM dose of 20 ton/ha and fertilizer rate of 240:180:180 kg NPK/ha were applied during transplanting. Full dose of FYM, Phosphorous, Potash and half dose of nitrogen were applied at the time of transplanting as basal dose and remaining half dose of Nitrogen was top dressed at 30 days after transplanting (DAT) and 60DAT. Black polythene of 30μ thickness was used as mulch, and irrigation was given immediately after transplantation. Weeding was conducted at 30, 45, and 60 days after transplanting. Regular observations were made on onion growth and development in different plots.

2.3 DATA COLLECTION AND ANALYSIS

The observations on different parameters such as plant height, number of leaves, bulb diameter, bulb thickness, root length, skin thickness, number of scales, and bulb yield were recorded. Ten plants from each plot were taken for the observation of data. The data on bulb diameter, bulb thickness, and skin thickness was taken using Vernier's caliper and the data on the plant height and number of leaves were taken on 30DAT, 60DAT, and 90DAT respectively. The plants were harvested after 131 days on the 1st of May, 2023.

The data was then prepared for data analysis by arranging in Microsoft Excel and after that, the arranged data was subjected to an analysis to determine its normal distribution. For that purpose, Shapiro-Wilk test was used. Similarly two-factor ANOVA test was also done to identify the significance of the results and, the mean of different parameters was compared by least significant difference (LSD test) as described by Gomez and Gomez (1984); in R-studio 4.3.2.

3. RESULTS AND DISCUSSIONS

3.1 PLANT HEIGHT

Plant height varied among the different treatments. Red Creole had the tallest plants in both the control (no mulching) and mulched environments until 60 days after transplanting (60DAT). After that point, Red Creole's (74.6 ± 2.7[a] cm) plants grew rapidly, especially in the absence of mulching. Khumal 2 (66.8 ± 1.2[b] cm) closely followed Red Creole in terms of plant height in both conditions, surpassing the other types. Meanwhile, Khumal 1 (66.1±0.7[b] cm) showed better plant height than AVON 1103 (61.4 ±1.8[cde] cm) and AVON 1052 (58.4±3.0[def] cm) when mulching was used, but AVON 1103 (59.6±0.8[de] cm) exceeded AVON 1052 (57.4±0.7[ef] cm) and Khumal 1 (54.9±1.7[f] cm) when there was no mulching.

Red Creole plants benefited from mulching, achieving a maximum height, which may be because of its ability to optimally utilize the soil moisture that is conserved from mulching (Anisuzzaman et al., 2009).

According to Sarkar et al. (2019), higher soil moisture with lower soil temperature might be responsible for keeping the favorable growing microclimatic environment in the soil which might cause vigorous growth of a plant that ensures increased photosynthetic capacity by leaves and ultimately attain the maximum bulb development and plant height.

The plant height of different onion genotypes along the crop cycle grown under mulching and non- mulching has been represented in Figure 1.

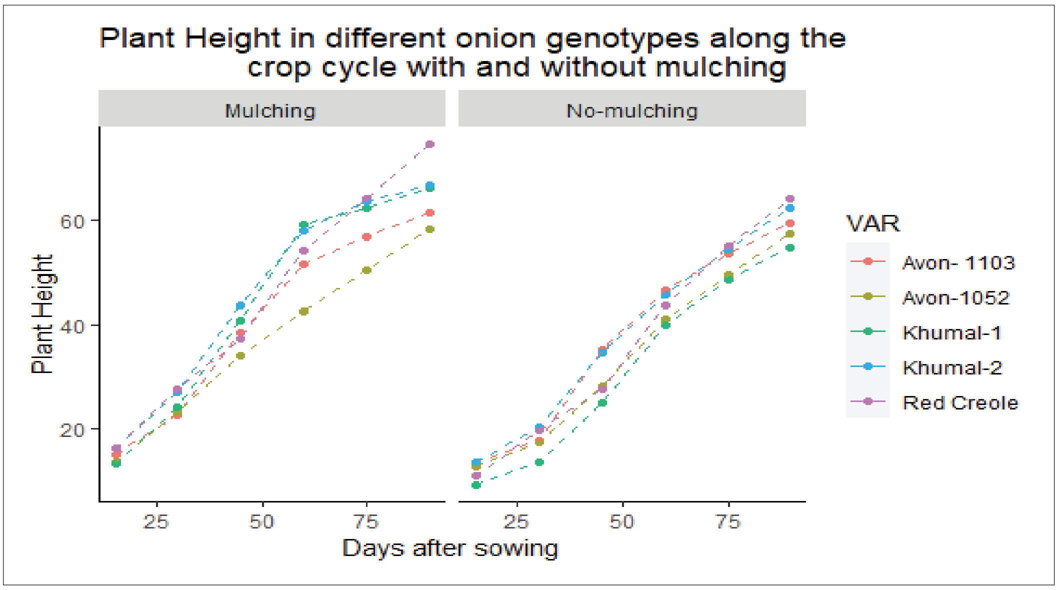

Figure 1. Plant height during different phases of growth in onion with mulching and without mulching

3.2 LEAF NUMBER

The leaf number showed significant differences when grown under different conditions of mulching. Red Creole (10.6±0.6[a]) showed the maximum number of leaves under mulching whereas Khumal 2 (7.7±0.2[cd]) surpasses Red Creole under non- mulching. Khumal 1 showed the highest leaf count(8.8±0.5[b]) under mulching up until 45 DAT after which its progress was slower than that of Red Creole. Under both conditions, AVON 1052 (7.7±0.2[cde] under mulch and 6.8±0.2[e] under non-mulch) was found to bear the least number of leaves.

The genetic make-up of the variety and its compatibility for various climatic and soil conditions may be the causes of the variations in leaf count (Gosai et al., 2018). The significant results on number of leaves were also reported from Singh (2017) and Gautam et al. (2019). In contrast, non-significant difference on the number of leaves between treatments were reported from Mitiku and Tadesse (2018).

Plants grown during the entire season under polythene film mulches slightly increased the vegetative growth stage of onion plant. Mulching with polythene films alter the microclimatic conditions of soil affecting the number of leaves (Sarkar et al., 2019). Ashrafuzzaman et al. (2011) stated that mulches provide suitable condition for producing a higher number of leaves in chilli and in onion.

The number of leaves in different onion genotypes along the crop cycle grown under mulching and non- mulching has be represented in Figure 2.

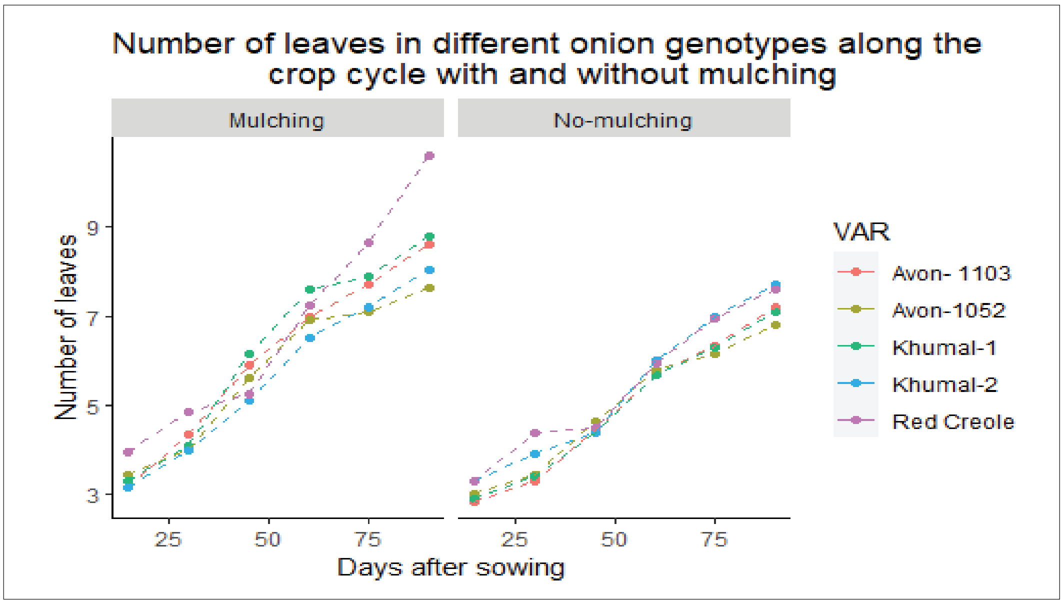

Figure 2. Number of leaves during different phases of growth in onion with mulching and without mulching

3.3 BULB DIAMETER (POLAR AND EQUATORIAL)

The analysis showed significant differences across genotype, mulch environment, and their interaction at both equatorial and polar bulb diameter. Among the genotypes, Khumal 2 and AVON 1103 produced plump bulbs matching the equatorial diameter of the standard variety Red Creole, while Khumal 1 and AVON 1052 had substantially lower equatorial bulb diameters than the standard check. In addition, Khumal 2 had significantly higher polar diameters than all the genotypes and the standard check Red Creole except Khumal 1, suggesting a large and long tapering shape of the bulbs in Khumal 2. The differences in the polar diameters were not as conspicuous as the equatorial diameter among the genotypes as shown in Table 1.

The equatorial and polar diameters as affected by the mulching environment, however, was very clear with bulbs produced under a mulched environment being larger(50.7±0.6[a]mm and 41.8±1.1[a]mm) exhibited by significantly higher equatorial and polar diameter respectively, compared to bulbs produced without mulching (43.5±1.3[b]mm equatorial and 35.8±0.5[b]mm polar diameter). Red Creole (49.6±0.6[a]mm) and Khumal 2 (49.0±1.7[a]mm) has the largest equatorial diameter among all while AVON 1052 (43.6±3.2[c]mm) shows the smallest equatorial diameter. Incase of polar diameter, Khumal 2 (42.5±2.1[a] mm) shows the largest diameter while AVON 1103 (35.7±0.9[c]mm) shows the smallest diameter.

The interaction of the genotypes and the mulching environment showed that the equatorial bulb diameter in all the onion genotypes remained at par in the mulched environment and the differences among the genotypes in the equatorial bulb diameter as discussed above were observed only in the absence of mulching. In contrast, the polar diameter was different along the varieties when mulching was provided but remained unaffected without mulching. Khumal 2 (47.9±0.9[a] mm under mulch and 37±0.7[cd] mm under non-mulch) and Khumal 1 (44.3±0.9[ab] mm under mulch and 34.9±0.3[d] under non-mulch) produced bulbs with greater polar bulb diameter than other genotypes and the standard check variety Red Creole.

Higher polar diameter found in mulching of Khumal 2 represented by the long tapering bulb shape of the genotype, are overexpressed in an increased temperature and water-abundant environment. The higher number of scales and greater scale diameter in Khumal 2 can be attributed to their larger bulb size among all the genotypes. Similar trends of increase in bulb diameters across mulching environments are also reported by Mushtaq et al. (2013). As suggested by Abu-Gharbieh et al. (1991), mulching increases temperature, and water retention and reduces weed infestation to produce larger onion bulbs. The increase in bulb size can be further aggravated by increased nutrients (N, P, and K) availability under plastic mulches (Basnet et al., 2018)

3.4 NECK DIAMETER

The experiment conducted highlighted that there were no notable variations in neck diameter among the various onion genotypes. However, a significant contrast emerged in terms of neck diameter between two distinct management conditions: mulched and non-mulched. In this context, the non-mulched condition displayed the largest neck diameter (1.3±0.04[a]). The interaction between genotypes and mulching also showed some impacts in the neck diameter.

Within the range of genotypes studied, with the exception of Khumal 1 and AVON 1103, there was an evident increase in neck diameter when they were cultivated without the application of mulch. AVON 1103 exhibited no notable variance in neck diameter whether grown with or without mulch while Khumal 1 demonstrated the smallest neck diameter when subjected to mulching. Notably, among all genotypes investigated, the reference variety, Red Creole, displayed a substantial difference in neck diameter; with largest observed in bulbs grown in the absence of mulch as shown in Table 1.

The primary reason for the greater neck diameter could be attributed to the increased presence of reserved nutrients within the larger bulbs, which was found to be Red Creole. This led to a higher leaf count, resulting in the production of a greater amount of nutrients. These nutrients were subsequently stored in the bulb, consequently leading to the observed larger neck diameter (Desta et al., 2021).

3.5 ROOT LENGTH

The present study has undertaken a comprehensive analysis, revealing noteworthy distinctions pertaining to genotypes and mulching conditions in relation to root growth parameters. The root length of the bulb was measured by taking the average length of five roots taken from the bottom end of the bulb by swiftly cutting with a sharp blade at the root top and measuring with a centimeter scale. Notably, among the genotypes studied, the Red Creole (11.7±0.6^{a} cm) genotype emerged as a standout performer in terms of root length, a statistically significant outcome that parallels the performance of Khumal 2 (10.7± 1.6^{a} cm). In contrast, the root length of AVON 1103 (4.1± 0.2^{e} cm) and Khumal 1 (4.4±0^{e} cm) was found to be notably limited under mulching. Upon closer examination of genotype interactions, it was observed that Khumal 2 (14.5± 1.2^{a} cm) exhibited the most extensive root diameter when grown without mulch. This finding contrasts with the mulched scenario of AVON 1103 (4.1± 0.2^{e} cm), which displayed the least root length as is shown in Table 1.

Table 1. Effect of onion genotypes and mulching on bulb diameter, neck diameter and root length of onion in Pokhara, 2023

Treatments	**Bulb diameter (equatorial) (mm)**	**Bulb diameter(polar) (mm)**	**Neck Diameter (mm)**	**Root length (cm)**
Factor A				
Red Creole	49.6±0.6 ^{a}	37.7±0.8^{bc}	1.2±0.1 ^{a}	11.7±0.6 ^{a}
AVON 1052	43.6±3.2 ^{c}	38.6^{bc}±1.6^{bc}	1.2±1.1 ^{ab}	6.5±0.4 ^{b}
Khumal 2	49.0±1.7 ^{a}	42.5±2.1 ^{a}	1.2±0.1 ^{a}	10.7±1.6 ^{a}
Khumal 1	44.9±1.8^{bc}	39.5±1.8 ^{ab}	1.1±0.1^{a}	6.1±0.7 ^{b}
AVON 1103	48.3±1.6 ^{ab}	35.7±0.9 ^{c}	1.2±0.04 ^{a}	6.0±0.8 ^{b}
LSD	3.6	3.6	0.1	1.4
CV%	7.5	9.1	9.3	16.1
p-value	<0.01	<0.001	NS	<0.001
Factor B				
Mulch	50.7±0.6 ^{a}	41.8±1.1 ^{a}	1.1±0.03 ^{b}	6.5±0.6 ^{b}
Non-Mulch	43.5±1.3 ^{b}	35.8±0.5 ^{b}	1.3±0.04 ^{a}	9.9±0.7 ^{a}
LSD	2.3	2.3	0.1	0.9
CV	7.5	9.1	9.3	16.1
p-value	<0.001	<0.001	<0.001	<0.001

Treatments		Bulb diameter (equatorial) (mm)	Bulb diameter(polar) (mm)	Neck Diameter (mm)	Root length (cm)
Combined effects of mulches and genotypes on the plant growth characters of onion					
Red Creole	Mulch	50.4±0.8^{ab}	37.8±0.6^{cd}	1.0±0.1^{d}	11.5±1.1^{b}
	Non- mulch	48.9±0.7^{abc}	37.5±1.6^{cd}	1.5±0.1^{a}	12.0±0.8^{b}
AVON 1052	Mulch	50.6±2.5^{ab}	41.7±2.3^{bc}	1.1±0.1^{d}	5.5±0.2^{de}
	Non- mulch	36.5±2.7^{e}	35.5±0.5^{d}	1.3 ±0.1^{b}	7.5±0.2^{c}
Khumal 2	Mulch	52.9±1.4^{a}	47.9±0.9^{a}	1.3±0.04^{ab}	6.9±0.6^{cd}
	Non- mulch	45.0±0.8^{cd}	37.0±0.7^{cd}	1.1±0.05^{cd}	14.5±1.2^{a}
Khumal 1	Mulch	49.0±0.6^{abc}	44.3±0.9^{ab}	0.9±0.01^{d}	4.4±0.0^{e}
	Non-mulch	40.9±1.8^{de}	34.9±0.3^{d}	1.3±0.06^{b}	7.7±0.6^{c}
AVON 1103	Mulch	50.6±1.2^{ab}	37.2±0.7^{cd}	1.3±0.04^{b}	4.1±0.2^{e}
	Non- mulch	45.9±2.8^{bcd}	34.3±1.4^{d}	1.2±0.07^{bc}	8.0±0.7^{c}
LSD		5.1	5.1	0.2	1.9
CV		7.5	9.1	9.3	16.1
p-value		<0.05	<0.001	<0.001	<0.001

From the analysis, it was found that the roots grown under non-mulching condition in all genotypes showed greater ability of soil penetration than that of mulched ones. As such, Khumal 2 showing the most extensive root diameter significantly higher than its mulched condition, maybe to make maximum use of available water from deep soil layers (Wang & Xing, 2016). Similarly, AVON1103 showing the smallest root diameter under mulched condition as compared to its non-mulched condition, maybe because of the implementation of plastic film mulching leading to an increase in soil water availability and soil temperature in the top soil itself, thereby limiting the necessity for further penetration of roots for water (Jia et al., 2018). Similar conclusions were also derived from the report of Gao et al. (2014) which related the increase in moisture in topsoil to restricting root growth under plastic film mulching.

3.6 NUMBER OF SCALES, SCALE DIAMETER

The conducted analysis reveals substantial variations among the genotypes concerning scale numbers. Notably, AVON 1103 exhibited the fewest scales, whereas the reference variety Red Creole and the genotypes AVON 1052, Khumal 2, and Khumal 1 demonstrated statistically comparable scale numbers. Furthermore, a notable disparity in scale numbers existed between the mulched and non-mulched genotypes, with the mulched genotype yielding greater number of scales, although their interaction yielded insignificant results.

Likewise, the investigation identified a significant distinction in scale diameter attributed to genotypic differences, mulching conditions, and their interaction. Remarkably, the mulch of AVON 1052 yielded the largest scale diameter than its non-mulch. In all genotypes, mulching favored the larger scale diameter except in the case of AVON 1103 where there was no significant difference between the scale diameter of mulched and non-mulched condition and had the least diameter than other genotypes which is shown in Table 2.

Table 2. Effect of onion genotypes and mulching on number of scales, scale diameter and bulb yield of onion in Pokhara, 2023

Treatments		No. of scales	Scale diameter (mm)	Yield (t/ha)
Factor A				
Red Creole		8.7±0.4[a]	0.3±0.03[c]	16.5±1.2[a]
AVON 1052		8.7±0.4[a]	0.9±0.04[a]	11.8 ±1.4[bc]
Khumal 2		8.7±0.4[a]	0.8±0.05[b]	13.9±0.9[b]
Khumal 1		8.7±0.4[a]	0.2±0.03[d]	11.40±1.7[c]
AVON 1103		5.8±0.3[b]	0.2±0.005[d]	12.3±0.9[bc]
LSD		0.6	0.04	2.1
CV%		7.7	7.5	15.4
p-value		<0.001	<0.001	<0.001
Factor B				
Mulch		8.9±0.2[a]	0.6±0.08[a]	15.7±0.6[a]
Non-Mulch		7.4±0.3[b]	0.4±0.06[b]	10.7±0.7[b]
LSD		0.4	0.02	1.3
CV		7.7	7.5	15.4
p-value		<0.01	<0.001	<0.001
Combined effects of mulches and genotypes on the plant growth characters of onion				
red Creole	Mulch	9.5±0.3[a]	0.4±2.4[e]	17.3±1.2[a]
	Non-mulch	8.0±0.4[b]	0.2±1.1[fg]	15.7±0.5[a]
AVON 1052	Mulch	9.5±0.3[a]	1.1±1.7[a]	14.8±0.8[a]
	Non-mulch	8.0±0.4[b]	0.8±0.5[c]	8.9±0.3[cd]
Khumal 2	Mulch	9.5±0.3[a]	1.0±0.8[b]	16.0±0.4[a]
	Non-mulch	8.0±0.4[b]	0.7±0.5[d]	11.7±0.2[bc]
Khumal 1	Mulch	9.5±0.3[a]	0.3±0.9[f]	15.7±0.4[a]
	Non-mulch	8.0±0.4[b]	0.2±0.7[g]	7.0±0.3[d]
AVON 1103	Mulch	6.5±0.3[c]	0.2±0.3[g]	14.6±0.2[ab]
	Non-mulch	5.3±0.2[c]	0.2±0.6[g]	9.9±0.3[cd]
LSD		0.9	0.05	2.9
CV		7.7	7.5	15.4
p-value		NS	<0.001	<0.05

Smith et al. (2017) conducted a comprehensive field experiment to assess the effects of different mulch types on onion growth and found that organic mulches led to an increase in the number of scales per bulb, attributing this effect to improved moisture retention and soil temperature moderation provided by the mulch. These favorable conditions are believed to promote better bulb development, leading to increased scales number.

In contrast, plastic film mulching has also been investigated by researchers like Brown and Johnson (2019), whose study highlighted that while plastic mulch had an impact on onion growth, the relationship with scale number was not universally consistent across all onion genotypes. This suggests that the response to mulching can be influenced by genetic factors and the interplay of various environmental conditions.

Regarding scale diameter, nutrient availability has been suggested as a contributing factor. Green et al. (2020) demonstrated that mulching with materials rich in nutrients could positively affect scale diameter. Nutrient-rich mulches may enhance the overall nutrient content in the soil, leading to larger and more developed onion scales.

3.7 BULB YIELD

The application of analysis of variance has unveiled highly significant variations in bulb yield across distinct genotypes and mulching conditions. Notably, the reference cultivar Red Creole exhibited the highest bulb yield. Following closely, the yield of Khumal 2 was statistically comparable to AVON 1103 and AVON 1052, while a significant difference was observed in the yield of Khumal 1 with the lowest yield among the others. This was found in contrast with report of Luitel et al. (2021) where AVON 1052 exhibited the highest bulb weight, followed by Red Creole and AVON 1103.

Furthermore, striking difference in the yield was observed between two management conditions: mulch and non- mulch with higher yield in mulching condition in all genotypes. In terms of interaction, when mulching is done all genotypes are able to yield as much as Red Creole but when there is no mulching Khumal 2 is better than other genotypes, while, Khumal 1 showed the most significant difference between mulching and non-mulching conditions with its non- mulch condition showing the least yield out of all as shown in Table 2.

The increase in yield when mulching can be attributed to the suppression of weeds that reduce the competition for uptake of nutrients (Mutetwa & Mtaita, 2014). Mulching is known to increase soil moisture and temperature significantly within the range of 0-25 cm soil depth (Jamil et al., 2005) which then help to release available nutrients for plant uptake that result in higher growth and development (Rachel et al., 2018). Under non- mulched condition, soil moisture percentage is less than the mulched that might hamper plant growth resulting in lower size of bulb, which, in turn results in low bulb yield.

The number and expansion of onion leaves is an important morphological process that contributes to the overall photosynthetic capacity of the plant. Photosynthesis is essential for producing carbohydrates, which are then transported to the bulb for growth. Plastic mulch can affect leaf expansion and number, as in case of Red Creole, by modifying microclimate conditions around the plant, such as temperature and humidity, potentially leading to variations in photosynthesis and, consequently, bulb yield (Shin et al., 1988). Similarly, Khumal 2 had loosely attached scales than Red Creole, which had compressed scales, leading to slightly larger bulb diameter in Khumal 2. This, combined with more number of scales were the reason for Red Creole to ultimately have higher bulb yield despite not having the highest bulb diameter. To conclude, the highest leaf number, maximum height of plant and larger bulb diameter in Red Creole led to its highest yield.

As such, the difference in yield between different genotypes under mulching and non-mulching has be shown in figure 3.

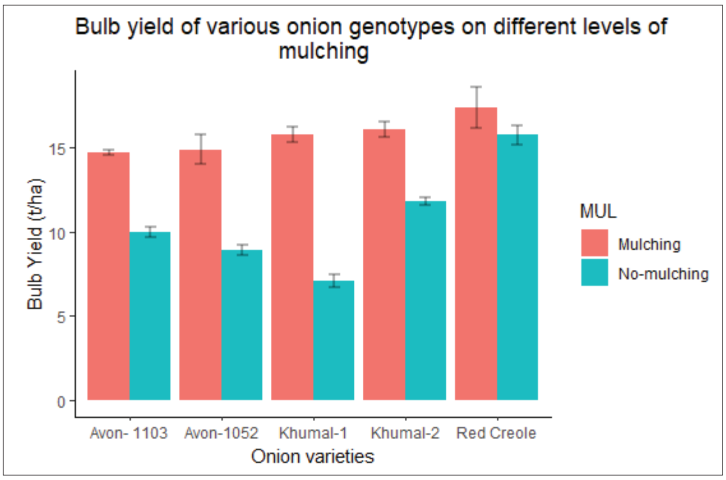

Figure 3. Bulb yield of various onion genotypes on different levels of mulching

CONCLUSION

In a controlled experimental investigation assessing the influence of mulching on the agronomic performance of onion cultivation, significant advantages associated with mulch application were found. Among a diverse range of onion genotypes evaluated, Khumal 2 demonstrated exceptional characteristics, showing a reduced incidence of bulb splitting and optimal utilization of soil moisture, thereby resulting in augmented bulb dimensions and overall increased bulb yield. This augmentation in yield was due to the development of a more expansive fresh mass within the plants, a pivotal factor in bulb initiation and maturation.

The employment of mulching provided conducive environmental conditions for onion growth, encompassing regulation of temperature and preservation of soil moisture. Specifically, the utilization of polyethylene mulch showed positive ramifications. Notably, enhancements were observed in leaf count and photosynthetic efficiency, along with stimulated root proliferation, from enhanced water and nutrient absorption efficiency. These synergistic effects collectively increased the metabolic activities throughout the growth and developmental phases of the plants.

Cumulatively, polyethylene mulching exerted a beneficial influence on soil microclimate modulation, vegetative growth promotion, and physiological vigor enhancement, surpassing the performance of non-mulched control counterparts.

Predicated upon these empirical insights, despite having a similar yield as Red Creole, Khumal 2 emerged as the most promising cultivar for adoption in the Pokhara valley. It was due to Red Creole showing bulb splitting problems in nearly 95% of the bulb population, which is not a desirable character for consumer and market preference. Nonetheless, a multi-year assessment is imperative to facilitate informed recommendations to farmers, incorporating comprehensive evaluations of additional parameters such as insect pest resistance, post-harvest attributes, and consumer preferences, among others.

DECLARATION

The authors declare no conflict of interest.

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MISSING THE LINK: STAKEHOLDERS' PERCEPTION TOWARDS AGRICULTURE ACADEMIC INSTITUTIONS' CONTRIBUTION TO INTEGRATE RESEARCH EXTENSION AND EDUCATION INSTITUTIONS IN NEPAL

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ABSTRACT

Currently, thirty Agriculture Academic Institutions (AAI) in two broad categories: constituent campuses and affiliated colleges under six universities are executing agriculture and veterinary science programs nationwide. All these universities have different course curricula, faculties, academic resources, and research & outreach capacities. Literature show that Nepalese AAIs have minimal activities to engage their graduates in communities and service learning. In this sense, AAIs are missing the opportunities to connect farming communities, enterprises and industries. Similarly, faculties of AAIs are mostly confined to classroom teaching and their competencies of engagement in the policy arena are under-utilized. Further, faculties and researchers because of their limited participation in policy engagement are missing the opportunities to share their evidence, expertise and experiences in the (Agriculture Research, Extension, and Education) AREE network. On this ground, a study was designed to capture the AREE stakeholders' opinion that 'Should academic institutions be a part of agriculture research, dissemination of technologies and policy engagement along with the teaching-learning activities?' A cross-sectional perceptual survey was conducted (n=250) using a five-point Likert scale. Cross-tab analysis and one-way ANOVA were conducted to assess the difference in the stakeholders' opinions. The reliability coefficient (0.633) was calculated using Cronbach alpha reliability methods. The findings showed that stakeholders perceived AAI should not be confined merely to teaching-learning activities. It means the stakeholders desire to review the existing mandates of education institutions and expand their roles in the tripartite functions of research extension and education. The stakeholders are not in favor of establishing an arrangement for the apex agency to integrate all of these institutions. To connect and strengthen linkage and integration between AREE institutions, classroom components should be connected with farming & business communities, and industries through service learning in community multi-stakeholder platforms.

Keywords: Agriculture academic institutions, Community engagement, Integration, Service learning

1. INTRODUCTION

Agriculture Academic Institutions (AAI) across the globe educate researchers and extension experts to fulfill the demands of human resources in the agriculture sector (Philips, 1999; Bhattarai et al., 2019). This is reinforced to differing extents through the instruction of hands-on agriculture expertise at higher education levels, in addition, to research conducted

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at specialized AAI. Inadequate connections among research, extension, and education leads to systematic 'bottleneck' within the national agriculture innovation system (Van Crowder & Anderson, 1990). These bottlenecks hinder their capacity to effectively contribute to development (Bourgeois, 1990; Rolling, 1990; Kaimowitz, 1990). The benefits of the robust connections are widely recognized. Even when there is no missing task and responsibilities for each task are assigned, integration cannot be completed without coordination among interrelated tasks, the greater the specialization of the task, the greater the need for integration (Bourgeois, 1990; Gauchan & Timsina, 2022). This is the principle often emphasized in the organizational literature.

Integration is essential for completing tasks even when they are well-defined and responsibilities are assigned. Coordination among interconnected tasks becomes crucial, especially when tasks are highly specialized. This principle is frequently highlighted in organizational literature (Bourgeois, 1990; Robbins et al., 2019).

Proof demonstrates that the integration of research, extension, and education has the potential to enhance the overall performance of the agriculture innovation system. Bourgeois (1990) highlighted the immense tactical significance of establishing seamless inter-organizational linkages to achieve continuous agriculture development cannot be overstated. In the words of Crowder and Anderson (1990) -Why then, the issues of linkage raises the question of why it is pervasive and persistent?

In underdeveloped nations, agricultural research, extension, and education often exist as separate entities. Even in developed countries, these systems can be institutionally distinct, but effective methods of coordination have been established to manage their interconnected natures (Falvey & Bardsley, 1995). Development initiatives in less developed countries have sometimes assumed that adopting a model of institutional integration, like the Land Grant Commission (LGC) system that combines teaching research and extension, is feasible. However political experiences suggest that this approach is expensive and unlikely to yield long-term success. Each country possesses its unique organizational requirements that must be taken into account when designing programs aimed at enhancing the agricultural knowledge system.

Association with higher agriculture education institutions (AAI) with agriculture education has followed a complex trajectory, addressing regional, national, and global food and environmental education and research in the political-economic sector (Falvey & Bardsley, 1995). This historical journey spans over 150 years, the faculties, across its diverse stages of development, is positioned within the broader context of the university and other entities involved in agricultural education. In the days to come the AAIs have to have a crucial role in promoting the advancement of agriculture (Philips, 1999). They must progressively operate on a global scale, collaborating to establish the most effective platform for education and research in agriculture domains (Atchoarena & Holmes, 2004). These collaborations must have prioritized concerns about the environment and enhancing production capacities in less developed nations. These joint efforts will enable specialized focus within each institution, allowing experts to push the boundaries of knowledge in their respective fields.

1.1 RESEARCH QUESTION

This paper is pursued to answer the following two-fold research questions. The first research question is factual type and the second one is more developmental and theoretical than the first one.

1. What is the perception of stakeholders about AAIs role in AREE institution linkage and integration?
2. What possible roles of AAIs could contribute to the linkage and integration with AREE institutions in Nepal?

1.2 OBJECTIVES OF THE RESEARCH

The study specifically seeks to determine AREE stakeholders' opinions toward the role of education institutions. The specific objectives of the study are:

1. To ascertain the views of agriculture research, extension, and education personnel regarding the possible role of AAI in integrating and linking AREE institutions.
2. To develop and suggest a framework for integrating research, extension, and teaching activities led by education institutions in Nepal to promote community engagement and service learning.

2. REVIEW OF LITERATURES

2.1 AGRICULTURE EDUCATION IN NEPAL

Agricultural education in Nepal has experienced blinking prosperities and compromised mergers, usually failing to attempt to catch up to past and current needs and rationalize institutional expenditures and contributions in the development sector (Bhattrai et al., 2019). The vision and vigor of the 1960s were sometimes less evident in public service approaches to the management of agricultural and related education over the century-long history. The then His Majesty's Goverment of Nepal opened School of Agriculture in 1957, under the agriculture section could not have got the academic spirit until 1968. Development of agricultural education infrastructure were followed by the vision of agriculture development but not by the agriculture academicians in the country so the pattern of agriculture education was not so much aligned with the land grant model but did follow the trickle-down approach same as the development pattern of the country (Maharjan & Dhakal, 2023). Agricultural education in Nepal has changed rapidly by number and intake without scoping study the need assessment (Bhattarai et al., 2019; Timsina, 2021; Jaishi et al., 2022). Agricultural education industries and universities have passed through different names to meet the changing needs of the world.

Agricultural programs currently underway in Nepal can be classified in three different ways (Bhattarai et al., 2019; Timsina, 2021; Jaishi et al., 2022).

1. Agriculture universities and institutions that offer agricultural study programs for Bachelor, Masters, and PhD program
2. Technical schools and colleges, which are a combination of related agricultural and pre-diploma and diploma education in the short and long term under CTEVT programs.

3. Technical and vocational school education (TVE) agriculture program for grades 9-12 run by public high school.

Agriculture education and allied sector development are broadly divided into three categories by their phase of development: Foundation phase, technical-vocational education development phase and university expansion phase. The first education institution was established under the Ministry of Agriculture Development in 1957 in the name of the 'School of Agriculture' to produce a labor force for farmers defined as junior technical assistants (Bhattarai et al., 2019). Later in 1996, the school was converted to the faculty of agriculture and began a two-year program intermediate of agricultural science (IAAS, 2020). The agricultural education system in Nepal offers pre-diploma, diploma, bachelor, master, and doctoral degree programs. In master's degree, program offers fifteen specific disciplines in agriculture and allied areas of extension, the development sector, industry, banking, and cooperation. About thirty agriculture academic institutions (AAI) of private and constituent agricultural colleges and institutions implement their academic program with about 2500 graduate intake capacity annually (Shrestha & Timilsina, 2022; Jaishi et al., 2020). However, many agricultural graduates are unemployed and under-utilized, and many of them change their disciplines to other sectors. At the same time public research, extension, and education systems facing a serious human resource crisis. The quality of teaching-learning has declined over time, specifically in private affiliated colleges in remote satellite colleges. While many agricultural universities do not rise to the set standards in education. To meet the demand for low-level educational needs many public institutions CTEVT are offering pre-diploma, diploma, and certificate courses. Since 2014 higher education under the Ministry of Education also implemented agriculture courses in grades 8, 9, 10, 11, and 12.

School education in the agriculture stream is also been prioritized in recent decades. Recently, the government has changed the school's curriculum, which requires compulsory education for the ninth, tenth, eleventh, and twelfth grades (Bhattarai et al., 2019). To increase the number of agricultural technical workers in the country, the latest amendments have prepared a ninth and tenth-grade curriculum for those students who are motivated to obtain a higher education. Under this stream currently in 48 of 77 districts, operated by local government schools run JTA programs in which students in each class (ninth, tenth, eleventh and twelfth grade) teach five different agricultural subjects in combination with other subjects. The focus has been given to more on the practical application (60:40 theories and practical) basis.

Table 1. Policy constraint and policy gaps in AAI-community engagement in Nepal

Policy constraints	Policy gaps	Evidence gaps	Research priorities
Functional and operational mechanisms for service learning and community engagement are required	Holistic teaching research and extension policies in the changed higher education context are yet to be developed	Empirical information and database, inventory on the extent of vertical and horizontal coordination among AAIs and community	Identify the factors for appropriate institutional mechanisms and policy framework for the development of service learning and AAI community engagement

Source: Authors compilation

Regarding the infusion of higher education into extension and advisory services at the national level, the AAI has now been included in the REE committee recently which is the national apex and coordinating entity of AREE mechanism. The REE coordination committee has been formed to advise AREE institutions on setting their AREE priorities at the national provincial and field levels. Currently, this boarding mechanism is secretariat by the Department of Agriculture. This committee mechanism is envisioned to be established on four levels: National, provincial, cluster, and municipal. Thus, the AAIs can play technical backstopping and other potential roles through this mechanism.

Ramasamy and Selvaraju (2007) mentioned that AAI should emphasize producing graduates by revisiting the curriculum as job providers, not job seekers. This is possible only through the engagement of graduates in rural agricultural work experience, industrial tie-up programs, community service learning and community-AAI engagement programs (Mitchel, 2008). Vocational schemes are another scheme for students who are unable to pursue higher education (Jaishi et al., 2022). At present agriculture extension, research, and education are conducted by three different institutions under two different ministries.

Weak horizontal and vertical linkage and integration mechanisms among the services of these institutions (Das et al., 2019). Currently, neither of the AAI of six universities can meet its preeminent standard of Land Grant Universities in its teaching, research, and extension mandates. The current funding structures, mechanisms, human resources, capacities of the faculties and the associates, policies, and mandates are in conflicting situations to provide its goal and objectives because of external, internal and personnel factors (Table 2).

Table 2. Factors affecting achievement of the objectives of Agriculture Academic Institutions of Nepal

External factors	Internal factors	Personnel factors
Weak national, provincial, and local support	Failure to achieve the multidisciplinary goal of AAI	Weak participation in the policy process
Decrease in financial investment	Absence of research and outreach projects and program	Improper and inadequate lobbying by AAI leaders
Vested interest in a graduate circle and political influence	Inbreeding in staff capacity	Lack of creativity and expectation in both faculties and graduates
Isolation of AAI from national higher education system	Declining the teaching and research facilities	Absence of skills to link & integrate with business, industry, market & community

Source: Bajracharya (2020), QAAC (2021), UGC (2021)

2.2 THEORETICAL FRAMEWORK OF THE STUDY

The study applied the description of system theory and inter-organizational theory of integration. System theory provides the analytical framework to facilitate the understanding of the undercurrents of inter-group association (Alawa et al., 2020). According to Hooyman (1976), inter-organizational theories describe how two or more formal organizations or institutions relate to each other functionally. This functional relationship can be useful in assessing the structural variables that affect the problems and the potential of cooperation between and among the agencies. System theory stresses the casual boundaries influenced by context and defined by structure, functions and roles. So both classroom components and community components must be viewed as a holistic education system (UGC, 2022, UGC, 2023). Every system is more than the sum of its parts. Regarding the AIS model, education should be an integral part of technology generation and extension and outreach of technology to enhance the production system toward achieving sustainable agriculture and rural development (Sulaiman, 2015; Hellin & Camacho, 2017).

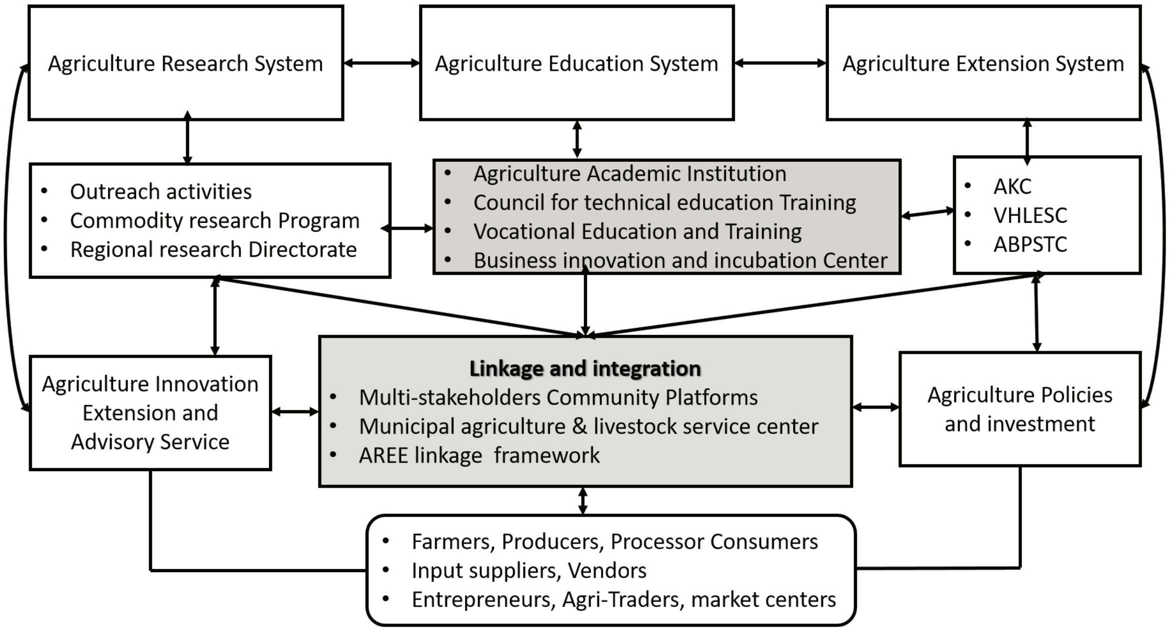

Figure 1. Three subsystem of AREE of Nepal and its integration with AREE framework

Literature shows that educational institutions must be an integral part of agricultural innovation systems along with all sorts of capacity development processes in the field of agriculture and rural development (Chakraborty, 2020; Alawa et al., 2020). In the National Agricultural Research and Extension System (NAERS), AAI is not included yet, but stakeholders are realizing the significance of AAI at different forums and platforms. The major slab, as perceived apparently, is the difference of affiliation of educational, research, and extension institutions in two separate ministries. Agriculture education goes under the Ministry of Education (MoE) whereas agriculture research is operated by NARC Act, 2089 and the extension functionaries are under the Ministry of Agriculture and Livestock Development (MoALD). Thus, they are mutually exclusive in way of integration or to be linked formally together. In this way, as AAIs are not included in MoALD, they cannot get ample opportunities to use research and outreach funds from the ministry.

3. MATERIALS AND METHODS

A cross-sectional deductive approach based on the positivist philosophy was applied. An opinion survey as a research design was conducted to measure the opinions of the personnel responsible for AREE institutions. A total of 250 respondents from four categories of strata: research, extension, education and private sector were considered (Table 3).

Table 3. Stakeholders and number of respondents taken in the opinion survey

AREE Stakeholders	Respondents by the level of operation			Total
	Executive-level	Mid-level	Field-level	
Research agencies	33	30	13	76
Extension agencies	19	33	18	70
Education agencies	23	20	11	54
Private sector agencies	27	19	4	50
Total	102	102	45	250

A five-point Likert-type scale was developed and a self-administered questionnaire method of data collection technique was used. This technique is more common because all the respondents of this survey have a higher level of education. It is more economical and has a higher level of rate of return. The self-administered survey is a questionnaire that is designed explicitly to be completed by respondents without the assistance of interviewers or bias (Cleo & Dillman, 1995). Perception analysis was conducted to assess the views of AREE stakeholders. Mean, mode, range, and standard deviation were calculated using cross-tab analysis and compared the views of AREE stakeholders. The decision level: agreement and disagreement were analyzed using the sum and the mean of opinions.

4. RESULTS

4.1 SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE RESPONDENTS

Of the respondents were 58.40 percent were from the public sector 21.60 percent were from the corporation sector and 20 percent from the private sector. As stated in the sampling strategies from the research sector 30.40 percent, extension 28 percent, education sector 21.60 percent, and private sector represented 20 percent respectively (Table 3). The number of projects handled, district exposures, number of training workshops participated number of publications of the respondents from four categories of institutions are displayed in Table 4. The researchers assumed that a higher number of entities positively correlated with a higher number of functional linkage projects and programs. The table shows that the standard deviation of almost all items found higher than the mean value demonstrates the varied capacity of respondents within the organization.

Table 4. Socio-demographic characteristics of respondents by type of organization

	Number of projects handled				No. of training workshops & seminars				Number of publication			
Agency	Re	Ex	Ed	Pr	Re	Ex	Ed	Pr	Re	Ex	Ed	Pr
Mean	9.82	5.20	5.29	6.68	21.39	18.27	20.16	23.42	19.25	3.05	28.01	4.18
SD	15.15	13.53	4.71	8.66	24.83	21.92	20.15	24.05	47.58	4.19	55.10	9.81
Minimum	0	0	0	0	0	0	3	0	0	0	0	0
Maximum	120	100	20	50	150	100	100	100	400	20	280	50

Note: Re=Research agency, Ex=Extension agency, Ed=education agency, Pr=Private agency

4.2 STAKEHOLDERS' PERCEPTION OF AAI ROLE IN AREE LINKAGE AND INTEGRATION

One of the most confounding aspects of the Likert scale used to measure the perception of people many of the variables are psychological in the form of latent constructs difficult to observe directly (Blanchard et al., 2014). The Likert-type scale is constructed by adding up the defining the items of observation. According to John (2010), the Likert-type scale is a composite of the battery of multiple items. Altogether an items scale was prepared and asked about their views regarding the possible roles of education institutions in research-extensioneducation integration. participants agreed that the participating efforts are occurring throughout the many disciplines primarily driven by external agencies but they also agree that the integration is their mandate. Lack of funding and skilled human resources are cited as primary barriers to integration. Although not in the same way respondents agreed that organization structures are inclined to integration however the organization's goals, functions, and annual targets are imposed to compel them to work in isolation. Despite the divergence in perspective among the AREE stakeholders all agreed to have value in integration (Table 5).

Table 5. AREE stakeholder's response towards the AAI role in linkage and integration

Items	Perceptual statement	Mean	Mode	SD	Range	Sum	Decision
1	Agriculture Academic Institutions (AAIs) can bridge the AREE institutions for linkage and integration	1.60	2	.581	2	399	Agreed
2	AAI may engage in technology transfer through a community engagement and service learning program	1.64	2	.600	2	410	Agreed
3	AAI engagement in policy formulation and sharing may strengthen AREE linkage and integration	1.82	2	.552	2	456	Agreed
4	AAI could engage in the capacity building and technical assistance of the personnel of other AREE institutions	1.71	2	.572	2	427	Agreed
5	A separate and apex agency is essential to link and integrate all these AREE institutions for technical assistance	2.77	3	1.24	4	692	Disagreed

The weightage mean score of the observed items was calculated as 9.54/5=1.90. All the individual items of the scale were compared with the weighted mean score and the decision was made. It is estimated that all the items except 5, have a mean value lower than the weighted mean. It indicates that people irrespective of their organization have agreed to foresee the AAIs role in bridging AREE institutions, technology transfer, policy engagement, and capacity building. However, people have slightly different opinions about the need for a separate agency may be one of the options to integrate the AREE institution. Having a higher range value of 4 of the 5th item indicated that stakeholders are very much divided on this particular opinion. Disagreement on the need for a separate apex agency is probably because of the current nature and characteristics of the job they are doing. Mostly they are unaware of the value of integration through apex agency. The reasons for this perception also can be justified that the internal organizational pressures and culture of traditional AREE institutions are often insufficient to ensure the linkage and integration take place. In a study in India, Soam et al. (2023) mentioned that National Education Policy 2020 demands a separate multi-stakeholder higher education institution. This institution will facilitate the research, and innovation, which requires effective linkage among stakeholders more specifically among academia and industry.

According to Fortner (2022) complementarity of linkage and integration between AREE actors go beyond the respective research scaling-up capabilities. Partnership in the projects and program for baseline assessment, feasibility study, mid-term evaluation, impact evaluation, and technology evaluation AREE actors can contribute commentary functions within each of the of research-extension-education-farmers' continuum (Crowder & Anderson, 1997; Glover, 2019; Fortner, 2022).

The chi-square test of independence was carried out to examine the association between types of organizations (research, extension, education, and private sector) and their perception of AAI roles. Five items to explain the AREE persons' perception were constructed to measure their opinions. The null hypothesis for this test is that there is no relationship between their perception and the stakeholders' type of organization. The result shows that 1st, 2nd ,3rd and 4th statements have a significant relationship between the type of organization and the perception. However, the 5th statement related to the need for separate agencies to bridge the AREE intuitions differ significantly (Table 6). However, the perception of the personnel by level of respondents has no significant association between the perception and the level of respondents (Executive, mid and front line) for all of five perceptual statements (p=.221, p=.181, p=.999, p=.893, p=.631). Partial eta squared (η^2) was calculated by comparing more than two groups of people to estimate how large of an effect of independent variables on dependent variables. the test showed a small effect size of independent to dependent variables for all five perceptual statements ($\eta^{2=}$.055, .055,.053, .020, .007).

Table 6. Respondents' statement to measure the perception towards AAI's role of AREE integration by types of organization and level of respondents

Items	Statement of perception	Level of significance		Eta Squared (η^2)
		Type of organization	Level of respondents	
1	AAI can bridge the AREE institution for integration	p=.003	p=.221	.055
2	AAI may engage in technology transfer through a community engagement program	p=.006	p=.181	.055
3	AAI engagement in policy formulation and sharing may enhance AREE integration	p=.004	p=.999	.053
4	AAI could engage in the capacity building and technical assistance of other AREE institution	p=.008	p=.893	.020
5	A separate agency is essential to integrate AREE institutions for technical assistance	p=.132	p=.631	.007

The test of one-way ANOVA was conducted to test whether the perception of AREE stakeholders by organization and level of respondent differ or not? The hypothesis was, there was no difference in the opinions of the people by the organization and level of the respondents towards the AAI role and contribution. In the case of the type of organization, the alternative hypothesis is accepted and can be said that the respondents of different organizations viewed differently and the association was found significant (p=.046) between the type of respondent by the organization and the perception. Also in the case of the level of respondents, respondents viewed significantly different opinions towards AAI-community engagement. That means all the respondents by type and level of respondents agreed that AAI-community engagement can promote linkage and integration among AREE institutions.

Table 7. Difference of the perception of the stakeholders towards the Community-AAI's engagement

Cases	Sum of Squares	Df.	Mean Square	F	p	η^2	ω^2	η^2_p
Types of organization	53.932	3	17.977	3.834	0.046	0.010	0.045	0.033
Level of respondent	9.090	2	4.545	0.969	0.008	0.381	0.008	0.000
ToO ✻ LoR	19.234	6	3.206	0.684	0.017	0.663	0.016	0.000
Residuals	1115.901	238	4.689					

5. DISCUSSION

Agriculture research, extension and education linkage in general are weak in Nepal (Gauchan et al., 2022). Early in the 90 decades Crowder and Anderson (1997) and Rivera (1995) were in favors of the integrative approach of AREE. The existing linkage mechanisms are more formal rather than effective, and efficient in action and outputs. The tripartite relationship between these research-outreach and teaching functions interface is critical (Gauchan et al., 2022). The results from the above analysis showed that stakeholders perceived that AAI should not be confined only merely teaching learning activities. It means the stakeholders desire to review the existing mandates of education institutions and expand their roles in the tripartite functions of research extension and education. The post-pandemic situation and National Education Policy (2019) demand that community engagement be mainstreamed in all teaching-learning and research service activities.

The study by Alawa et al. (2020) recommended agriculture education and extension through policies for implementation. Findings also agree with the (Philip, 1999; Shrestha &Timsina, 2022; Jaishi et al., 2023) Linking learning with community service, linking research with community knowledge, knowledge sharing and mobilization, devising new curricula and courses, including practitioners as teachers and social innovation by students are the major approaches to community engagement. The AAI can choose any combination of community engagement forms. In light of the global and national approaches currently available, the University Grant Commission has set key five principles of community engagement and service learning (UGC, 2022). HAI is being encouraged to foster social responsibilities and community engagement through the principle of mutual learning and respect, university-wide in faculty and disciplines, credit-based course for students, credit for teachers for their engagement and the linkage with local institutions.

Several research findings agreed on the positive impact of academic collaboration on research productivity, but the link is not understandable. However, there is little consensus on the benefits of academy-business interactions. The evidences of this scant and contradictory relation are also cited (Rivera-Hurta et al., 2011). Henize et al. (2009) stated that collaboration among different types of stakeholders is often viewed as a positive factor between knowledge creators and problem-solving communities. Rijnsoever et al. (2008) stated that the collaboration among researchers to develop academic careers and science-industry collaboration are not clear. All levels of network activity within the scientific community is positively related, academic rank and networking activity is strongly correlated but authors showed the non-academic interactions show no correlation between academic rank.

The high value of collaboration among scientists and university researchers' interaction with the business community is generally acknowledged. According to Rijnsoever and Hessels (2021) the drivers and barriers of university-community-industry collaboration are oriented towards heterogeneous factors: the intellectual goal, recognition, and monetary incentives. This heterogeneity shows that a combination of interventions will required for the government to promote university-industry-community linkage (Rijnsoever et al., 2008).

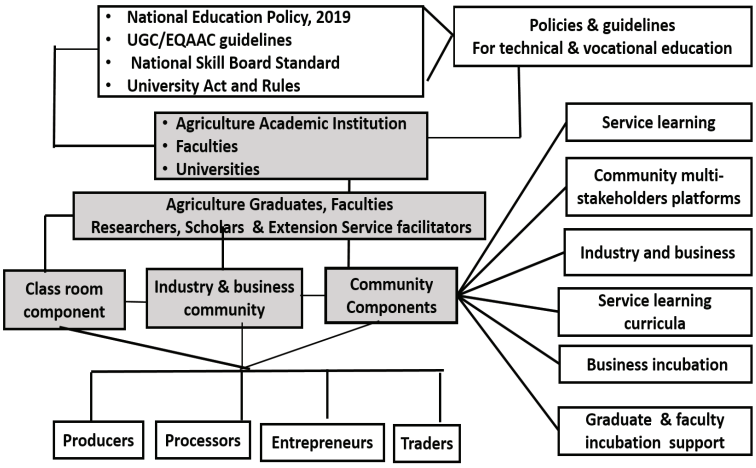

Figure 2. Three components of agriculture education and community engagement framework for Nepalese AAI

Rivera-Huerta et al. (2011) found positive relation between university researcher and farmers' interaction. So the new ideas for putting learning theories into practice educators should be aware. According to constructionism philosophy of learning, learning theory is about people's learning behavior. According to this theory, learners have to be exposed to more exposure and observation to make teaching happen (Nichols, 2000). Constructionism roots into the social, and psychological philosophy of education and learnings (Oliver, 2000). According to experiential learning theory, learning depends on how much of experiences is transformed to knowledge (Alkan, 2016). It is an engaged learning process whereby learners learn by doing in the guidance of researchers and educators. In this sense community engagement is key not only for maximization of learning but also for linking and integrating in common platforms. In 1964 Kolbs summarized four stages of the cycle: Concrete experiences, reflective observation, abstract conceptualization and active experimentation. These four stages of learning emphasize that learning is a process. Activity theory of learning is a psychological meta-theory is a paradigm or framework about studying thought and consciousness. According to the activity theory of learning, practical action in a sociocultural world through six related elements: object orientation, community externalization, tool mediation, social hierarchical structure and rules (Hung & Wong, 2000). The productivity of new recommendations is positively influenced by both of breadth of linkage and their duration for university research and development (Rivera-Huerta, 2011). So maximum number and duration of community exposures must be highlighted and emphasized in both classroom components and community components. through revitalizing AAI curricula.

6. CONCLUSION

Theoretical and dysfunctional linkage and integration of AREE exist. So the variety of reasons for reform in linkage and integration had become necessary in the national agricultural extension system of Nepal. The perceptions of the researcher, extension experts, educators, development experts, and private entrepreneurs were crafted. The design and implementation of an integrated AREE system will require a realistic assessment of the opportunities and constraints within the institutional context of a specific nation with particular attention to internal, external, human, structural, and psychological factors to improve the linkage and integration system.

Agriculture research, extension and education will be the instruments of growth that must be integrated. AAI has great potential to improve the integration. The question of how AAI contributes for systematic integration is the focus of this paper. How do these mechanisms operate in practice? The answer depends on how far the AREE stakeholders are willing and able to make them work. Several structural mechanisms are to be found to utilize the opportunities of integrations. With the structural and functional linkage and integration of educational institutions into the AREE institutions network, education actors could also actively participate and minimize the linkage gaps.

Inputs from AREE stakeholders overwhelm the perception that the academic institution should be a part of the mainstream of designing agriculture research, agriculture policy formulation, and dissemination of technologies. The study provides insight into integrating classroom and community components: Linking community knowledge, knowledge mobilization, designing new curricula, linking service learning with industries & incubation centers, and graduate innovation. It is, therefore, the opportunities in this sector must be scaled up so which can attract and mentor high-quality graduates by improving the standard of research and teaching learning relevance by blending AAI-community engagement and service learning approaches. Linkage and integration in this sense improve the quality of AAI and promote sustainable innovation and growth. The results of this research are explorative in nature. Future research have to design to explore the details of strength of relationship and associated factors. Also the details of research on the necessity of apex agency to connect and integrate all these AREE intuitions in national level is further research.

SUGGESTION FOR IMPLICATIONS

1. To accomplish the commitments of AAI, there is a need for adequate blending of classroom components with community components. AAI–community engagement and service learning system to be set up in AAI. It helps to solve the dual problem of human resource shortage and promotes real-time solutions for farming communities.
2. The establishment of the innovation-incubation hub in AAI may support the integration of research, extension and community outreach activities to blend teaching-learning and experience learning is strongly suggested. The higher Agriculture Academic Institution must focus a research and innovation by setting up incubation centers, and technology development process centers in frontier research areas.
3. It is recommended that the existing structure of the apex agency like a center or central directorate of agriculture research extension and education be strengthened to identify, develop, implement, and monitor the AREE integration efforts. In addition, the agency also provides a springboard for securing resources for faculty and extension educators to carry out capacity enhancement efforts. The curriculum of any capacity development should be approved and assessed by this agency.

Relevancy of curriculum is a big question is to assess what a student, industry, community, producers, and entrepreneurs need and what kinds of curriculum they are interested. So continuous curriculum feedback system should be maintained through workshops. The instructors and educational designers in the academic institution have to be aware of what is going on in the workforce, and service and industry sectors.

DECLARATION

The authors declare no conflict of interest.

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PREVALENCE OF SNAILS AND FARMERS' PRACTICE TOWARDS THE MANAGEMENT OF GIANT AFRICAN SNAIL, *Achatina fulica Bowdich*, 1822 IN KAPILVASTU, NEPAL

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ABSTRACT

The Giant African Snail (GAS), Achatina fulica Bowdich, 1822, is the world's largest, most damaging, and highly invasive land snail, capable of consuming about 10% of its body weight daily and affecting at least 500 types of plants. Despite the high incidence of this pest, management options are limited and ineffective. In this context, this study was carried out to assess overall snail distribution, damage and management practices adopted by farmers against GAS. A household survey of randomly selected 60 households was carried out using semi-structured questionnaires at Banganga Municipality-01, Kapilvastu, Nepal. The results revealed the prevalence of three different snails: the GAS, Achatina fulica Bowdich, 1822, the Common snail, Indoplanorbis exustus (Deshayes, 1834), and the Paddy Snail or Ghonghi or Ghongi, Pila globose (Swainson, 1822) in moist areas, drains, and grassy lands, among them, GAS causing the most significant damage during the rainy season. The most vulnerable stage of crops to GAS was the vegetative stage of development (53.3%) in vegetables and fruits, with the most preferred crop family being the Cucurbitaceae (45%). The majority of respondents (48%) believed that the lack of effective control measures was the main reason for the growing infestation and extent of damage. The 'Hand-picking and killing' method was considered the most effective and suitable method in the farming community over other control measures. It has been reported that the snail problem has increased over the years, and very little effort has been made by the concerned authorities to manage this pest. In conclusion, snails, especially GAS, pose major challenges to agricultural production in Nepal. Therefore, appropriate and cost-effective management strategies are required for their sustainable management.

Keywords: Ghonghi, Hand-picking, Invasive-pest, Kitchen-garden, Management

1. INTRODUCTION

The mollusks are soft-bodied invertebrates having exterior shells often made of calcium, which make up the second-largest phylum in the animal kingdom. Among the six taxonomic classes viz. Cephalopoda, Monoplacopoda, Amphineura, Scaphopoda, Bivalvia, and Gastropoda that make up this phylum, but only Gastropods include more than 80% of the species (Kumar, 2020a). *Achatina fulica* Bowdich, 1822, the Giant African Snail (GAS), is the most significant molluscan pest of crops (Gołdyn et al., 2016) attacking about 500 different plant species. The Global Invasive Species Database has listed GAS as one of the "100 Worst Alien Invasive Species " (Nelson, 2012). *A. fulica* is nocturnal (Raut & Barker, 2002), a hermaphrodite species (Pawson & Chase, 1984), native to Africa but introduced to tropical areas of the world (d'Ovidio et al., 2019). Land-dwelling mollusks have a simple

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life cycle: they deposit eggs that hatch into offspring, which, although often different in color from adults, have a similar form. Juveniles eat, grow into adults, and reproduce through either hermaphroditism or amphimixis (Wilson, 2007). Due to their high reproductive potential, a single snail can rapidly multiply into a large population, making their management challenging. During the day, they seek shelter in moist, shady areas, but at night, they emerge and damage various crops, resulting in significant economic losses (Kumar, 2020a).

GAS typically affects vegetables, decorative gardens, and small-scale agriculture (Prasad et al., 2004) and also crawls up the walls of houses in large numbers, degrading the aesthetics (Raut & Barker, 2002). The snails are extremely ravenous and easy to feed, devouring almost everything (Carvalho & Silveira Júnior, 2021).

They also serve as a vector of parasitic rat lungworm, Angiostrongylus cantonensis (Chen, 1935), which causes eosinophilic meningitis in humans (Pollard et al., 2008). Additionally, other mammalian species, such as rodents, dogs, and horses, can contract the disease in addition to humans (Pollard et al., 2008). According to data from Samoa, for instance, agricultural losses range from 45 to 85 percent for root crops (*Alocasia spp.,* yam leaves and stems, (*Discorea* spp.), taro petioles and above-ground tubers (*Colocasia*), vegetables (brassicas, sweet and green peppers, pumpkins), and young banana leaves, particularly Cavendish varieties (Pollard et al., 2008). A. fulica has been implicated in the transmission of plant diseases *Phytophthora palmivora* (Butler, 1919) in black pepper (*Piper nigrum* L.), betel pepper (*Piper betel* L.), coconut (*Cocus nucifera* L.), papaya (*Carica papaya* L.), and vanilla (*Vanilla miller*), Taro (*Phytophthora colocasiae* Racib) and *Phytophthora parasitica* Dastur in aubergine/brinjal (*Solanum melongena* L) and tangerine (*Citrus reticulata* Blanco). The relative value of *A. fulica* as a transmission agent in the epidemiology of these illnesses under typical cropping conditions has not been fully defined, even though the significance of these disease organisms is well documented (Gołdyn et al., 2016; Raut & Barker, 2002). It does appear that not much is being done to create better molluscicides (Martin, 1991). Crops of soy and corn suffered yield losses of 50% to 90% due to slug damage (Kumar, 2020a).

In Nepal, Budha and Naggs (2008) reported the first entry of GAS from the eastern part of Nepal, probably originating from India, and distributed it to the Terai region, Siwalik hills, Mahabharat Range's lower slopes, and Mid Hill ranges. Most of the warm, muggy tropics and subtropics are home to *A. fulica*. GAS can tolerate temperatures between 9 to 29°C (48 to 84°F). Air temperatures below 2°C (36°F) cease the activities the snail while above 30°C (86°F) cause aestivation (dormancy) (Nelson, 2012). Therefore, Nepal's Terai (Southern plain of the country) region is the most suitable space for the large-scale infestation the GAS. Metaldehyde, methiocarb, salt, or a mix of these compounds with other molluscicides are frequently used in a variety of bait formulations or foliar sprays for the chemical control of snails. The usage of metaldehyde, which is non-selective, could put the survival of non-target snails, particularly the endemic fauna, in peril (Prasad et al., 2004). There are only a few known bacterial pathogens and almost no viruses that can infect slugs or snails and there are no diseases with a strong potential for commercial development. Additionally, there are no known fungi that affect young or adult molluscs (Wilson, 2007). Despite being largely ignored in the literature on pest control, gastropod mollusk species today pose some of the most serious and difficult-to-solve problems to sustainable agriculture. As other pest groups like insects have seen the development of efficient control measures, gastropods are only now beginning to be recognized as important, particularly in certain crops in kitchen garden and fields (Raut & Barker, 2002). To prevent future infestations from spreading to new areas, swift control measures must be implemented (Nelson, 2012). The first mechanical approach for its management is collecting by hand and subsequent squashing (Kumar, 2020b). Conventional methods of GAS management are labor-intensive, unprofitable, and unsustainable, with many being environmentally unfriendly (Singh et al., 2005). Therefore, there is an urgent need for a management approach that integrate physical and mechanical methods, as well as use of botanicals and chemicals, to reduce crop loss. With the aim of developing a viable and effective management strategy, a study was carried out to identify the prevalent snail species in the study area, their host crops, the affected stages, and the common management practices followed by local farmers.

2. MATERIALS AND METHODS

2.1 SURVEY SITE

Based on the information from the Agriculture Knowledge Centre (AKC), Banganga Municipality-1 of Kapilvastu district, Lumbini Province, Nepal, was purposefully selected for the study. The AKC identified this area as having a serious infestation of giant African snails in its kitchen gardens (Figure 1).

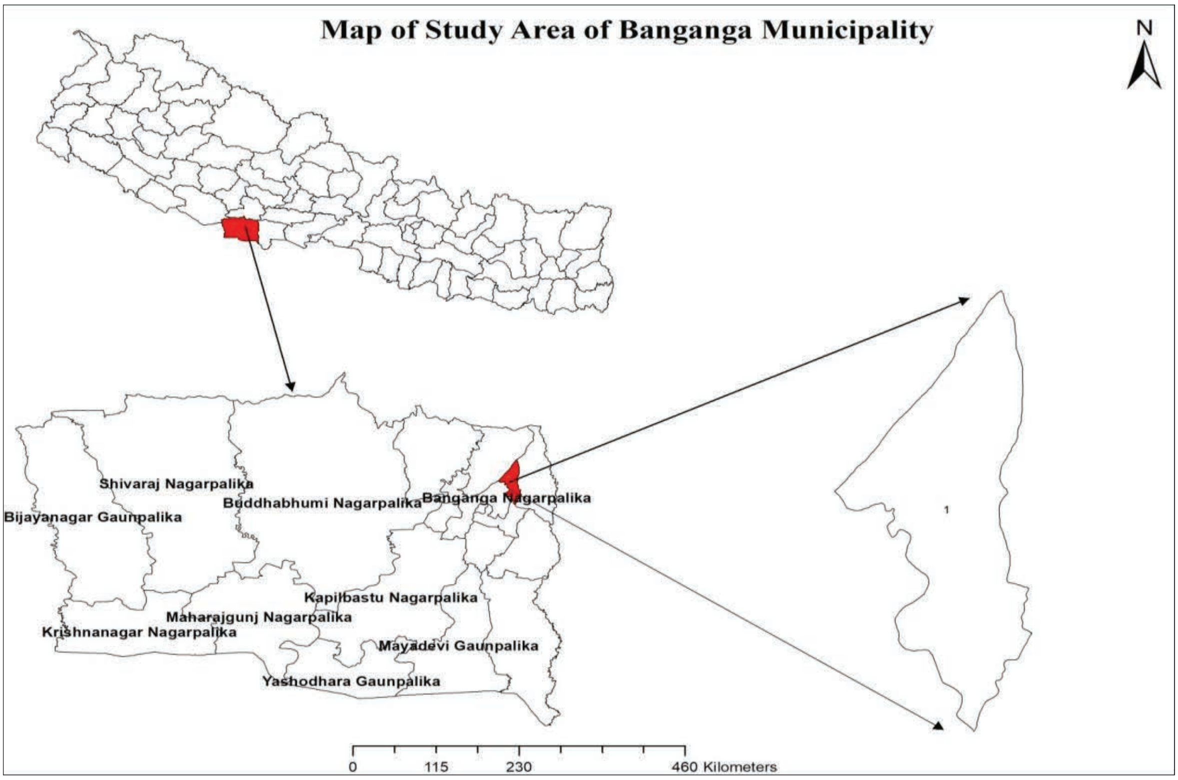

Figure 1. The survey site: Banganga-01, Kapilvastu, Nepal

2.2 QUESTIONNAIRE PREPARATION AND SURVEY

A semi-structured questionnaire was prepared to assess basic information about the Giant African Snail, its distribution, the host affected, the type of damage, and its consequences, along with management practices adopted. The questionnaire was pre-tested with the 10 kitchen garden farmers who were not part of the main survey. After the pre-test, some questions were added, and some were further simplified. An interview was carried out with the head of 60 kitchen garden households selected through the simple random sampling method which constituted the sample of the study. The farming households of the Banganga municipality who grew vegetables throughout the seasons every year constituted the population of the study. The sample size was taken to be almost 5% of the total kitchen garden households. Collected snails were identified by using snail identification manuals authored by Budha (2016). During the interview period, observations were made in person, and records were kept digitally using a camera.

2.3 STATISTICAL ANALYSIS

The data were generated from primary sources i.e., household surveys. Data tabulation and analysis were carried out by using MS Excel 2013 and SPSS (version 16.0). The final report was prepared using MS Word 2019 and Mendeley Desktop (version 1.19.8).

3. RESULTS

3.1 TYPES OF SNAILS COLLECTED AT THE FIELD

Three different types of snails, i.e., GAS, *Achatina fulica* Bowdich, 1822, Common snail, *Indoplanorbis exustus* (Deshayes,1834), and paddy snail or Ghongi, *Pila globose* (Swainson,1822) were identified (Budha, 2016) from the crop field of respondents (Figure 1; a, b, c). All the respondents noticed the presence of snails in the kitchen garden during the rainy season. Among them, the highest percentage (66.7%) observed all three types of snails, while 33.3% observed only GAS.

a **b** **c**

(a) *Indoplanorbis exustus (Deshayes,1834)* (b) *Pila globosa (Swainson,1822)* (c) *Achatina fulica Bowdich, 1822*

Figure 1. Different types of snails collected from Banganga-01, Kapilvastu, Nepal

3.2 SEASONAL DAMAGE, HOSTS PLANTS AND DAMAGE SYMPTOMS OF GAS

Rainy-season vegetables were found to be the most affected (78.3%), followed by winter vegetables (21.7%), as shown in Figure 2. No damage was observed in summer season vegetables. Among different developmental stages of plants, the vegetative stage was the most vulnerable (53.3%), followed by the seedling stage (25%). The lowest damage was observed during fruiting stage (8.4%) (Figure 3). Among the different hosts plants, respondents revealed that the highest damage was in cucurbits (45%), followed by fruits (25%), with the lowest damage observed in solanaceous crops (10%) (Figure 4). Defoliation (40%) was found to be the most severe symptoms of damage, followed by slime trails (26.7%) (Figure 5). Ribbon-like excrement was the least severe damage symptom observed (15%) (Figure 7).

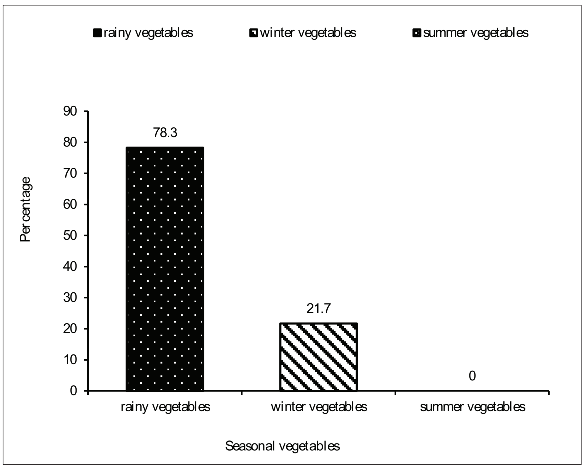

Figure 2. Affected rates of vegetables based on the season by Giant African Snail

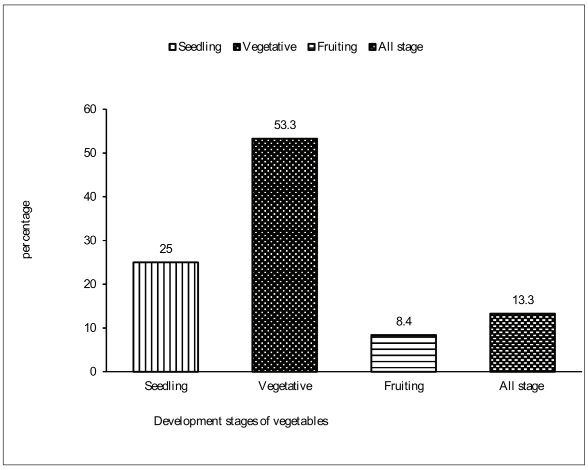

Figure 3. Stage of development of vegetables damaged by Giant African Snail

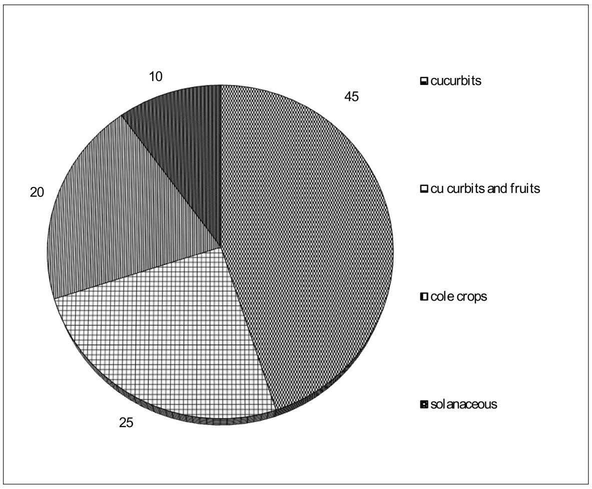

Figure 4. Hosts affected by Giant African Snail

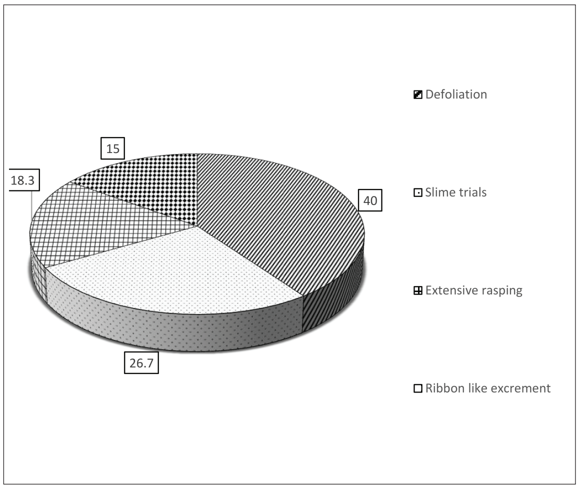

Figure 5. Sign of damage of Giant African Snail

3.3 TYPES OF DAMAGE

Respondents also reported that the highest percentage of damage was to crops (53.3%), followed by crops and the environment (28.3%), which includes disease transmission and the production of foul-smelling excrement. The lowest damage was observed in human health (8.3%), as GAS can transmit parasitic nematode, which causes serious health issues in humans and animals (Figure 6). Figure 7 shows the ribbon-like excrement symptoms of Giant African Snails observed in the kitchen garden.

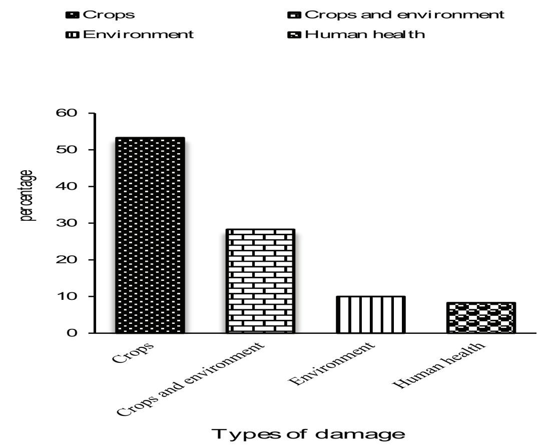

Figure 6. Type of damage caused by Giant African Snail

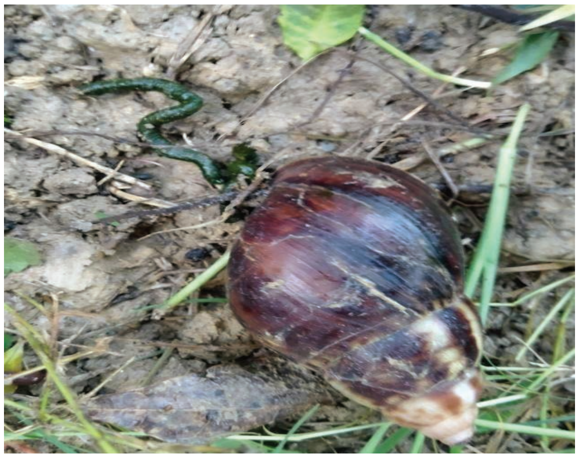

Figure 7. Ribbon-like excrement of Giant African Snail

3.4 INFESTATION FACTOR AND MANAGEMENT EFFORTS

Besides this, crop production practices were revealed as an influencing factor for infestations. Among these, a lack of effective control methods (48.3%) was found to be the primary factor, followed by poor drainage (26.7%). Excessive weed growth contributed (18.3%), while minimum tillage (6.7%) was the least contributing factor (Figure 8). All respondents were involved in different management efforts, with the highest percentage of involvement recorded in mechanical methods (46.7%) due to their cost-effectiveness and ease. This was followed by the use of salt (31.7%). The use of chemicals had a 21.7% response, while no response was found for the use of botanicals (Figure 9).

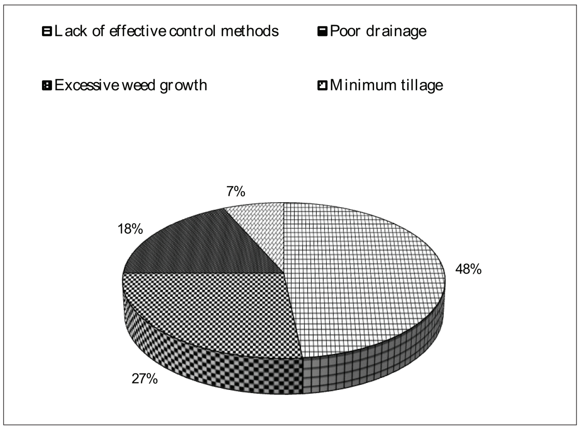

Figure 8. Crop protection practices influencing the Giant African Snail infestation

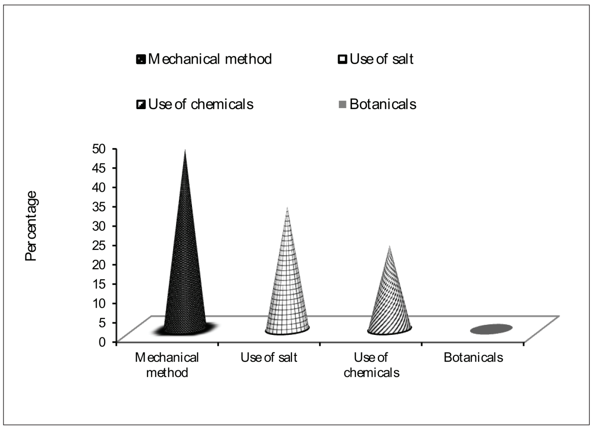

Figure 9. Crop protection interventions applied against the Giant African Snail

3.5 RANKING OF CONTROL EFFORTS AGAINST GAS

Hand-picking and killing were found to be the most frequently followed control measures, followed by the use of salt, while the use of chemicals was least preferred method (Table 1). Additionally, farmers were found to practice throwing pests into water canals, onto roads for crushing, or using rice husk as a barrier around crops.

Table 1. Ranking of control efforts adopted by farmers against *A. fulica* at Banganga, Kapilvastu in 2020

Control measures	Total score	Rank
Hand-picking and killing	6	1
Use of salt	5	2
Throwing in water canals	4	3
Throwing on the road for crushing it	3	4
Use of rice husk as a barrier around crop	2	5
Use of chemicals	1	6

4. DISCUSSION

Our study was limited to kitchen garden of surveyed households There was very little literature available assessing the status of snails and addressing the issues related to the Giant African Snail (GAS) in Nepal. Despite some farmers complaining about insect damage, the GAS is still mostly a concern for household kitchen gardens, primarily targeting vegetable crops (Pollard et al., 2008), which aligns exactly with our findings. GAS was found to be the most prevalent snail in the area, similar to the distribution reported in Africa (Raut & Barker, 2002), the Caribbean sub-region (Pollard et al., 2008), coastlines of Assam, Tamil Nadu, Odisha, Kerala, and West Bengal (Kumar, 2020a), and the Andaman and Nicobar Islands in the Bay of Bengal (Prasad et al., 2004). Prasad et al. (2004) reported that three families; Cucurbitaceae, Cruciferae, and Leguminoseae sustained the most harm, corresponding to our finding that cucurbit crops were mostly affected (45%). However, tuberous crops such as *Discorea* spp. and *Alocasia* spp. are equally affected by GAS in Caribbean sub-regions (Pollard et al., 2008). Fruits ranked second in the kitchen garden in our study, but in the Caribbean sub-region, numerous fruit trees, including tannia, pineapple, mango, breadfruit, coconut, and citrus, are equally harmed (Pollard et al., 2008). This may be due to the prevalence of fruits as the main crop in the study area. Similarly, ornamental plants such as hibiscus, gliricidia, variegated immortelle, croton, aloe, and ornamental palms are also affected if present in the kitchen garden (Pollard et al., 2008) , but our study was not solely limited to ornamentals.

GAS rely on the availability of moisture; hence, their activity is limited to the monsoon season (Raut & Barker, 2002), which aligns with our findings showing that rainy-season crops are predominantly affected. Additionally, Carvalho and Silveira Júnior (2021) in Brazil reported that during the rainy season, when precipitation rises by about 2276.9 mm, the majority of locals (approximately 82% of the interviewees) confirmed a significant increase in the prevalence of GAS, corroborating our observations. Higher rainfall corresponds to increased sexual activity among the snails. For example, in May and June 2007, with rainfall measuring 180 mm and 202 mm, respectively, 41% and 43% of the snails were sexually active. In contrast, only 5% and 9% of the snails were sexually active in January and February, the months with the least amount of rainfall (19 mm and 37 mm, respectively) (Silva & Omena, 2014). Although we did not record precipitation and moisture levels during the survey period, the highest response percentage regarding infestation of rainy-season vegetables was reported (78.3%). This could be attributed to increased sexual activity during the rainy season (Silva & Omena, 2014). The inactivity observed during the winter season may be due to the onset of dry weather, which triggers *A. fulica* to undergo aestivation (Kumar, 2020a; Raut & Barker, 2002).

GAS primarily harm vegetables and are seen as a serious issue in kitchen and backyard gardens (Budha & Naggs, 2008; Thiengo et al., 2007), which corroborates our results. We found the vegetative stage to be mostly vulnerable, similar to the report of Budha and Naggs (2008), but in contrast to the finding of Raut and Barker (2002), who reported seedling or nursery stage is most vulnerable irrespective of the crop. Like Raut and Barker (2002), we also have reported defoliation to be a mostly noticed symptoms of infestation. Raut and Ghosb (1983) reported leaf consumption as the most preferred feeding behavior in castor, drumstick, pothos, fig, bottle gourd, papaya, etc. which supports our finding where defoliation symptoms gained the highest (40%) response. In general, people adopted diversified practices of gathering and killing, using salt, throwing in water canals, throwing on the road for crushing, use of rice husks as a barrier around the crop, use of chemicals such as metaldehyde (Sajeev & Vijayan, 2014). Our findings reported the gathering and killing method to be the mostly adopted method of management followed by the use of salt which exactly matches with the previous results (Budha & Naggs, 2008; Kumar, 2020b; Raut & Barker, 2002; Thiengo et al., 2007; Shah, 1992).

5. CONCLUSION

The Banganga Municipality-01 of Kapilvastu, Nepal offers ideal conditions for the survival, growth, and reproduction of the GAS. GAS has been found to be very destructive in kitchen gardens, especially during the rainy season. However, most farmers have little knowledge regarding the consequences of their presence and management practices. Different management efforts have been adopted, with hand-picking being a major practice, followed by the use of salt and the application of chemical pesticides. If proper strategies and awareness regarding GAS management are developed by stakeholders, including local government, and concerned organizations, better control of GAS could be achieved. Additionally, healthy, and fresh crops could be harvested from the kitchen garden with minimal GAS trouble if managed rationally.

DECLARATION

The authors declare no conflict of interest.

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PLANT CHARACTERISTICS AND BULB YIELD OF ONION AS INFLUENCED BY FARM YARD MANURE AND POTASSIUM APPLICATION UNDER MAIZE-BASED CROPPING SYSTEM AT DAILEKH

Binod Prasad Luitel[1,*], Yubaraj Bhusal[1], Bishnu Bahadur Bhandari[2]

ABSTRACT

This study was conducted to investigate the effect of different levels of farm yard manure (FYM) (0, 10 and 20 t/ha) and potassium (K_2O) fertilization (0, 30, 60 and 90 kg/ha) on plant characteristics and bulb yield of onion cv. 'Red Creole' at Horticulture Research Station (HRS), Dailekh during two consecutive years (2019 and 2020). Experiments were laid out in factorial randomized complete block design with three replications. The combined analysis revealed that FYM significantly affected on plant height, number of leaves/plant, leaf length, bulb diameter, bulb weight and bulb yield. But the significant effect of K_2O was observed on plant height, number of leaves/plant, leaf length, bulb weight and bulb yield. The highest bulb yield (37.4 t/ha) was recorded at the treatment of 10 t/ha FYM, whereas K_2O fertilization at 90 kg/ha produced the highest (39.9 t/ha) bulb yield. The combined application of 10 t/ha FYM and 30 kg/ha K_2O produced the highest (41.7 t/ha) bulb yield and found the best treatment combination from the benefit cost ratio analysis. Therefore, the combination of 10 t/ha FYM with 30 kg/ha K_2O can be recommended to apply at the soils having medium organic matter and high K_2O content to get the highest bulb yield at maize-based cropping system of upland condition in Dailekh.

Keywords: Bulb yield, Combined analysis, Cropping system, Potassium, Upland

1. INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important vegetables worldwide and used as flavorings or as vegetables in stews, and salads. Onion is the best sources of flavonoids in the human diet, which is related to reduce the risk of cancer, heart disease and diabetes (Gereufael et al., 2020). In Nepal, it ranks at the third position among the production of vegetables after tomato and cabbage (Acharya & Shrestha, 2018). According to the statistics of MoALD (2020), onion is cultivated in 20, 424 ha land with a total production of 2, 84,926 t with productivity of 13.9 t/ha. The productivity is quite low compared to India (16.18 t/ha). Despite the different factors affecting onion production, unbalanced fertilizer application and inappropriate fertilizer rate are the major reasons for low onion productivity in Nepal.

Organic manures are commonly used as an important component of nutrient supply system and to improve crop yield (Shah et al., 2019). FYM improves soil physical and chemical properties that are important for plant growth. Moreover, organic fertilizers have positive effect on root growth by improving the root rhizosphere conditions and also plant growth is encouraged by increasing the population of microorganisms (Shaheen et al., 2007). Organic

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fertilizers are easily available and can be applied to reduce the amount of chemical fertilizers. Organic manure is not just to reduce the chemical fertilizers, its necessary to have a balanced use of chemical and organic fertilizers so that adverse effect of chemical fertilizers can be minimized. FYM with balanced amount of chemical fertilizer helps in improving the fertility, productivity and physical properties of the soil (Abusaleha & Shanmugavelu, 1988). K_2O is the third essential primary plant nutrient which is required for the plants in large amount. It is required for photosynthesis, fruit formation, osmotic regulations, disease resistance, promotion of enzymes activity, translocation of assimilates and maintaining agronomic productivity and sustainability (Mengel, 1985). Continuous use of potassic fertilizers alone through inorganic sources affects soil productivity and, thus results in lower yield with poor quality of produce (Mamatha, 2006). The role of K_2O in the activation of many enzymes, storage qualities, increased bulb sizes and bulb yield has reported (Pachuri et al., 2005).

Most researches in onion crop in Nepal so far are focused on variety evaluation (Gautam et al., 2019; Luitel et al., 2021) and seed production techniques (Tiwari, 2014; Bhusal & Luitel, 2023). But the effect of FYM and K_2O fertilizers on bulb production particularly in maize-based cropping system at upland condition of mid-hill has not been studied yet. The effect of K_2O on bulb yield has been studied by previous researchers in different countries (Rani & Jha, 2018; Andishmand & Norri, 2021). The application of inorganic fertilizers without the use of organic manure has resulted micronutrient deficiencies, imbalance soil physical and chemical properties and unsustainable crop production (Yohannes et al., 2017). This research was carried out to ascertain the effect of FYM and inorganic K_2O on plant characteristics and bulb yield of onion cv. 'Red Creole' at upland condition of Dailekh.

2. MATERIALS AND METHODS

2.1 STUDY AREA AND EXPERIMENTAL MATERIALS

The experiments were carried out in 2019 and 2020 from November to the end of May at Horticulture Research Station (HRS), Dailekh (28˚50'49.8" N longitude and 81˚43'19.4" E latitude, at an elevation of 1, 255 m above sea level). According to the agro-climatic classification of Nepal, the climatic zone of the study area is generally sub-tropical with an extended dry period ranging from October to May (seven to eight months). A maximum effective rainy season ranges from 120 to 140 days with average rainfall of 470 mm. The area has average temperature of 15°C with a mean maximum temperature of 26.5°C in May and minimum temperature of 6.8°C in January (HRS, 2020). The soil texture of the study site is clay loam with pH 5.6–6.0 (HRS, 2020). The maize was preceding crop in the experimental site and trial was conducted in upland condition. The cropping pattern was maize-vegetables. 'Red Creole', a popular variety having the characteristic of long storability and strong pungent was used as an experimental material. For the experiments, the seeds produced at HRS, Dailekh were used.

2.2 EXPERIMENTAL DESIGN AND PLANT CULTIVATION

Experiment was designed in factorial randomized complete block with three replications, consisting of 12 treatments with three replications. Three levels of FYM (0, 10, and 20 t/ha) and four levels of K_2O (0, 30, 60 and 90 kg/ha) were applied to the soil at different combinations. But recommended dose of nitrogen (N) and phosphorous (P_2O_5) i.e. 100 kg/ha and 80 kg/ha was consistently applied to all the treatments. The experimental plot was ploughed three times followed by levelling and marked out into blocks and plots. The spacing between the blocks and plots were 1.0 m and 0.5 m, respectively. Field experiments were laid out in factorial randomized complete block design with three replications. The inorganic fertilizers used were N in the form of Urea (46% N), P_2O_5 in the form of diammonium phosphate (DAP, 18% N, 46% P_2O_5), K_2O in form of muriate of potash (MoP, 60% K_2O). The well-rotted FYM was collected from the research station. The half amount of N, full doses of P_2O_5 and K_2O, and FYM were applied uniformly to all the plots before seedling transplanting. Remaining half amount of nitrogen was top-dressed equally at 40 and 60 days after transplanting. The plot size for each treatment was maintained at 2 m^2 with plant spacing of 20 cm × 20 cm and five rows were maintained at each plot. Ten seedlings (40 days-old) were were transplanted on December 15 in 2019 and 2020, and each treatment consisted of 50 seedlings. Soil samples were taken at 0-15 cm depth block wise before treatment application and analyzed for pH, organic matter (OM), N, P_2O_5 and K_2O at Regional Soil Testing Laboratory, Department of Agriculture, Khajura, Banke. Intercultural practices including irrigation, weeding and top-dressing were done as recommended by Chalise and Pun (2015).

2.3 DATA COLLECTION

Data on plant height, number of leaves/plant, leaf length, bulb diameter and individual bulb weight were collected from five randomly selected plants excluding the border plants. Plant height (cm) was measured using a meter scale from the ground level to the tip of the terminal leaves of five randomly selected plants at the maturity time and averaged. Number of leaves/plant was counted from five randomly selected plants at maturity and averaged. Leaf length (cm) was measured at physiological maturity stage from the sheath to tip of the leaf of five plants using a meter ruler and averaged it. Bulb diameter (mm) was measure at the widest portion of matured bulbs at harvest using digital Vernier caliper (150mm, Model: DC-515) and averaged. Individual bulb weight (g) was weighted on randomly selected five bulbs using digital balance (H-Honda™, India) and averaged it. Total bulb fresh weight (kg) was measured at all harvested bulbs in each plot that were measured in kg/plot and finally converted into bulb yield (t/ha).

2.4 STATISTICAL ANALYSIS

Data were subjected to analysis of variance (two-way ANOVA) using GenStat Release 10.3 DE Software (VSN International Ltd., UK) Discovery Edition. Pearson's correlation was estimated to see the association between different characters using SPSS 20.0 statistical analysis package (SPSS Inc., Chicago, IL, United States). Besides, cost of FYM, urea, DAP and MoP were taken from the market, and information on market price of onion bulbs was collected to calculate the benefit-cost ratio.

3. RESULTS AND DISCUSSION

3.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

The physical and chemical analysis of experimental soil was analyzed after harvesting the maize crop. The results of soil analysis showed the acidic pH (5.6), medium OM (2.5%), medium total N (0.13%), high available P_2O_5 (88.8 kg/ha) and available high K_2O (315.0 kg/ha). The textural class of soil found to be clay loam. The total N of experimental soil was 0.13% which is considered as medium according to Tekalign et al. (1991). According to the rating of Bruce and Rayment (1982), pH is classified as acidic, neutral and alkaline. The optimum pH for onion production ranges from 6 to 8 (Nikus and Mulugeta, 2010). Olsen et al. (1954) stated that the availability of phosphorous >25.0, 18.0–25.0. 10.0–17.0, 5.0–9.0 and < 5.0 mg/kg are classified as very high, high, medium, low and very low, respectively. According to Maria and Yost (2006), organic carbon content of <1.5, 1.5–2.5 and >2.5% were grouped as low, medium and high, respectively. The available potassium <110.0 kg/ha, 110.0–280.0 kg/ha and >280.0 kg/ha is considered as low, medium and high, respectively.

3.2 EFFECT OF FYM AND K_2O ON PHENOLOGICAL CHARACTERS

Plant height

Plant height of onion was significantly ($P<0.05$) influenced as the main effect of FYM and K_2O fertilization (Table 1). The results showed that plants grown at 20 t/ha FYM produced the highest (62.8 cm) plant height, but the plants grown at 0 t/ha FYM and 10 t/ha FYM did not show statistically different plant heights. Plant height measured at 60 kg K_2O/ha produced higher (62.9 cm) than the rest of the treatments, although it was statistically similar with those treated with 30 t/ha and 60 K_2O kg/ha. Aftab et al. (2017) have stated the maximum plant height (48.16 cm) of onion at 120 kg K_2O/ha and minimum (33.9 cm) at control treatment. The interaction effect between FYM and K_2O on plant height was significant ($P<0.05$). But in a study by Andishmand and Norri (2021), they have reported the maximum plant height (50.5 cm) at the combination of 20 t/ha FYM + 150 kg/ha N+100 kg/ha P_2O_5+100 kg K_2O.

Leaf number

Main effect of FYM on number of leaves/plant was significant ($P<0.05$). However, the number of leaves/plant at FYM treatments were not statistically different. But effect of K_2O fertilization had highly significant ($P<0.01$) effect on number of leaves/plant. The highest (10.5/plant) leaf number was recorded at the plot treated with 60 kg/ha and rests of the treatment showed statistically similar number of leaves/plant (Table 1). But in a study by Aftab et al. (2017), they reported the highest number of leaves (7.5/plant) at 120 kg K_2O/ha. But interaction effect of FYM and K_2O on number of leaves/plant was non-significant ($P<0.05$). The highest number of leaves/plant (15.4) were recorded at the treatment of 150 kg N/ha and 45 t FYM/ha and the lowest was in control (Kokobe et al., 2013). But in our study, the levels of FYM did not show statistically different in number of leaves/plant. The increase number of leaves/plant in response to the increased application of K_2O fertilization might be due to role of K_2O in plant metabolic process including synthesis, transport and storage of photoassimilates that plays shoot growth in plants (Hawkesford, 2012).

Leaf length

Main effects and their interaction had significantly ($P<0.05$) affected the length of leaves (Table 2). The highest (51.7 cm) leaf length was measured at 20 t/ha FYM, but it showed statistically similar with the treatment of 10 t/ha FYM. Kokobe et al. (2013) indicated that the leaf length was increased by 28% with the application of FYM compared with the control. Our study showed that the application of 10 t and 20 t FYM/ha gave 4.15 % and 6.18% higher leaf length than that of control. Bagali et al. (2012) reported that the availability of higher quantities of nutrients, improvement of physical properties of soil and increased activity of microbes with higher levels of organic matters helps in increasing vegetative growth. In this study, FYM also improved the physical properties of the soil which might be increased the uptake of nutrients and that might be helped in increasing leaf growth of onions. Likewise, the leaf length measured at 30, 60 and 90 kg K_2O/ha treatments was not significantly different, but the lowest (47.9 cm) leaf length was measured at control treatment. FYM and K_2O interaction on leaf length was significantly ($P<0.05$) different (Table 1).

Table 1. Effect of FYM and K_2O on plant height, number of leaves/plant and leaf length of onion at HRS, Dailekh, 2019 and 2020

Treatments	Plant ht. (cm)		Mean	Leaf (no./plant)		Mean	Leaf length (cm)		Mean
	2019	2020		2019	2020		2019	2020	
FYM, t/ha									
0	54.5	67.3	60.8	10.0	9.0	9.5	46.8	50.1	48.5
10	55.7	65.3	60.8	11.0	9.0	10.0	48.7	52.5	50.6
20	59.5	66.2	62.8	11.0	9.0	10.0	49.8	53.6	51.7
F-Test			*			*			*
LSD (0.05)			1.98			0.53			2.25
K_2O, kg/ha									
0	53.4	65.7	59.6	10.0	9.0	9.5	46.4	49.5	47.9
30	57.1	65.2	61.1	11.0	9.0	10.0	49.4	52.9	51.2
60	57.5	66.6	62.1	11.0	10.0	10.5	48.4	52.1	50.2
90	58.3	67.5	62.9	12.0	9.0	10.5	49.5	53.8	51.6
Mean	56.57	66.24	61.41	10.88	9.24	10.20	48.43	52.07	50.25
F-Test			*			**			*
LSD (0.05)			2.28			0.61			2.60
FYM × K_2O			*			NS			*
LSD (0.05)			3.96			1.05			4.50
CV (%)			5.6			9.1			7.7

Note: NS: Non-significant at $p<0.05$, *significant at $p<0.05$, **highly significant at $p<0.01$.

The interaction effect of FYM and K_2O on plant height and leaf length is given in Table 2. The highest plant height (63.7 cm) was measured at 10 t FYM/ha along with 90 kg K_2O/ha, but the value was not statistically different from rest of the treatments except 10 t FYM/ha and 0 kg K_2O/ha and control. Similarly, the combined application of 20 t FYM/ha along with 90 kg K_2O resulted the highest leaf length (52.8 cm), but the value was not statistically different from the rest of the treatments except control. The lowest leaf length (41.8 cm) was measured at control.

Table 2. Interaction effect of FYM and K_2O on plant height and leaf length of onion at HRS, Dailekh

FYM, t/ha	Plant height (cm)				Leaf length (cm)			
	K_2O, kg/ha				K_2O, kg/ha			
	0	30	60	90	0	30	60	90
0	53.3	62.0	60.7	62.4	41.8	50.8	50.9	50.3
10	57.4	60.1	60.7	63.7	48.7	51.6	50.1	51.9
20	63.4	60.7	64.7	62.6	53.3	51.1	49.7	52.8
LSD (0.05)				3.97				4.50
CV (%)				5.6				7.7

4. EFFECT OF FYM AND K_2O ON BULB CHARACTERISTICS AND YIELD

4.1 BULB DIAMETER

FYM had highly significant ($P<0.01$) effect on bulb diameter and treatment treated with 20 t FYM/ha produced the highest (77.7 mm) bulb diameter. However, it was statistically similar with treatment treated with 10 t/ha FYM. Main effect of K_2O and their interaction effect on bulb diameter was non-significant ($P>0.05$) (Table 3). In contrast, Aftab et al. (2017) have reported the significant differences in bulb diameter in various K_2O fertilization.

4.2 AVERAGE BULB WEIGHT

Individual bulb weight had highly significantly ($P<0.01$) affected by FYM treatments (Table 3). The individual bulb weight was highest (181.1 g) at 20 t/ha FYM treated plot, whereas the lowest (155.0 g) bulb weight was obtained from nil application of FYM. Abbey and Kanton (2004) have reported that number of leaves/plant and leaf length increase in response to FYM application which results in an increase in assimilate production and allocation to the bulb. In this study, the increase in leaf length might also be contributed to enhance the onion bulb weight. Application of K_2O fertilization did not produce significantly different bulb weight. However, FYM and K_2O interaction on individual bulb weight was non-significant ($P<0.05$) (Table 3).

4.3 BULB WEIGHT

Main effect of FYM and K_2O on bulb weight was highly significant (Table 3). The highest bulb weight (7.5 kg/plot) was recorded at 10 t/ha FYM, but it showed statistically similar with treatment treated with 20 t/ha FYM (7.4 t/ha). Likewise, bulb weight produced the highest (7.9 kg/plot) at the treatment treated with 90 kg/ha K_2O but it was statistically similar with the treatment treated with 60 kg/ha K_2O (7.4 kg/plot). The lowest (6.1 kg/plot) was produced at control plot. Interaction effect between FYM and K_2O was significant ($P<0.05$) on bulb weight (Table 3).

4.4 BULB YIELD

Bulb yield of onion was significantly ($p<0.01$) affected by FYM and K_2O fertilization (Table 3). Bulb yield was the highest (37.4 t/ha) at the treatment of 10 t/ha FYM which is statistically similar with bulb yield obtained at treatment of 20 t/ha FYM. However, the lowest bulb yield (31.6 t/ha) was obtained from nil application of FYM. Jawadagi et al. (2014) have reported the highest bulb yield at FYM applied plots. The addition of FYM into the soil facilitates to breakdown the complex nitrogenous compounds and makes steady N supply throughout the growth period of the crop. This process might be attributed to more availability and uptake of nutrients by the crop and increases the crop yield. Bagali et al. (2012) have reported the similar results of organic manures application in onion. Further, increased bulb yield in onion using the combined application of organic manure and chemical fertilizer has reported by Rawal (2014). Gereufael et al. (2020) reported the highest bulb yield (35.9 t/ha) in the combined application of 103.5 kg/ha N + 30 t/ha FYM/ha. Onion fertilized with 90 kg/ha K_2O produced the highest (39.9 t/ha) and the lowest bulb yield (30.3 t/ha) was produced at nil K_2O treated plants.

Table 3. Effect of FYM and K_2O on bulb traits, bulb weight and bulb yield of onion at HRS, Dailekh, 2019 and 2020

Treatments	Bulb diam. (mm)		Mean	Ind. Bulb wt. (g)		Mean	Bulb wt. (kg/plot)		Mean	Total bulb yield (t/ha)		Mean
	2019	2020		2019	2020		2019	2020		2019	2020	
FYM, t/ha												
0	76.5	69.1	72.8	133.6	176.5	155.0	6.4	6.3	6.3	31.7	31.4	31.6
10	76.7	73.6	75.2	154.3	176.4	165.3	7.5	7.5	7.5	37.3	37.4	37.4
20	77.6	77.7	77.7	178.2	184.0	181.1	6.5	8.3	7.4	32.7	41.4	37.1
F-Test			**			**			**			**
LSD (0.05)			2.36			13.71			0.56			2.80
K_2O, kg/ha												
0	76.4	72.6	74.5	148.5	168.2	158.3	5.7	6.5	6.1	28.5	32.2	30.3
30	76.2	77.0	76.6	168.0	174.2	170.6	6.9	7.2	7.1	34.8	36.2	35.5
60	79.0	73.2	76.1	154.1	191.8	172.9	6.7	7.6	7.4	33.7	37.8	35.7
90	76.2	71.0	73.6	151.9	181.8	166.8	7.8	8.2	7.9	38.7	41.0	39.9
Mean	76.93	73.45	75.19	155.4	179.0	167.2	6.78	7.36	7.07	33.93	36.80	35.36
F-Test			NS			NS			**			**
LSD (0.05)			2.73			15.83			0.64			3.23
FYM×K2O			NS			NS			*			*
LSD (0.05)			4.73			27.42			1.12			5.68
CV (%)			5.4			14.1			11.0			13.6

Note: NS: Non-significant at $p<0.05$, *significant at $p<0.05$, **highly significant at $p<0.01$.

The interaction effect of FYM and K_2O on bulb weight and yield was significant ($P<0.05$) (Table 4). The maximum (8.5 kg/plot) bulb weight was recorded at 10 t FYM in combination with 90 kg K_2O, but it was statistically similar with 0 t FYM + 90 kg K_2O/ha, 10 t FYM + 30 kg K_2O/ha, 20 t FYM + 60 kg K_2O and 20 t FYM + 90 kg K_2O/ha. With regard to bulb yield, the combination of 10 t/ha FYM at each 30 kg and 90 kg K_2O/ha produced 41.7 t/ha and 42.2 t/ha, respectively. Furthermore, plots treated with 20 t/ha FYM in combination with 90 kg/ha K_2O yielded 39.9 t/ha. Yohannes et al. (2013) mentioned that the combined application of 150 kg/ha N and 45 t/ha FYM produced the highest bulb yield (36.85 t/ha). But in this study, we found that FYM at 10 t/ha in combination with 30 kg K_2O also resulted similar yield to that of 10 t FYM/ha + 90 kg K_2O/ha and 20 t FYM + 90 kg K_2O/ha applied.

Table 4. Interaction effect of FYM and K_2O on bulb weight and bulb yield of onion at HRS, Dailekh

FYM, t/ha	Bulb weight (kg/plot)				Bulb yield (t/ha)			
	K_2O, kg/ha				K_2O, kg/ha			
	0	30	60	90	0	30	60	90
0	4.9	6.2	6.7	7.5	24.7	30.9	33.3	37.5
10	6.2	8.3	6.9	8.5	30.8	41.7	34.9	42.2
20	7.1	6.8	7.8	8.0	35.6	33.9	38.9	39.9
LSD (0.05)				1.12				5.60
CV (%)				11.1				13.6

4.5 CORRELATION AMONG THE MEASURED TRAITS

The Pearson's correlation coefficients of plant and bulb traits in onion are presented in Table 5. Plant height was positively and significantly correlated with leaf length (r = 0.65**), bulb diameter (r = 0.33**), individual bulb weight (r = 0.41**), bulb weight (r = 0.31**) and bulb yield (r = 0.32**). Number of leaves/plant showed significant and positive association with individual bulb weight (r = 0.40**), bulb weight (r = 0.47**) and bulb yield (r = 0.46**). Bulb diameter was positively and significantly correlated with individual bulb weight (r = 0.89**), bulb weight (r = 0.49**) and bulb yield (r = 0.52**). A strong positive and highly significant correlation was found between bulb weight and bulb yield (Table 4). The significant and positive correlation between average bulb weight and bulb yield was reported by Gereufael et al. (2020).

Table 5. Pearson's correlation coefficients of plant and bulb traits in onion at HRS, Dailekh, 2019-2020

Variables	PHT	LN	LL	BD	IBWT	BWT	BY
PHT	1.0	−0.19	0.65**	0.33**	0.41**	0.31**	0.32**
LN		1.0	−0.12	−0.14	0.40**	0.47**	0.46**
LL			1.0	0.26*	0.31*	0.32*	0.31*
BD				1.0	0.89**	0.49*	0.52**
IBWT					1.0	0.38*	0.42**
BWT						1.0	0.98**
BY							1.0

Note: *significant at $p<0.05$; **highly significant at $p<0.01$. PHT: Plant height (cm), LN: Leaf (no./plant), LL: Leaf length (cm), BD: Bulb diameter (mm), IBWT: Individual bulb weight (g), BWT: Bulb weight, BY: Bulb yield (t/ha).

4.6 ECONOMIC ANALYSIS

The economic analysis on use of FYM in onion production is given in Table 6. Marginal rate of return was 22.2 which is high, was obtained from the plots with 10 t/ha FYM applied.

Table 6. Economics of FYM use in onion at HRS, Dailekh, 2019-2020

FYM (t/ ha)	Value of added nutrient cost (Rs.)	Bulb yield (t/ha)	Yield increment (t/ha)	Value added onion cost (Rs.)	Marginal rate of return (MRR)
0	0	31.6	0	0	0
10	10,000	37.4	5.8	2,32,000.0	22.2
20	20,000	37.1	5.5	2,20,000.0	10.0

The economics of different levels of K_2O fertilization onion is estimated and presented in Table 7. The marginal rate of return was higher (74.6) in 30 kg K_2O/ha than rests of the treatments.

Table 7. Economics of K_2O use in onion at HRS, Dailekh, 2019-2020

K_2O (t/ha)	Value of added nutrient cost (Rs.)	Bulb yield (t/ha)	Yield increment (t/ha)	Value added onion cost (Rs.)	Marginal rate of return (MRR)
0	0	30.3	0	0	0
30	2,750	35.5	5.2	2,08.000	74.6
60	5,500	35.7	5.4	2,16,000	38.3
90	11,000	39.9	9.6	3,84,000	33.9

Benefit cost analysis of different levels of FYM and K_2O in onion is given in Table 8. In this study, benefit cost ratio showed the highest (53.0) at the treatment combination of 0 t/ha FYM + 100 kg N/ha + 80 kg P_2O_5/ha + 30 kg K_2O/ha and the lowest (30.2) was in 20 t/ha FYM + 100 kg N/ha + 80 kg P_2O_5/ha + 90 kg K_2O.

Table 8. Effect of different FYM and K_2O combination on its economic benefit and production cost/ha (all other factors remain constant) at HRS, Dailekh, 2019-2020

FYM:N:P_2O_5:K_2O, kg/ ha	Bulb yield (t/ha)	Fertilizer cost (Rs.)	Total income, (Rs.)	Net benefit, (Rs.)	Benefit cost ratio
0+100+80+0	24.7	20,130	9,88,000	9,67,870	48.1
0+100+80+30	30.9	22,880	12,36,000	12,13,120	53.0
0+100+80+60	33.3	25,630	13,32,000	13,06,370	50.9
0+100+80+90	37.5	31,130	15,00,000	14,68,870	47.1
10+100+80+0	30.8	30,130	12,32,000	12,01,870	39.8
10+100+80+30	41.7	32,880	16,68,000	16,35,120	49.7
10+100+80+60	34.9	35,630	13,96,000	13,60,370	38.2
10+100+80+90	42.2	41,130	16,88,000	16,46,870	40.0
20+100+80+0	35.6	40,130	14,24,000	13,83,870	34.5
20+100+80+30	33.9	42,880	13,56,000	13,13,120	30.6
20+100+80+60	38.9	45,630	15,56,000	15,10,370	33.1
20+100+80+90	39.9	51,130	15,96,000	15,44,870	30.2

5. CONCLUSION

We studied the effect of FYM and K_2O fertilization on plant characteristics and bulb yield of onion in two years (2019 and 2020) at Dailekh. The main effects of FYM and K_2O on plant height, number of leaves/plant, leaf length, bulb weight and bulb yield were found significantly different. The combination of 10 t/ha FYM with each 30 kg and 90 kg K_2O produced 41.7 t/ha and 42.2 t/ha, respectively. But marginal rate of return was higher in 10 t/ha FYM and 30 kg/ha K_2O used. The bulb yield at 10 t/ha FYM along with 30 kg/ha K_2O had significantly higher than nil FYM and 30 kg/ha K_2O applied. Considering the cropping pattern, existing soil properties, available resources and yield, present study is recommended 10 t/ha FYM along with 30 kg/ha K_2O for sustainable onion production. This recommended fertilizer would be appropriate for onion cultivation having similar soil properties of maize-based cropping system under upland condition of Dailekh. Since the experimental plot consisted of high K_2O status, further study is needed to narrow down ranges of K_2O (less than 30 kg K_2O/ha) in order to determine its effect on growth and bulb traits. In addition, the effects of FYM and K_2O fertilization on bulb yield, nutrient uptake, soil physical and chemical properties, bulb quality and storability need to be further investigated at maize-based cropping system in mid-hills of Nepal for for corroborating these results.

DECLARATION

The authors declare no conflict of interest.

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HYDROGEN CYANAMIDE: A CHEMICAL TO PREPONE NATURAL BUDBURST TIMING OF GRAPEVINE CULTIVARS IN NEPALESE CONTEXT

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ABSTRACT

Grapes primarily belongs to mediterranean climate but overtime due to successful vine management practices, its cultivation has been extended to sub-tropics and tropics. In Nepal, grape cultivation has been started about 8 decades ago, and the demands of this crop has been increasing every year. However, the critical challenge of heavy rainfall coinciding with the berry harvest period has limited the production window, necessitating innovative solutions. This study explores the potential of grape cultivation in Nepal by assessing significance of hydrogen cyanamide (HC) application to ensure early and uniform budburst and therefore fruit maturity before monsoon. Winter pruning and HC application at 2-5% concentration has been found effective in preponing budburst and maturity in some grapes varieties 'Steuben' and 'Cabernet Sauvignon' in Nepal, but the results depend on date and dose of HC application in particular variety and specific growing condition. Application of HC at 2% concentration has resulted in earlier budburst by about 3 weeks in var. Cabernet Sauvignon in Dhading, Nepal. Also, the earlier treatment of HC and pruning in comparison to normal time of pruning (December 15 to January 15) has resulted in earlier and higher budburst and observed fruitfulness in varieties like 'Steuben' and 'Cabernet Sauvignon' in warm temperate belt of Nepal. Thus, the study concludes the prepone of natural budburst is a must need practice for successful viticulture in terai and mid-hills of Nepal. It also emphasizes the need of more research to optimize the application of HC and ensure its efficacy in advancing budburst and maturity specific to variety and locality. Overall, the findings aim to inspire growers, enhance commercial viability, and contribute valuable insights to the viticulture sector in Nepal.

Key words: Budburst, Dormancy, Grapevine, Hydrogen cyanamide, Pre-pone

1. INTRODUCTION

Grape (*Vitis* spp.) cultivation in Nepal is believed to have been started within the Rana regime (>75 years ago). The estimated area under grape cultivation is about 40 ha in 2022 (Acharya, Acharya, Kushwaha, & Dahal, 2023) with estimated total fresh production of about 76 tonnes per annum in Nepal (Atreya, Lamichhane, & Kafle, 2015). Small vineyards on government research stations/farms were established in temperate and warm temperate climates from 1968 AD. However, viticulture has not been much prioritized and commercial grape cultivation is only limited to few farms like Kewalpur Agro Farm Vineyard, Dhading.

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Grapes were primarily grown in mediterranean type of climate (hot and dry summer followed by cool winter) (Arroyo-García et al., 2006). Over time, grape cultivation has been extended over subtropical to tropical climatic regions including China, India, Brazil, Turkey etc (Jones, White, Cooper, & Storchmann, 2005). In mediterranean climates, budburst starts in spring and is followed by a period of 5-6 months to crop harvesting (Mullins, Bouquet, & Williams, 1992), whereas in warmer climates the period to crop harvesting is shorten about three months after budburst (Dahal, Bhattarai, Midmore, Oag, & Walsh, 2017). In the regions with a summer followed by monsoon and a short-mild winter, a single pruning with forcing of budburst and a single harvest is the accepted practice (Lavee, 2000).

In Nepal, monsoon coinciding harvest and associated diseases have been considered the major limitations for successful grape cultivation. Grape technology development projects planted grapevines in eastern terai and then to western terai during 1980's and 1990's but were heavily infected by diseases (Joshi, 1986; Shrestha, 1998). The monsoon coincided with harvesting time reduces the quality of berry and invites the high humidity associated diseases. Thus, the bottleneck for successful viticulture in Nepal is the harvesting time coincides with monsoon period (Atreya et al., 2015). In 2017, Warm Temperate Horticulture Centre, Kirtipur failed to harvest 40% of total bunch harvest due to early rains during in the monsoon. Innovative techniques to shift harvesting time earlier than monsoon has been a common practice but has not yet adopted in Nepalese viticulture (Dahal et al., 2017).

Shifting of natural budburst time 20-30 days earlier than the natural budburst time hastened the crop maturity by at least 20 days that skip the overlapping period of berry maturity with calendar monsoon in the central part of Nepal. The key regulators of bud dormancy are temperature, especially accumulated chilling time, and photoperiod (Carmona, Chaïb, Martínez-Zapater, & Thomas, 2008; Fennell & Hoover, 1991). Due to suboptimal chilling temperature and a brief winter in subtropical climates, the application of a dormancy breaking chemical i.e. Hydrogen cyanamide (H_2CN_2 syn. HC) followed by pruning in winter is vital to induce uniform budburst (Lavee & May, 1997; Lombard, Cook, & Bellstedt, 2006). Applications of HC in the range of 2 to 5% v/v to buds in table grape varieties and even in wine grapes negate the effect of endo-dormancy by producing transient respiratory disturbances and oxidative stress (Pérez, Vergara, & Rubio, 2008). Breaking of winter dormancy in buds varies with concentration, time of application, bud physiological stage and genotype (Sánchez et al., 1994). So far, HC has no commercial use in Nepal but has been used for research at 2-5% v/v in varieties like 'Steuben' and 'Cabernet Sauvignon' in past few years. Thus, this study aims to understand the current scenario of grape cultivation in Nepal and facts and speculations about application of HC in preponing budburst in grapevines for better and uniform yield. Furthermore, it will be helpful for other researches in grapevines, aiming to inspire growers and enhance the commercial viability of Nepalese vineyards.

2. METHODOLOGY

This review article relies on literatures drawn from various sources, including books, journals, conferences, proceedings, reports, theses and webpages related to viticulture. Since the researches on grapevine are limited in Nepalese context, publications are also rare. In recent years, couple of researchers are working to address the problems of grapevines in Nepalese context in particular to develop the technologies for early harvesting. Hence, key informants and the perspectives, insights from growers, experiences and information from various stakeholders have also been included into the content.

3. RESULTS AND DISCUSSION

3.1 STATUS OF GRAPEVINES IN NEPAL

In Nepal, vineyards are maintained by government farms like Directorate of Agricultural Research and the Nepal Agricultural Research Council, and some private sectors such as Kewalpur Agro Farm, The Fruits Land Nepal and so on. The estimated area under grape cultivation in these farms is about 772 Ropani (around 40 ha) with around 10,437 number of grapevines (Acharya et al., 2023).

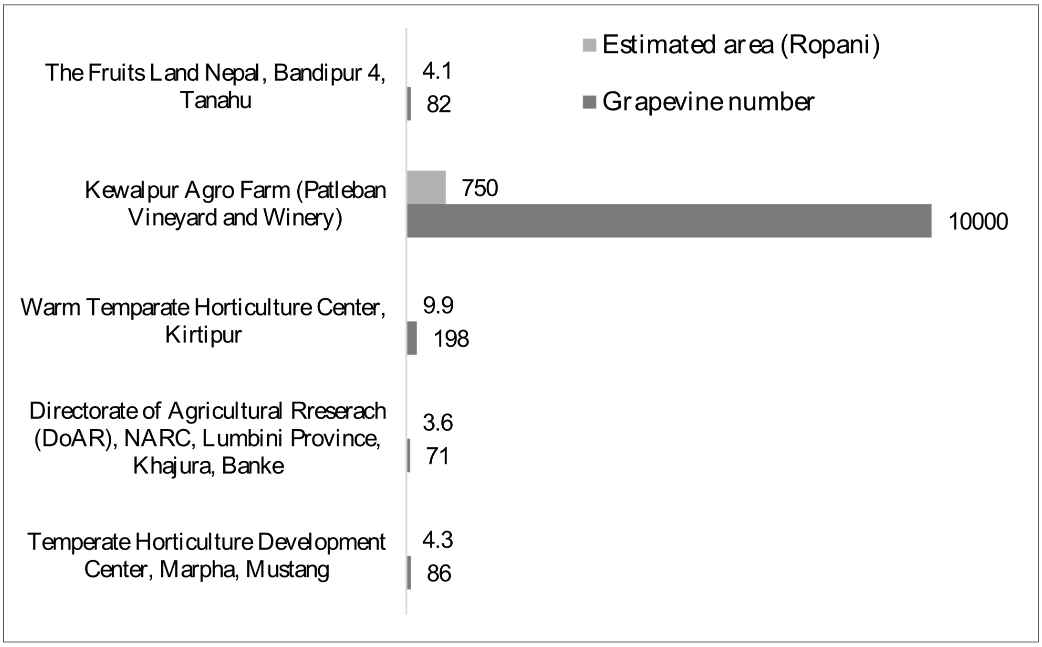

Figure 1. Status of grapevine cultivation in Nepal (Acharya et al., 2023)

3.2 GRAPE DEMAND AND SUPPLY IN NEPAL

Worldwide, grape consumption is increasing, as part of a trend towards 'convenience' fruit (small fruit that can be consumed without preparation) (Dahal et al., 2017). Grapes both table and wine enjoy modest popularity among consumers in Nepal. As people being aware of nutritional importance of fruits and some western influence on drinks, the demand of fruit including grape is increasing in Nepal. But there is always a gap between demand and supply and Nepal is trying to fulfill the gap through importing maximum of its fruit consumption which is not sustainable in long run. There was almost 8 times more import of grapes from 2014 to 2022 (Figure 2). With increasing population pressure, it is anticipated that Nepal will have increasing demand for grapes. Thus, with favorable climate and opportunities in agriculture, Nepal needs to figure out way for sustainability and giving some priorities in emerging fruit production sector as well.

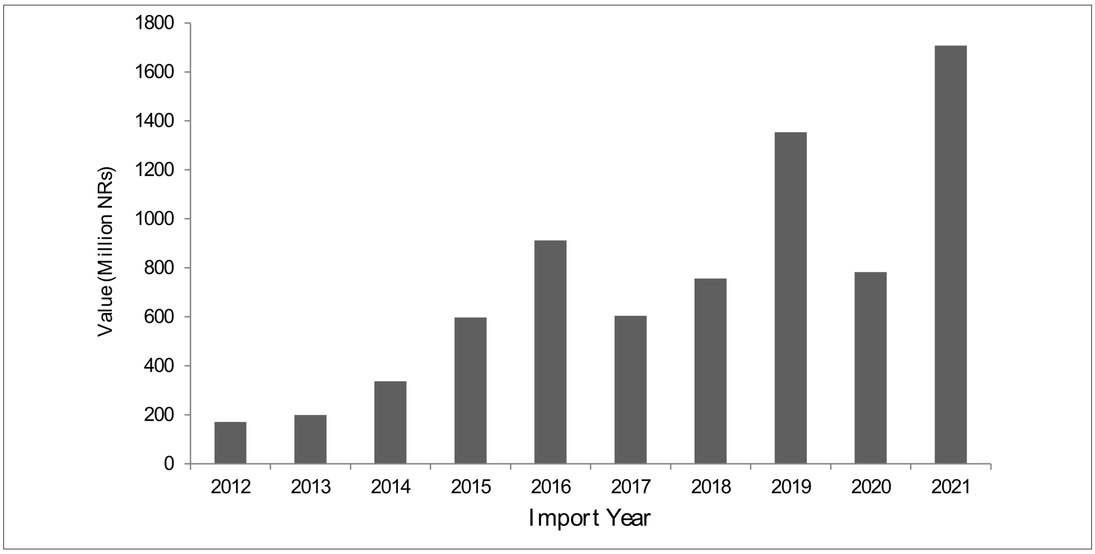

Figure 2. Import trend of fresh grape in Nepal during 2012-2021

Source: GoN (2023)

3.3 STATUS OF GRAPEVINES RESEARCH IN NEPAL

In late 1980s, several projects regarding, varietal evaluation and technology development in grapes were initiated in Nepal, particularly in Eastern Terai parts (Gotame, Gautam, Shrestha, Shrestha, & Joshi, 2020; Shrestha, 1998) but later in mid 1990s, the grape research priorities were shifted to dry subtropical western parts of Nepal (Regional Agriculture Research Station (RARS), Banke). At RARS Banke, the growth behaviors of several grape cultivars were evaluated for four successive years (Joshi, 1986). Varietal evaluation trails were performed in Warm Temperate Horticulture Centre (WTHC), Kirtipur as well, where Japanese varieties like, 'Steuben', 'Muscut Bailey A', 'Kyoho' and 'Black Olympia' were compared with other cultivars like, 'Himrod', 'Delawar', 'Olympia' and 'Tono Red' (Gotame et al., 2020). Similarly, in mid 1990s, three years varietal evaluation trial was conducted in RARS, Banke where several Indian cultivars were evaluated, out of which, Perlette and Beauty Seedless were recommended for earliness, parthenocarpic nature and good yielding characteristics (Gotame et al., 2020; KC, 1999). Miyoshi et.al. (1997) applied to GA_3 at full bloom stage on var. Himrod that had very small berry size in Kirtipur, Kathmandu reported increased berry size by 20% and 10% with 50 ppm and 100 ppm of GA_3 respectively. During 2019-2021, research were carried out to develop the innovative grape production techniques by using plant growth regulators i.e. gibberellic acid, hydrogen cyanamide and timing of pruning in different grapevine cultivars (var. Himrod and var. Steuben as table grapes and var. Cabernet Sauvignon as wine grape) in Warm Temperate Horticulture Research Centre (WTHC), Kirtipur (27°30' N latitude to 85°15' E longitude and at an altitude of 1,320 meters above sea level) and Kewalpur Agro Farm Vineyard, Dhading, Nepal (27°6` Latitude 85°6` longitude and at an altitude of 855 meters above sea level). In WTHC, Kirtipur, the HC was applied to var. Steuben and it was found that pruning followed by 2% HC application after a week was found effective leading to early and uniform budburst (Dhakal, 2021). Earlier bud burst was observed in earlier pruning followed by HC application (before December 9) and late in later application (after December 9) in var. Steuben (Dhakal, 2021).

According to Ghimire (2022) and Sapkota (2022), applying 2% HC following pruning preponed natural budburst timing and had considerable effect on growth stages, quality of budburst and quantity of budburst percentage of vine in cv. Cabernet Sauvignon in Dhading, Nepal (Ghimire, 2022; Sapkota, 2022). They suggested the optimal range of HC concentration is between 2 to 5% and the treatment preponed the budburst by 3 weeks in cv. Cabernet Sauvignon in Dhading, Nepal, also advised that the HC concentration beyond 5% led to detrimental effect in budburst, flowering and yield. Gibberellic acid application at concentration between 30 to 40 ppm when berries are around 4 mm size has been found more effective in improving quantitative measurements of grape berries and bunches especially in var. Himrod in WTHC, Kirtipur, Kathmandu, Nepal (Poudel, Atreya, & Dahal, 2022). A research was conducted on assessing the dormant bud fruitfulness by bud dissection method in var. Himrod and var. Steuben in Warm Temperate Horticulture Centre, Kirtipur which suggest bud dissection as an effective tool to analyze bud fruitfulness and predict the yield for following season (Poudel, Dhakal, Atreya, Sapkota, & Dahal, 2023). Currently, there is similar on-going research in grape bud fruitfulness and effects of different doses upto 40 ppm and time of GA application after fruit set in table grape cultivars in Kewalpur Agro Farm (Patleban Vineyard and Winery), Dhading.

3.4 GRAPEVINE IN WARMER CLIMATE

Expansion of grape production towards warmer climates is increasing since late 1990's through innovative vine management and the use of growth regulators e.g. hydrogen cyanamide (HC). The timing of key management operations (e.g. pruning, use of PGRs) are usually determined by temperature and rainfall patterns of different regions. In wet regions, a single harvest with single/double pruning is the general practice because the second harvest is not practical due to effect of rainy season on vine growth (Leao, 2014). Combinations of pruning, use of plant growth regulators (bud breaker and growth retardant) and harvesting practices alter the vine growth and dormancy in buds, hence the grape production becomes possible in wider climates around the world (Midmore, 2015). Exploration of production technologies with respect to our growing environment, topography and monsoon calendar is utmost important for the successful viticulture.

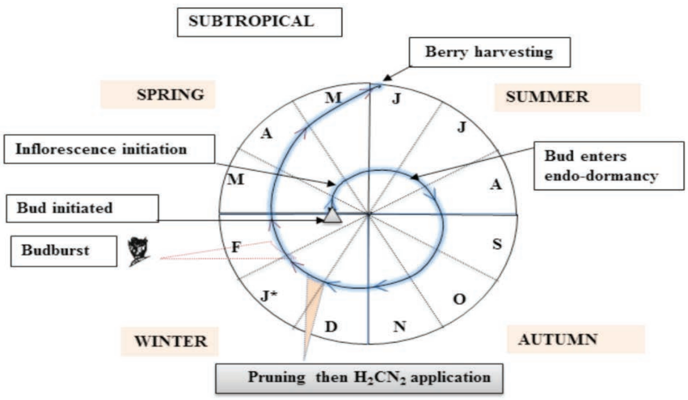

Figure 3. Reproductive cycle of the grapevine in accordance to grapevine growth stages in subtropical condition (J*- January) (Adopted from Dahal et al., 2017)

Pruning during winter season, when the vines are in dormant, is an important cultural operation to regulate vine yield. Pruning is a relatively simple method that can be used to directly limit the crop load and to select potentially fruitful buds. Response of grapevines to the timing of winter pruning and application of HC can be exploited to manipulate time of budburst and, in turn, the subsequent phenological events (Martin & Dunn, 2000). Thus, intensity as well as timing of pruning(s) and use of HC are two important practices around the world for successful vineyards in the area where the chilling temperature is suboptimal (Lavee, 2000). The main challenge in Nepalese viticulture is harvesting coinciding with the monsoon, causing significant losses. Efforts to shift harvesting earlier have been limited. A proposed solution involves advancing budburst by 20-30 days using hydrogen cyanamide after winter pruning, addressing issues related to temperature and photoperiod regulation of bud dormancy in subtropical climates as indicated in Figure 4.

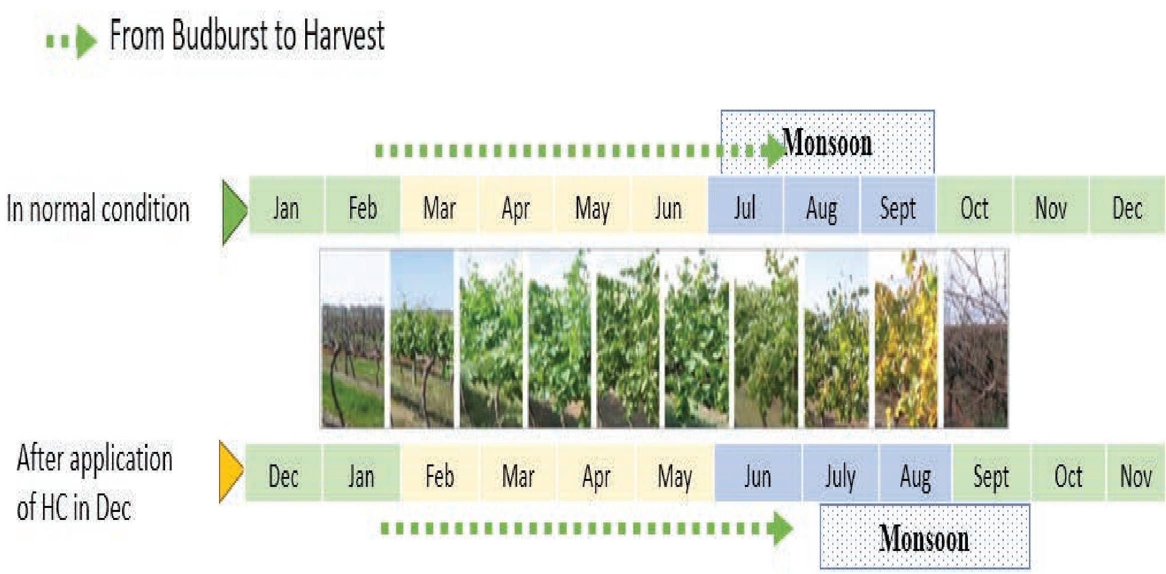

Figure 4. The lifecycle of grapevine in Nepal showing current problem and solution

3.5 APPLICATION OF HYDROGEN CYANAMIDE (HC)

Hydrogen cyanamide as bud breaker

Grapevine shows distinct response in accordance to various bud breaking agents. While standard dormancy breaking agents like Dinitro-ortho-cresol (DNOC) and thiourea have little to no effect on grapevine bud opening (Nir & Lavee, 1992), HC, popular as dormancy breaking chemical for woody perennial fruits, is the most effective in grapevines (Shulman, Nir, Fanberstein, & Lavee, 1983). Dormex® (a.i. 49% HC) is popular for its use to release buds from dormancy as well as enhancing a more uniform and rapid bud opening (Halaly et al., 2008). According to Vergara, Parada, Rubio, and Perez (2012), HC seems to induce respiratory and oxidative stress by disrupting the function of the mitochondrial cytochrome pathway, which results in the breaking of bud dormancy. However, the mode of action and interaction between respiration, cell cycle regulation and oxidative signaling has not been completely elucidated.

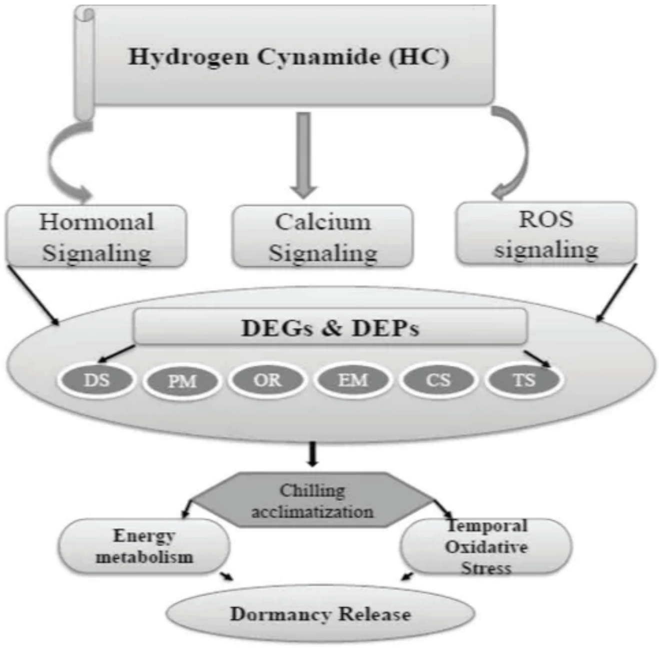

Figure 5. A proposed model of bud dormancy release in grapevine after HC application *(In this model, HC application leads to expression of genes and proteins related to hormone signaling, ROS signaling and calcium signaling which includes DS (defense and stress), PM (protein metabolism), OR (oxidation-reduction), EM (energy metabolism), CS (cell structure) and TS (transcription and signaling). Here, DEGs and DEPs implies differentially expressed genes and differentially expressed proteins respectively.)*

Source: Khalil-Ur-Rehman et al. (2019)

Hydrogen cyanamide promotes dormancy release with the association of hormone signaling, calcium signaling, hypoxia, and oxidative stress (Halaly et al., 2008; Pérez, Vergara, & Or, 2009). In accordance to Khalil-Ur-Rehman et al. (2019), HC stimulates the activity of proteins and genes involved in energy metabolism, which may cause grapevines to budburst early. Exogenous HC treatment raises the expression level of sucrose synthase, pyruvate decarboxylase, a sucrose non-fermenting (SNF)-like kinase, grapevine dormancy breaking-related protein kinase, and alcohol dehydrogenase (Ophir et al., 2009; Pérez et al., 2008). The accumulated soluble sugars provide energy for the plant to withstand low temperature in winter and maintain normal growth (Horikoshi, Sekozawa, & Sugaya, 2017). Halaly et al. (2008) mentioned HC application leads to temporary oxidative stress to release buds from dormancy. Reactive oxygen species (ROS), stimulation of the antioxidative machinery, respiratory stress, and the induction of glycolysis as a feedback effect are all brought on by transient oxidative stress (Buchanan, Gruissem, & Jones, 2015). HC temporarily elevates the level of hydrogen peroxide (H_2O_2) and rapidly upregulates certain genes associated with oxidative stress (Sudawan, Chang, Chao, Ku, & Yen, 2016), which causes a sharp decrease in catalase (CAT) activity and transient stimulation of peroxidase (POD) and ascorbate peroxidase (APX) activities that precedes the release of bud from endodormancy (Nir & Lavee, 1992; Gil Nir, Shulman, Fanberstein, & Lavee, 1986). HC enhances the budburst by Calcium (Ca^{2+})

signaling and stimulated changes in phosphorylation and transcription regulators (Pang et al., 2007). Calreticulin is a key protein involved in calcium signaling produced by modifying calcium homeostasis during dormancy regulation (Zhuang et al., 2013). The application of HC lowers the concentration of Abscisic Acid (ABA), which upturns the activity of amylase and encourages starch catabolism and soluble sugar accumulation (Liang et al., 2019). HC decreases the endogenous ABA level by promoting ABA degradation and inhibiting ABA synthesis (Khalil-Ur-Rehman et al., 2017). HC releases bud from dormancy by increasing the content of ethylene and cytokinin (Ophir et al., 2009).

Doses of hydrogen cyanamide

In subtropical viticulture, hydrogen cyanamide treatment is a popular and effective technique. On the other hand, genotypes and the timing of application (days before natural budburst or days after pruning) affect the concentration of HC. Grape varieties for table purpose should generally be treated with 2% v/v a.i. of HC with a non-ionic surfactant and a coarse droplet spray with a nozzle pressure of less than 40 psi. For temperate woody perennials, 2% HC is thought to be a nearly lethal dosage (Fuchigami & Nee, 1987). However, Siller-Cepeda, Báez, Stichez, Gardea, and Osorio (1994) found no adverse effects on grapevine growth and yield at 29° North in Mexico when grapevines were treated with up to 8% a.i. of HC at pruning or 5, 10, or 15 days after pruning. Dokoozlian (1998) suggested that the doses of HC could be increased or reduced depending on the ratio between the exposure of chilling temperature (<7^{o}C) and chill-negating temperatures (hours >20^{o}C). HC application has been found effective in preponing budburst by 3 weeks as compared to control in var. Carbernet Sauvignon at Kewalpur Agro Farm, Dhading, Nepal (Sapkota, 2022). The research was conducted from January 2021 to July 2021 in order to examine the effect of six different HC concentration ranging from 0-8% on budburst and yield attributes of grapevine var. Cabernet Sauvignon, among which 2% HC concentration was found as the best treatment in preponing the natural budburst time and maturity of harvest (Sapkota, 2022).

Hydrogen cyanamide application dates

Hydrogen cyanamide effectiveness on budburst depends on stage and depth of dormancy that also influence on berry maturity (McColl, 1986). In the Jordan Valley's subtropical climate, buds treated with HC sprouted 4-26 days earlier than the control, advanced flowering by 4–13 days, and produced berries with noticeably better quality than the control (Muhtaseb & Ghnaim, 2008). Earlier application of HC can advance fruit maturity by 2-3 weeks (McColl, 1986). Lavee and May (1997) mentioned that early application of HC under warm subtropical condition, advanced maturity of fruit but decreased yield due to reduced number of shoots, reduction in budburst percentage and non-uniform delayed budburst. However, in Australia's subtropical environment, HC spraying 4-6 weeks before to natural budburst greatly boosted crop production while having little to no effect on the timing of berry maturation for the cv. Muscat Hamburg variety (George, Nissen, & Baker, 1988). Moreover, it is suggested that late application especially at high concentration damage to the buds and a delay in their opening (Shulman et al., 1983).

Pruning and hydrogen cyanamide application

It is necessary to decide when and how much of the previous season's growth should be cut during the winter (dormant) pruning of grapevines to promote bud opening and preserve crop load. In the tropics as opposed to the subtropics, dormant buds respond more strongly to the pruning stimulus. In areas with low and often insufficient winter chilling, winter pruning in combination with HC treatment is crucial for controlling budburst (Lavee & May, 1997; Lombard et al., 2006). When HC is applied during the inflorescence growth stage, fruit maturity may be advanced by two to three weeks, but yield may be lowered due to reduced cluster number, smaller cluster weight, and greater floral abscission (McColl, 1986; Or, Nir, & Vilozny, 1999; Shulman et al., 1983). In cv. Flame Seedless, HC applied 1-2 weeks after pruning delayed budburst by 5 days in comparison with vines sprayed at pruning time (Siller-Cepeda et al., 1994). HC applied as early as at the pruning time in a subtropical climate of Jordan Valley enhanced budburst and maturity than that with a later application (Muhtaseb & Ghnaim, 2008). All buds in dormant shoots sprouted within 35 days in Hermosillo Valley, Mexico (Siller-Cepeda et al., 1994) and 46 days after pruning in Jordan Valley (Muhtaseb & Ghnaim, 2008). An experiment was conducted to assess the effect of different time of HC application (HC at 5% concentration was applied 7 days after pruning and pruning were done at different dates from December 21, 2021) in var. Cabernet Sauvignon at Kewalpur Agro Farm, Dhading (Ghimire, 2022). Growth stage with reference to E-L stage of vine differed significantly between treatments with higher average growth stage in early treated vine (Ghimire, 2022). Higher budburst (around 55-68% in early trimmed vines while about 10-30% in late trimmed vines) and observed fruitfulness (around 50-55% in early trimmed vines while about 10-25% in late trimmed vines) in early trimmed vines indicate a considerable impact on grapevine growth modification from the timing of pruning and HC treatment. Earlier-treated vines also had fewer days until their initial budburst which was around 1 to 10.4 days to first budburst while later-treated vines had initial budburst after 24 days of treatment (Ghimire, 2022). Moreover, several bud growth parameters reveal a detrimental effect on late-pruned vines followed by HC application, which is thought to be caused by HC's phytotoxic effect on fragile buds following their natural emergence from dormancy (Ghimire, 2022). Early sprouted buds may suffer from frost damage resulting in subsequent penalties in yield. Thus, the combination of pruning and HC application with reference to natural budburst time should be studied for effective budburst, berry maturity time and yield of the variety in a specific growing environment.

4. CONCLUSION

Grape is an emerging crop in Nepal, experiencing a consistent rise in demands. However, the production has not been much prioritized due to insufficient research efforts in viticulture. The major challenge limiting grape production is excessive rainfall (monsoon) coinciding with the fruit harvest period. Despite of climatic potentiality of grapes cultivation in Nepal, the production window is short. Thus, winter pruning with HC application for artificial induction of bud dormancy release, emerges as a plausible strategy to prepone bud burst and achieve early maturity. Moving ahead, more research must be done to determine the timing and dosage of HC in early maturing varieties and given growth condition to maximize its efficacy in bud burst and maturity. Through careful vine management procedures, Nepal may overcome the obstacles caused by monsoon-related problems and fully reap the benefits of grape farming, improving the country's agricultural landscape and satisfying the growing demand for grapes in the area.

DECLARATION

The authors declare no conflict of interest.

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NUTRITIONAL EVALUATION OF SHORT-HORNED GRASSHOPPER (*Oxya hyla hyla* Serville) AS A SUBSTITUTE FOR SOYBEAN MEAL IN COMPOUND DIETS OF ROHU (*Labeo rohita* Hamilton)

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ABSTRACT

The growth effects of partial substitution of soybean meal for grasshopper meal (Oxya hyla hyla) in compound diets of Rohu fish (Labeo rohita) were evaluated for 75 days at the aquaculture research center in IAAS, Paklihawa Campus with 16 meshed cages of 1 m^{3}size, stocked with 12 fingerlings^3. Completely Randomized Design was used with 4 treatments and 4 replications. Treatments included the incremental substitution of Soybean meal (SM) for Grasshopper meal (GM) as 0% GM, 10% GM, 20% GM and 30% GM. Feeding rates were adjusted every month based on observed body weight. Fish parameters were observed at 16, 27, 45, 60 and 75 days after stocking, whereas, the physical water parameters were observed daily. During the study period, the recorded mean water temperature, pH, dissolved oxygen and survivorship were 19^{o}C, 8.2, 6.4 mg/L and 64.6% respectively. Average growth rate, relative growth rate, specific growth rate, daily weight gain and protein efficiency ratio showed no significant difference (p>0.05) among the treatments. The Feed Conversion Ratio of 20% GM and 30% GM were statistically similar and superior to 0% GM and 10% GM as well. To sum up, we did not have enough evidence to prove the superiority of grasshopper meal incorporated diet on rohu, perhaps because of a lower feed efficiency.

Keywords: Cage fish culture, Compound diets, Insect-protein substitution, Short-horned grasshopper

1. INTRODUCTION

Feed is considered the most important input in fish farming because it occupies about 50% of the whole farming cost (Craig et al., 2017). The fish feed has different ingredients originating from plant and animal sources. Plant sources are limited in the supply of nutrients like Vitamin B12 (Murphy & Allen, 2003; Rizzo et al., 2016; Watanabe et al., 2014). Furthermore, plant-based ingredients may contain anti-nutrients like phytic acid (Beckhout & Depaepe, 1994), glucosinolates (Liener, 1980), phytosterols (Ostlund et al., 2003), quinolizidine alkaloids like lupinin (Wink et al., 1998), various oligosaccharides (Wiggins, 1984), and protein inhibitors like trypsin. chymotrypsin, elastases and carboxypeptidases (Liner, 1980) have suppressive effects on the growth of feeding animal. Feed needs to be abundant in micronutrients to fulfil daily nutritional requirements. A high protein content is critical for fish growth and development. The amount of crude protein required in fish feed depends upon different aspects like feeding habits, temperature, water quality, genetic makeup and the growth stage of the fish (Craig et al., 2017). In a study with Rohu (*L. rohita*), 30% crude protein was found to be sufficient to obtain optimum growth (Singh et al., 2006).

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Insects are high in crude protein, fat, minerals, vitamins, and fibres (Mintah et al., 2020). An average insect has 29.6% dry chitosan, which has cholesterol-reducing properties (Caparros Megido et al., 2014) along with antiviral, anticancer, antifungal, antimicrobial, and bacteriostatic effects (Piccolo et al., 2017), in its body (Tauber, 1898). Globally, honeybee (*Apis mellifera*), silkworm (*Bombyx mori*), African palm weevil (*Rhynchoporus phoenicis*), yellow mealworm (*Tenebrio molitor*), mopane caterpillar (*Imbrasia belina*) and crickets (*Acheta domesticus*) are among the most commonly edible insects (Tang et al., 2019). About 1.9 billion people around the world have insects regularly in their diets (van Huis et al., 2015). The high protein content of insects assures a nutritional supplement. Insects are good sources of essential amino acids (Zielińska et al., 2015).

The use of insects as protein sources for feed formulation is not something new though. Insect-based feed is suitable for poultry (Pieterse et al., 2019; Veldkamp et al., 2012), fish (Lock et al., 2016), and pigs (Sogari et al., 2019; Spranghers et al., 2018). The use of mixed protein produces better growth than the use of a single type of animal/plant protein (Attalla & Mikhail, 2008). Asia is among the more tolerant places for insect-based feed. China, more importantly, considers the use of insects in feed formulation unless the producers do not break the government rules concerning feed and its additives (Lähteenmäki-Uutela et al., 2018). In North Korea, insect-based feed is prohibited (Jo & Lee, 2016). However, insects are common food and feed ingredients in South Korea (Han et al., 2017). Annex II of the Regulation (European Union) 2017/893 permits the use of certain insects like house cricket (*A. domesticus*), banded cricket (*Gryllodes sigillatus*), field cricket (*Gryllus assimilis*), yellow mealworm (*T. molitor*), lesser mealworm (*Alphitobius diaperinus*), black soldier fly (*Hermetia illucens*), and the common house fly (*Musca domestica*). In the US, the black soldier fly (*H. illucens*) is the only insect permitted to replace fish meal (Lähteenmäki-Uutela et al., 2018). Canada permits the use of the black soldier fly in all poultry and aquaculture after 2018 (Lähteenmäki-Uutela et al., 2018).

Out of all the insects, grasshoppers (Orthoptera) are among the largest diverse groups in the animal kingdom (Paulraj et al., 2009). They are oligophagous feeders with definite host preferences (Mulkern, 1967). *Oxya hyla hyla* (Orthoptera: Acrididae) is a multivoltine polyphagous pest of Poaceae (Das et al., 2012). These grasshoppers are green in colour. Brown bands run laterally from each eye up to the episternum with relatively short filiform Antennae. *O. hyla hyla* contains 64% protein constituting all essential amino acids (30% of DM, Glutamate, and Glutamine; 6% of DM, Serine), 28% carbohydrate, and only 2.58% fat (Ghosh and Mandal, 2019). It is fair to assume that the nutritional findings from close relatives of *O. hyla hyla* are similar to its very nutritional characteristics, if not the same. For instance, *O. fuscovittata* is confirmed to have 25% to 50% fish meal replacement potential in the case of black molly fish, *Poecilia sphenops* (Ganguly et al., 2014). A study suggests that 50% replacement of fish meal in the Rohu diet doesn't change its flesh quality, growth performance and feed utilization indicators (Ghosh & Mandal, 2019b).

The fish component in this study is Rohu (*L. rohita*) (Cypriniformes: Cyprinidae), which is a commonly distributed fish of Nepal (Neupane & Rajbanshi, 2022). It has a wide range of feeding niches from the bottom to the column (Rahman et al., 2008) and is fit for intensive farming (Jhingran & Pullin, 1985) making it suitable for cage culture (Kakati et al., 2018; Balkhande et al., 2019). Various animal proteins have been incorporated into the diets of Rohu to produce good growth performances (Ghosh & Mandal, 2019a; Sampathkumar & Raja, 2019). Reporting fish growth rates is challenging since the growth pattern varies with growth conditions and fish maturity. There are certain growth parameters such as absolute growth rate (AGR), specific growth rate (SGR) and relative growth rate (RGR) used to report fish growths (Hopkins, 1992). This study aims to understand the bio-efficacy of rice grasshopper incorporated feed in the growth and development of Rohu.

2. METHODOLOGY

2.1 EXPERIMENTAL SETUP

The study was conducted inside semi-submerged nylon cages in an earthen aquaculture pond at the Aquaculture Research center at the Institute of Agriculture and Animal Science, Paklihawa campus, Rupandehi. The cages had a 15 cm slit opening on the upper face. This slit was used for feeding, fish sampling and other maintenance activities. Each cage was installed half a meter apart from consecutive cages. The first cage was about a meter away from the pond's edge. The cages were fixed using sturdy ropes and a load was tied to the lower face of each cage. The experiment included four treatments (T0, T1, T2 and T3) and four replications. A completely randomized design was used with the treatments are mentioned in Table 1.

Table 1. Specification of different treatments

Treatments	Details
T0	0% soybean meal replaced with grasshopper meal
T1	10% soybean meal replaced with grasshopper meal
T2	20% soybean meal replaced with grasshopper meal
T3	30% soybean meal replaced with grasshopper meal

2.2 COLLECTION OF RICE GRASSHOPPERS (*Oxya hyla hyla*)

The grasshoppers were collected from the rice fields in Rupandehi and Parasi by handpicking as well as sweeping. Both nymphs and adult grasshoppers were collected without sexual sorting. The insects were abundant in green and damp rice fields. Grasshoppers were found to be relatively docile right after dusk.

2.3 INSECT PROCESSING

The collected insects were transferred into airtight containers to kill the insects by suffocation. Dead insects were sun-dried for 5 days. The dried insects were pulverized and passed through a wire mesh (2mm size).

2.4 PROXIMATE ANALYSIS

Proximate analysis displayed a high crude protein (CP) content of 63.21% in grasshopper meal, GM (Table 2). The CP in GM was second to fish meal. The fibre content in GM (fibre % = 7.5%) was highest among other protein sources, fish meal and soybean meal (Table 2). Moisture content in GM was as low as 5.7% (Table 2).

Table 2. Proximate analysis of feed ingredients

Ingredients	Crude protein%	Crude fiber%	Moisture%	Crude fat%
Grasshopper meal (GM)	63.2	7.5	5.7	2.9
Fish meal (FM)	67.5	6.3	4.5	NA
Soybean meal (SM)	35.5	6.7	2.0	14.7
Rice bran (RB)	13.5	8.4	9.9	12.9
Mustard oil cake (MOC)	40.6	NA	NA	NA

2.5 FEED PREPARATION

Different diets were formed specific to the treatment details (Table 3). After formulating the feed, 2g of commercially available vitamin premix (Table 4) and 2g of table salt were added for every 100g of formulated feed. Feed pellets were produced in a manually operated pellet machine (pellet size 3mm). The pellets were sun-dried for 4 days until crumbly in texture. The dry pellets were packed in labelled packs specific to each cage. The poly bags were then stored under dry conditions to avoid infection.

Table 3. Composition of different lab-formulated diets (in every 100g)

Ingredients	Amount in grams			
	T0	T1	T2	T3
Rice bran	39.5	42.5	45.5	48.8
Mustard Oil Cake	18.5	15.5	12.5	9.3
Soybean Meal	30	27	24	21
Fish Meal	12	12	12	12
Grasshopper Meal	0	3	6	9
Estimated CP%	31.6	31.6	31.6	31.5

Table 4. Composition of the commercial vitamin premix (in 1kg) used in feed formulation

S. N	Constituent	Content in 1kg of premix
1	Vitamin A	7,00,000 I. U
2	Vitamin D3	70,000 I. U
3	Vitamin E	250 mg
4	Cobalt	150 mg
5	Copper	1200 mg
6	Iodine	325 mg
7	Iron	1500 mg
8	Magnesium	6000 mg
9	Potassium	100 mg
10	Sodium	5.9 mg

S. N	Constituent	Content in 1kg of premix
11	Manganese	1500 mg
12	Sulphur	0.72%
13	Zinc	9600 mg
14	DL-Methionine	1000 mg
15	Calcium	25.5%
16	Phosphorus	12.75%

Note: The composition mentioned above are all factory-labelled figures.

2.6 FISH STOCKING AND ACCLIMATIZATION

Each cage was stocked with 2-month-old Rohu fingerlings (Average size 5.6g) at the rate of 12 fingerlings per m^3. Each group was weighed individually for the estimation of the initial stocking weight in each cage. Acclimatization was done for five days using commercial feed purchased from the source hatchery (Table 5).

Table 5. Composition of commercial feed (size 2mm) used for acclimatization

S. N	Feed elements	Max. Content (%)
1	Crude protein	32-34
2	Crude fat	5
3	Crude fiber	5.5
4	Moisture	11

Note: The composition mentioned above are all factory-labelled figures.

2.7 FEEDING RATE

The daily ration was fed at 9 AM every day. Fish were fed manually by 8% of their body weight (Ahmed & Abid, 2009) and the rates were adjusted every two weeks with changes in body weight observations.

2.8 DATA COLLECTION

Fish sampling was done randomly from each cage every fortnight starting 16 days after stocking (DAS). Sampling was done at the rate of 30% of the stocking population. Data observation was done at five time points throughout the study period at 16 DAS, 27 DAS, 45 DAS, 60 DAS and 75 DAS. Water quality parameters were observed every day at 3-time points (8 AM, 12 PM and 4 PM).

2.9 GROWTH PARAMETERS

Various growth parameters were calculated using the data obtained from various observations. All the parameters enumerated after the research activity have been mentioned below:

a. Absolute Growth Rate, AGR (g) = Final Mean Weight(g) – Initial Mean Weight(g) (Hopkins, 1992)

b. Relative Growth Rate, RGR (%) = (mean weight gain / initial mean weight) * 100 (Hopkins, 1992)

c. Specific Growth Rate, SGR (%) (Hopkins, 1992)

d. Feed Conversion Ratio, FCR (Ponzoni et al., 2013)

e. Daily Weight Gain, DWG (g) (Prein et al., 1993)

f. Protein Efficiency Ratio, PER (Zeitoun et al., 1976)

3. RESULTS

3.1 WATER QUALITY PARAMETERS AND FISH SURVIVORSHIP

The average weekly water temperature ranged from 16.4^{o}C to 23.1^{o}C (Figure 1). The temperature readings decreased gradually from the first week of the study to the sixth week. The seventh week saw a slight dip in average temperature. There was an overall decreasing trend of temperature throughout the study period. The dissolved oxygen (DO) was observed between 5.2 mg/L to 7.5 mg/L (Figure 2). The DO level was on the lower end of the range in the beginning which kept an increasing trend throughout the study period. The pH of the pond water ranged between 7.3 and 8.7 (Figure 3). The Secchi disc reading was between 14.6 cm to 19.6 cm. The overall mean fish survivorship observed was 64.58%. The mean survivorship for T0, T1, T2 and T3 were 50%, 70.8%, 66.7% and 70.9% respectively.

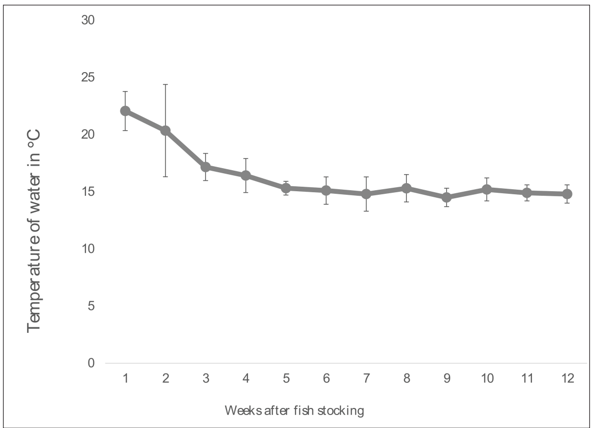

Figure 1. Weekly temperature (°C) of pond water after fingerling stocking

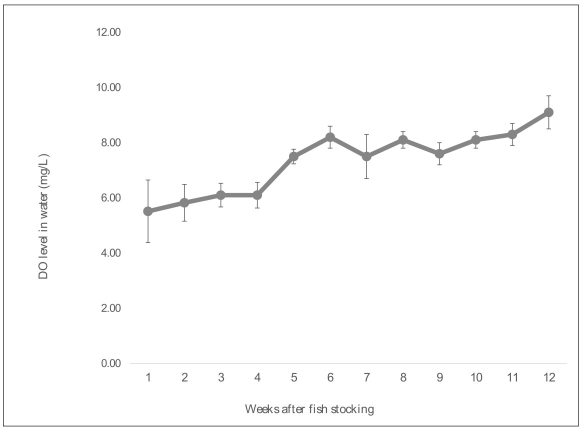

Figure 2. Weekly Dissolved Oxygen (DO) of pond water after fingerling stocking

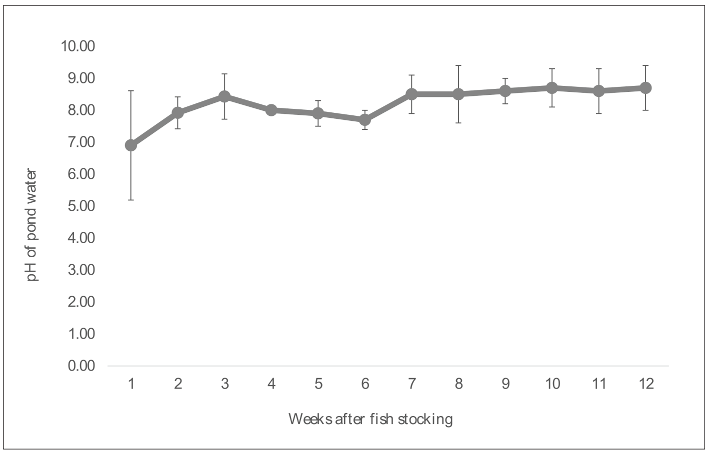

Figure 3. Weekly pH of pond water after fingerling stocking

3.2 FISH GROWTH PARAMETERS

There was no significant difference (p>0.05) between the stocking weights of different cages (Table 2). Similarly, there was no significant difference (p>0.05) between the harvest weights of different cages (Table 6). AGR, SGR and RGR, in all observations, were statistically non-significant at a 95% confidence interval (Table 7, Table 8 and Table 9).

Table 6. Stocking weight and harvest weight of fish in different cages

Treatments	Stocking weight (g)	Harvest Weight (g)
T0	71.4±5.8	123.3±12.7
T1	74.7±2.7	140.9±1
T2	60.2±3.1	148.9±18.8
T3	61.4±4.8	143.7±9.1
LSD	13.2	41.9
F-test result	NS	NS

Note: T0= 0% Grasshopper meal substitution; T1= 10% Grasshopper meal substitution; T2= 20% Grasshopper meal substitution; T3= 30% Grasshopper meal substitution.

Table 7. Observations on absolute growth rates between different time points

Treatments	AGR (g.) in given DAS					
	0-75 DAS	0-16 DAS	16-27 DAS	27-45 DAS	45-60 DAS	60-75 DAS
T0	4.3±0.8	0.8±0.5	1.0±0.6	1.0±0.3	0.6±0.2	1.0±0.2
T1	5.5±0.9	1.9±1.0	0.8±0.4	1.3±0.3	0.4±0.1	1.1±0.3
T2	7.4±1.6	1.3±0.7	2.9±1.9	1.3±0.4	1.0±0.2	0.9±0.1
T3	6.9±0.6	1.4±0.6	1.6±0.7	1.8±0.4	1.2±0.3	1.0±0.4
LSD	3.2	2.3	3.3	1.0	0.7	0.8
F-test result	NS	NS	NS	NS	NS	NS

Note: T0= 0% Grasshopper meal substitution; T1= 10% Grasshopper meal substitution; T2= 20% Grasshopper meal substitution; T3= 30% Grasshopper meal substitution.

Table 8. Observations on relative growth rates between different time points

Treatments	RGR (%) in given days after stocking (DAS)					
	0-75 DAS	0-16 DAS	16-27 DAS	27-45 DAS	45-60 DAS	60-75 DAS
T0	73.4±15.2	18.7±4.9	17.5±6.7	12.1±2.6	7.2±2.6	10.5±3.0
T1	88.2±2.1	29.6±15.0	12.3±7.0	15.2±4.0	4.3±1.2	10.0±2.6
T2	149.1±33.9	53.3±23.1	58.3±40.0	13.9±1.5	10.7±2.5	8.1±1.3
T3	136.2±15.2	57.4±21.3	22.7±10.2	24.1±7.3	12.8±5.0	10.3±4.2
LSD	64.6	54.2	65.4	13.6	9.7	9.1
F-test result	NS	NS	NS	NS	NS	NS

Note: T0= 0% Grasshopper meal substitution; T1= 10% Grasshopper meal substitution; T2= 20% Grasshopper meal substitution; T3= 30% Grasshopper meal substitution.

Table 9. Observations on specific growth rates between different time points

Treatments	SGR (%/day) in given Days After Stocking (DAS)					
	0-75 DAS	0-16 DAS	16-27 DAS	27-45 DAS	45-60 DAS	60-75 DAS
T0	0.3±0.1[b]	0.5±0.1	0.5±0.1	0.2±0.1	0.2±0.1	0.3±0.1
T1	0.4±0.0[ab]	0.7±0.3	0.4±0.2	0.3±0.1	0.1±0.0	0.3±0.1
T2	0.5±0.1[a]	0.6±0.3	1.5±0.9	0.3±0.0	0.3±0.1	0.2±0.0
T3	0.5±0.0[a]	0.7±0.3	0.8±0.3	0.5±0.1	0.3±0.1	0.3±0.1
LSD	0.2	0.8	1.5	0.3	0.2	0.2
F-test result	S	NS	NS	NS	NS	NS

Note: Post-hoc test by using DMRT; T0= 0% Grasshopper meal substitution; T1= 10% Grasshopper meal substitution; T2= 20% Grasshopper meal substitution; T3= 30% Grasshopper meal substitution.

3.3 FEED EFFICIENCY PARAMETERS

The PER and DWG means were significantly different to each other at a 95 % confidence interval (Table 10). PER was the highest in T2 (0.77±0.16) and the lowest in T0 (0.42±0.08). Means of FCR were found to be significantly different after one-way ANOVA at a 5% level of significance (Table 10). Both T2 (4.64±0.85) and T3 (4.63±0.36) were statistically similar to each other and had the lowest ratios among all the treatments. T1 (6.88±0.94) was similar to all other treatments.

Table 10. Feed efficiency indicators based on mean weight gain and feed consumed within 75 days after stocking

Treatments	PER	FCR	DWG (g)
T0	0.4±0.1	8.2±1.1[a]	0.1±0.0
T1	0.5±0.1	6.9±0.9[ab]	0.1±0.0
T2	0.8±0.2	4.6±0.9[b]	0.1±0.0
T3	0.7±0.1	4.6±0.4[b]	0.1±0.0
LSD	0.3	2.7	0.0
F-test result	NS	S	NS

Note: T0= 0% Grasshopper meal substitution; T1= 10% Grasshopper meal substitution; T2= 20% Grasshopper meal substitution; T3= 30% Grasshopper meal substitution.

4. DISCUSSION

Fish growth rates are directly proportional to metabolism (Wood & McDonald, 1997) and fish activity (Bartolini et al., 2015). Similarly, temperature plays a significant factor in fish development (Britz et al., 1997; Houlihan et al., 1993). The best temperature range for rearing *L. rohita* is 24-26°C (Kausar & Salim, 2006). However, the temperature range in this research is lower than the optimum temperature. This is one of the reasons that the present study observed low weight gain in the fish. In another study, it was possible to obtain a higher weight gain in fish reared in a polyhouse system with an inner temperature of 19°C when it was 14.8°C outdoors (Khan et al., 2004). A pH of 6.5 to 7.5 is the most favourable range and a DO level of above 5 mg/L is favourable for a productive fishpond (Wagle et al., 2018). The weekly observed DO (mean = 6.4 mg/L) levels were favourable for the pond culture of fish. However, the weekly pond pH (mean = 8.1) was slightly higher than the optimum level. The earthen pond produced higher turbidity while performing research activities like feeding, sampling and cage/pond maintenance. This turbidity has a negative influence on fish reared in ponds and cages (Lall & Tibbetts, 2009).

The mean AWG and RWG obtained at the end of the study are much higher than the results obtained in the study conducted at Tarahara, Nepal (Wagle et al., 2018). However, both AWG and RWG had no significant difference between the treatments. Furthermore, SGR was significantly different between treatments at 0-75 DAS. The Specific Growth Rates obtained from our study were inferior to the results from Wagle et al. (2018) at a comparable duration. The highest DWG was observed in 20% GM and 30% GM which was 0.1±0.0 g in both diets. However, the daily gains showed no significant difference from other treatments.

An exponential model is common in analyzing fingerling growths since it can produce reliable results with only mean initial and final weights (Gamito, 1998). The exponential model fits in growth analysis for a short growth period (Cuenco et al., 1985; Vinberg & Duncan, 1971; Weatherley, 1987). However, it is preferred in fish growth analysis more than other models for its easiness (Barnabé, 1994; Porter & Gordin, 1986). SGR is the most suitable parameter to measure growth in fingerlings (Hopkins, 1992). These rates assume an exponential model for growth. However, even this measure was observed to be non-significant at a 95% confidence interval between all five observation points except for SGR at 0-75 DAS.

Both the stocking and harvest weights were statistically non-significant . Stocking weights, not being different between cages, is a necessary requirement to prove no difference between the stocked fishes. This weeds out any possibility of variation just because of differences in average fish sizes. However, the non-significant differences (p>0.05) between harvest weights imply that there is no effect of partial substitution of grasshopper meal for soybean meal on the growth and development of Rohu. Ingredient substitution rates could be increased in further studies to explore if such non-significant results are just because of insufficient substitution of grasshopper meal.

Protein efficiency ratios were statistically similar to each other. However, the PER was found to be the highest in 20% GM. Feed conversion ratios were significantly different at a 95% confidence interval. Diet with 20% GM and 30% GM had the lowest feed conversion ratios. FCR decreased significantly with the increasing proportion of grasshopper meal.

A similar study was done by replacing soybean with cottonseed meal in grass carp fingerlings (Zheng et al., 2012). Soybean meal was replaced because it contains different antinutritional compounds that hurt fish intestinal mucosa (Francis et al., 2001). The antinutrients display severe effects on the mucosal layer if the proportion of soybean is greater than 50% in the feed formulation (Burrells et al., 1999). The findings on FCR for this study were contradictory to our findings. FCR for grass carp feed increased with increasing rate of cottonseed meal. However, our findings suggest that FCR decreases with an increased rate of grasshopper meal.

When the figures for PER and FCR are compared between the two studies, the average means are much higher in our study. Our FCR ranges between 4.6±0.9 to 8.2±0.9 whereas, the study by Zheng et al. (2012) shows an FCR ranging between 1.4±0.1 to 1.7±0.1. Similarly, our PER ranged between 0.4±0.1 and 0.8±0.1 in contrast to the findings from Zheng et al. (2012) ranging between 1.7±0.1 and 2±0.1. There is this huge gap in FCR/PER between our results and Zheng et al. (2012) because we were unable to extract the feed losses.

5. CONCLUSION

In conclusion, *O. hyla hyla* is as rich as fish meal in terms of being a protein source. It was hypothesized that a partial substitution of soybean meal with grasshopper meal would produce better results on the growth and development of Rohu. However, the study lacked the evidence to prove the hypothesis. We believe that using separate aquariums would have made it possible to extract feed deposits. It would have given us a better estimate of FCR and PER. Another reason for the non-significant effects of insect meal substitution could be the use of smaller substitution rates. As a result, we recommend the use of a higher substitution rate in further studies. As *L. rohita* is a tropical fish, we recommend the use of polyhouse structure around the rearing pond to increase temperatures during the winters for a higher weight gain.

DECLARATION

The authors declare no conflict of interest.

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CONSERVATION AND UTILIZATION OF SUMMER CROPS BIODIVERSITY IN NEPAL

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ABSTRACT

Nepal faces a pressing challenge with the alarming loss of around 50% of its summer crop genetic resources (SCGRs) and the endangerment of native landraces. To combat this decline, the national genebank in Nepal has developed 101 good practices for agricultural genetic resources (AGRs) conservation and utilization. Red zoning and red listing strategies aid in identifying conservation priorities. The Genebank collaborates with stakeholders to collect, characterize, and promote SCGRs, resulting in 6177 accessions representing 71 summer crop species stored in Seed Banks. Diverse conservation repositories include genebanks, tissue banks, DNA banks, community genebanks, school field genebanks, and agro-gene sanctuaries. In 2022, 724 accessions of 20 summer crops were distributed for research, while the registration of 19 landraces after genetic enhancements led to their inclusion under the National Seed Board. The free distribution of germplasm accelerates its utilization, further facilitated by online access. The genebank also promotes agro-insect field genebanks recognizing the importance of agro-insects and pollinators in biodiversity conservation. To maintain native SCGRs, value additions are emphasized, underlining the need to actively enhance genetic diversity in agricultural fields. These comprehensive measures underscore Nepal's commitment to safeguarding agrobiodiversity, ensuring food security, and bolstering agricultural resilience to climate and other stresses.

Keywords: Agronomic summer crop, Conservation, Database, Forage summer crop, Horticultural summer crop

1. INTRODUCTION

Nepal stands as a rich reservoir of agrobiodiversity, with its economic underpinnings deeply intertwined with the products and services drawn from these abundant resources (Gotame et al., 2019; Joshi et al., 2020, 2023; Ghimire et al., 2022; NAGRC, 2023). This diversity is a product of a complex interplay of factors, encompassing diverse agro-climatic zones, intricate farming systems, a tapestry of ethnicities, varying socioeconomic landscapes, substantial altitudinal variations, and the challenges posed by intricate topography. This intricate tapestry has given rise to numerous micro-niches, nurturing an extensive tapestry of agricultural diversity across the nation. The role of agrobiodiversity transcends conventional boundaries, permeating various agricultural disciplines, such as plant breeding, pathology, agronomy, entomology, and food science. It serves as a versatile solution to an array of agricultural challenges, including those stemming from environmental pressures and the specter of climate change. These resources serve as the foundational elements for genetic improvements and remain indispensable for upholding global food production systems.

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Their sustained availability represents a fundamental prerequisite for realizing heightened productivity and nutritional value. Safeguarding extant genetic diversity is pivotal for ensuring the sustainability of agriculture, and facilitating access to agricultural researchers, breeders, and farmers is equally crucial. The genebank's repository of Agricultural Genetic Resources (AGRs) serves diverse purposes, from securing long-term preservation to direct application in agricultural production, environment preservation, scientific experimentation, genetic enhancements, contributions to sustainable breeding, and material repatriation (NAGRC, 2022).

However, over the past forty years, the drive to modernize and commercialize agriculture has cast a shadow over traditional AGRs and indigenous knowledge, skills, and technologies. This transformation has had far-reaching consequences, including the depletion of ecosystems and the erosion of diversity. Climate change exacerbates these challenges. One of the significant drivers of this genetic erosion is the replacement of diverse farmers' varieties with modern alternatives. Alarmingly, more than 75% of global crop diversity vanished irrevocably during the 20th century (FAO, 1999).

Acknowledging the pivotal significance of conserving and sustainably exploiting agrobiodiversity for national development and to meet international obligations, such as the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the Government of Nepal, in partnership with the Nepal Agricultural Research Council (NARC), established the National Agriculture Genetic Resources Center (NAGRC, commonly known as Genebank) in 2010 in Khumaltar (NAGRC, 2023; Joshi et al., 2020). This monumental establishment, situated at an altitude of 1368 meters (27°40'N, 85°20'E), is dedicated to conserving and sustainably utilizing AGRs, ensuring the availability of invaluable genetic assets for the nation's prosperity. The Genebank comprises five integral units: Collection and Distribution, Conservation, Characterization and Evaluation, Biotechnology, and Documentation, Publication, and Training. These collaborative efforts have yielded substantial achievements in the management of agrobiodiversity and some major milestones are given in Table 1 (Joshi, 2017).

Table 1. Historical movement on conservation of agricultural genetic resources in Nepal

Year	Milestone
1984	Establishment of Plant Genetic Resource Section in Agriculture Botany Division of NARC
1986	Establishment of medium-term ex-situ conservation
2010	Establishment of National Genebank (NAGRC)
2012	Establishment of Field Genebank and Community Field Genebank
2013	Initiation of Tissue Bank and DNA Bank
2014	Establishment of Base Collection Room of 100,000 accessions capacity with -18^{o}C for long-term seed conservation (50-100 years)
2015	Establishment of Potato Park, Sugarcane Park, Ginger and Turmeric Park
2016	Establishment of short-term storage for vegetatively propagated and recalcitrant crops
2016	Establishment of Aqua Pond Genebank
2018	Establishment of Agro Gene Sanctuary

Source: Joshi (2017)

Agrobiodiversity is an integral facet of overall biodiversity, encompassing six primary categories and four subcategories, as depicted in Figure 1 (Joshi et al., 2020). Given its pivotal role in agricultural research and education, in addition to its contributions to food security, nutrition, business, health, and environmental sustainability and enhancement, the preservation of agrobiodiversity takes on paramount importance. However, the incursion of agricultural modernization has, regrettably, led to the erosion of numerous native and local agrobiodiversity components, placing many more on the brink of extinction (Joshi et al., 2020). It is imperative to undertake measures for the conservation of these invaluable resources to ensure their long-term availability, proper utilization, database management, comprehensive characterization, and the enhancement of their genetic performance. For reference, Table 2 provides a list of various summer crops (excluding forage crops).

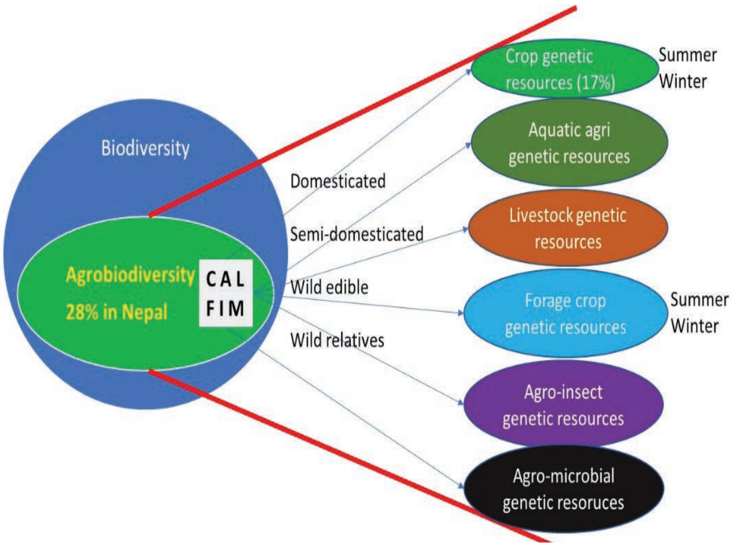

Figure 1. Components and sub components of agrobiodiversity (CALFIM: crop, aquatic agricultural genetic resource, livestock, forage, agro insect and agro microbe)

Source: Joshi et al. (2020)

This paper comprehensively covers the National Genebank's achievements over the past two years with a focus on summer crops. Its principal objectives include disseminating information about the conservation and preliminary research status of summer crops, promoting knowledge about best practices for the conservation and utilization of AGRs, and shedding light on matters and strategies concerning agrobiodiversity.

2. METHODOLOGY

In our research, a multifaceted methodology was employed to comprehensively investigate summer crop agrobiodiversity conservation. This methodology encompassed an extensive review of relevant literature, enabling us to synthesize existing knowledge and insights. Additionally, we conducted in-depth analyses of databases such as Genesys (https://www.genesys-pgr.org/, the NAGRC web portal (https://genebank.narc.gov.np/), and Joshi et al. (2023), thus incorporating the latest data and research findings. Furthermore, we embarked on fieldwork, exploring and visiting diverse summer crop areas to collect germplasm while simultaneously gathering essential passport and general information. To ensure a wellrounded perspective, we organized focused group discussions in all seven provinces, which enabled the collection of information on diversity, conservation status, impact, and pertinent issues and challenges. Lastly, interaction with key experts in the field was undertaken to verify and enrich the information gathered from both fieldwork and the literature, culminating in a robust and comprehensive research approach.

3. RESULTS AND DISCUSSION

3.1 SUMMER CROPS, CLASSIFICATION AND NATIONAL PRIORITY ISSUES

The National Genebank classifies crop genetic resources (CGRs) into two primary categories based on their growing season and economic utility: summer crops and winter crops. Summer crops are those cultivated during the warm or hot seasons, and the further classification of summer crops is illustrated in Figure 2. This paper specifically addresses the conservation status of these distinct summer crop groups.

Table 2. Lists of summer crops (agronomic and horticultural crops)

English Name	Nepali Name	English Name	Nepali Name	English Name	Nepali Name
-	Bayar	Cucumber	Kaankro	Perilla	Silaam
-	Haade Bayar	Custard apple	Seetaaphal or Sarifaa	Peruvian ground apple, Yakon	Bhui Shyau
-	Ban timilo	Double Bean	Asaare simi	Pigeon pea	Rahar
-	Harro	Drumstick	Sajiwan, Sital Chini	Pineapple	Bhuikatahar
-	Jamun	Elephant foot yam	Ole	Pointed Gourd	Parbal
Amaranth (grain)	Latte	Fig	Nivaaro	Proso Millet	Chino
Amaranth (Red)	Latte	Finger millet	Kodo	Pumpkin	Farshi
Amaranthus	Latte, Marshe, Lude	Foxtail Millet	Kaaguno	Rice	Dhaan
Arabica coffee	Coffee	French bean	Ghui Simi, Daal simi, Asaare simi	Ridge Gourd	Paate Ghiraulaa
Ash Gourd, Wax Gourd	Kuvindo	Ginger	Aaduwa	Robusta coffee	Coffee
Balsam Apple	Barelaa	Greater Yam, White	Tarul, Ghar	Rose apple	Gulaab-Jaamun
Banana	Keraa	Groundnut/ Peanut	Badaam	Sesame	Til
Barnyard Millet	Saamaa	Guava	Ambaa, Belauti	Sesbania	Dhainchaa
Butter tree	Chiuri	Hot Pepper	Piro Khursaani	Snake Gourd	Chichindo
Bead plum	Haade bayar	Jute	Paat	Sorghum/Great millet	Junelo

English Name	Nepali Name	English Name	Nepali Name	English Name	Nepali Name
Bean, French Bean, Kidney bean	Simi	Kodo millet	Kodi	Soybean	Bhattamaas
Bell (Sweet) Pepper	Bhede Khursaani	Kumquat	Muntalaa	Sponge Gourd	Ghiraulaa
Bitter Gourd	Tite karelaa	Large/ greater Cardamom	Alaichi	Summer squash	Deshi pharsi
Black Pepper, Pepper	Marich	Little millet	Dhan kodo, Kutki	Sunflower	Surya mukhi
Blackgram	Maas	Long Pepper	Pipalaa	Sunhemp	Sanai
Bottle Gourd	Laukaa	Maize	Makai	Sweet potato	Sakharkhanda
Cassava, Tapioca	Simaltarul	Mango	Aamp	Tamarind	Emli
Ceylon oak	Kusum	Mint (Field, Garden)	Pudinaa	Taro	Pidaalu
Chayote	Iskush	Monkey Jack	Badahar	Thin shelled walnut	Daante Okhar
Chilly	Khursaani	Mungbean	Mung maas	Tobacco	Surti
Cinnamon	Daalchini	Nepali Sumac	Sati bayar	Turmeric	Besaar
Cinnamon, Bay Leaf, cassia	Tejpatta	Niger	Philingo, Jhuse Til	Water Cress	Simsaag
Cotton	Kapaash	Okra	Bhindi	Wood apple	Bael
Cowpea	Bodi	Paspalum	Kodi	Yam	Tarul
		Pearl Millet	Ghonge	Zigyphus	Jangali bayar

Source: Gotame et al. (2019), Joshi and Shrestha (2017), Joshi et al. (2023) and NAGRC (2023)

National priority issues for the conservation and utilization of summer crops revolve around safeguarding AGRs to ensure their availability for future generations. These priorities encompass various critical aspects. The first priority involves the conservation of a diverse array of crop varieties. Preserving a wide range of crop varieties is essential to maintain genetic diversity, enabling crops to adapt to changing environmental conditions and evolving agricultural needs. Promoting native and local AGRs is the second key issue. Encouraging the sustainable cultivation of these varieties not only supports traditional agricultural practices but also maintains genetic diversity. This, in turn, enhances the resilience of crops to local conditions and market demands. Establishing conservation banks, including seed banks and genebanks, is the third priority. These banks serve as repositories for diverse crop varieties, ensuring their availability for research and breeding programs, thus safeguarding their genetic potential.

The development of a comprehensive online database is the fourth priority. This digital resource provides valuable information on genetic resources and their characteristics, facilitating research, breeding, and conservation efforts, while enhancing accessibility. The fifth priority involves red zoning and red listing. These efforts aim to identify danger regions/

vulnerable areas with high genetic diversity (red zones) and those species/ landraces facing threats (red listing). The objective is to rescue and conserve endangered germplasm, thereby preventing their loss.

On-farm research and breeding programs constitute the sixth priority. Collaborative initiatives involving farmers directly enhance the genetic traits of AGRs, ensuring they are better suited to local conditions and market demands. The seventh priority focuses on policymaking, guidelines, and capacity development. The formulation of clear policies and guidelines supports and regulates AGR-related activities, promoting sustainable practices and research. Moreover, capacity development is essential to equip a skilled workforce capable of implementing effective conservation and utilization strategies.

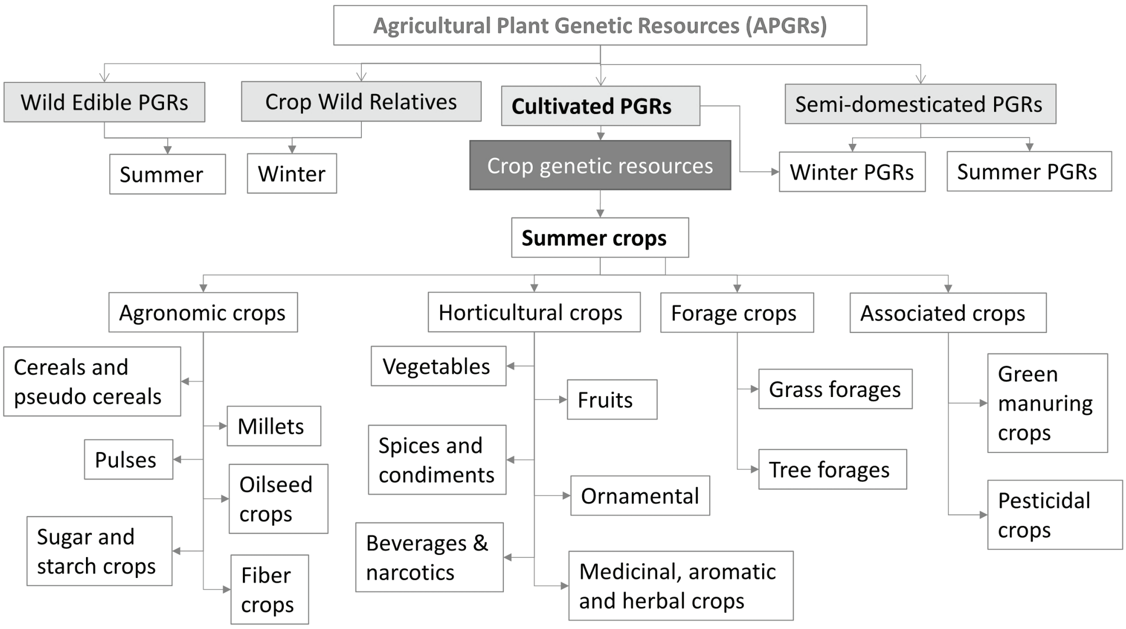

Figure 2. Classification and coverage of summer crops

Source: Joshi and Shrestha (2017)

3.2 CONSERVATION STATUS OF SUMMER CROP GENETIC RESOURCES

Collection

The routine activities of the genebank encompass the exploration and collection of agricultural plant genetic resources. In the past two years, a total of 1,033 samples representing 93 different food crop species were gathered from 17 districts.

Conservation

Over the specified period, 1,207 accessions of 12 different crops were regenerated and seed increased at Khumaltar, encompassing 1,003 accessions of six agronomic crops and 204 accessions of six horticultural crops. Furthermore, seed samples from 2,027 accessions belonging to 55 crop species were meticulously cleaned and subjected to germination testing. In addition, seed from 820 accessions of 39 different crop species were incorporated as new entries within active and base collections. A field genebank spanning an area of 1,500 square meters was established for vegetatively propagated crops and those with recalcitrant seeds. Various recalcitrant species, such as 86 accessions of turmeric, 55 accessions of taro, 49 accessions of garlic, and 21 perennial species were collected from diverse locations and are now maintained within the Khumal field genebank. Approximately 96 accessions representing five crops, including potato, sweet potato, sugarcane, banana and large cardamom, are preserved in the Tissue Bank. The selection of blast-resistant rice lines was accomplished utilizing nine SSR markers from a pool of 90 accessions. Furthermore, the diversity of 35 maize accessions was assessed, with DNA samples from 48 chilly accessions and 92 amaranth accessions preserved in the DNA bank. Collaborative initiatives were initiated with 11 different community organizations, with agreements to work together on-farm agrobiodiversity conservation. A comprehensive breakdown of summer crop conservation is provided in Table 3.

Characterization, evaluation and pre-breeding

The genebank's efforts encompassed the characterization and evaluation of a total of 1,397 accessions representing 17 different crops, including 1,005 accessions from six agronomic crops (rice, maize, foxtail millet, finger millet, and soybean) and 392 accessions from 11 diverse horticultural crops. This was carried out using descriptors developed by institutions such as IPGRI and other international bodies. Notably, 15 elite lines from five crops (comprising 2 each of okra and cucumber, 1 Anadi rice, and 5 each of finger millet and foxtail millet) were identified through pre-breeding, as documented in various research publications (Ghimire et al., 2022; Karkee et al., 2021; Thapa et al., 2022; NAGRC, 2022, 2023).

Database management

Passport data for all newly acquired collections and accessions conserved across short, medium, and long-term storage are diligently maintained and updated. Additionally, passport data from previous collections is also kept current. Presently, the genebank houses and preserves 10,084 crop varieties (including both summer and winter) along with their respective passport data.

Germplasm distribution

An essential objective of germplasm conservation within the genebank is to facilitate the utilization of this genetic material in plant breeding and related research activities. In the year 2022, seeds from 724 landraces representing 20 summer crops were distributed to students, NGOs, breeders, and farmers for research and sustainable germplasm utilization (as illustrated in Figure 3). It is essential to note that seed distribution occurs exclusively from the active collections. Additionally, diversity kits, which include pre-breeding lines (elite lines), site-specific best landraces, unique landraces, pre-release lines, and released varieties, were provided to various farmers during exploration and collection missions. It's important to note that seed distribution occurs exclusively from the active collections.

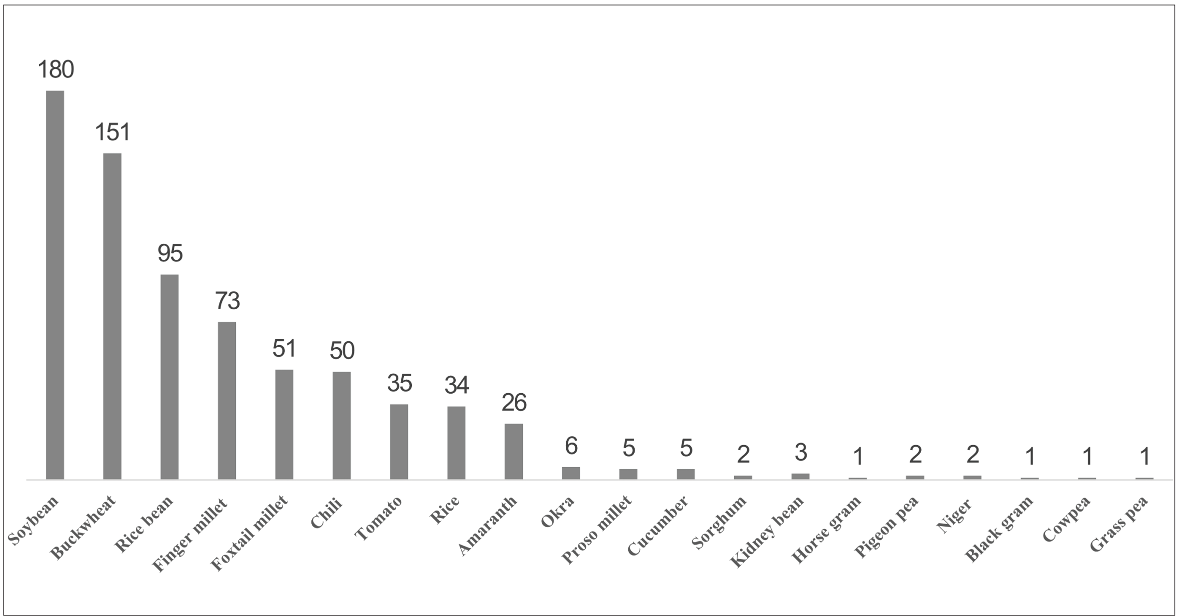

Figure 3. Number of accessions of summer crops distributed in 2022

Table 3. Total number of accessions of summer crops conserved in medium term at National Genebank, Khumaltar

Crop	Scientific name	नेपाली नाम	Accessions, n
Cereals	अन्नबालीहरु		
Maize	Zea mays L.	मकै	762
Rice, paddy	Oryza sativa L.	धान	2437
Pseudo-cereals	छद्म अन्नबालीहरु		
Amaranth	Amaranthus spp. (4 species)	लट्टे, मार्से	274
Common Buckwheat	Fagopyrum esculentum Moench.	मिठे फापर	136
Tartary Buckwheat	Fagopyrum tataricum L. Gaertn.	तिते फापर	173
Millets	कोदो जन्य बालीहरु		
Barnyard Millet	Echinochloafrum entacea Link.	सामा	4
Finger Millet	Eluesine corocana L. Gaertn.	कोदो	1055
Foxtail Millet	SetariaitalicaL. Beauv.	कागुनो	46
Little Millet	Panicum sumatrense Roth.	कुट्किक, धान कोदो	1
Proso Millet	Panicum miliaceum L.	चीनु	43
Sorghum	Sorghum biclor L.	जुनेलो	6
Pulses	दलहन बालीहरु		
Adjuki Bean	Vigna angularis Ohwi & Ohashi	मास लहरी	1
Bean, French Bean	Phaseolus vulgaris L.	सिमी	268
Black Gram	Vigna mungo L.	मास	45
Cowpea	Vigna unguiculata L.	बोडी	33
Grass Pea	Lathyrus sativus L.	खेसरी	106
Green Gram, Mung Bean	Vigna radiata L.	मुंग, हरियो मास	9
Horse Gram	Dolichos biflorus Roxb.	गहत	42

Crop	Scientific name	नेपाली नाम	Accessions, n
Pigeon Pea	Cajanus cajan L.Huth.	रहर	12
Rice Bean	Vigna umbellate Thung. Ohwi&Ohashi	मस्यांग, सिल्टुङ	113
Soybean	Glycine max L. Merr.	भटमास	155
Oilseed Crops	तेल बालीहरु		
Groundnut	Arachis hypogaea L.	बदाम	5
Niger	Guizotia abyssinica L. Cross	फिलिंगे, झुसेतिल	11
Perilla	Perilla frutescens L.	सिलाम, तिल्खुरो	15
Sesame	Seasamum indicum L.	तिल	25
Sunflower	Helianthus annuus L.	सुर्यमूखी	1
Vegetables	तरकारी बालीहरु		
Balsam Apple	Momordica balsamina L.	बरेला, करेला, चुच्चे करेला	8
Bitter Gourd	Momordica charantia L.	तिते करेला, करेला	1
Bottle gourd	Lagenaria siceraria	लौका	4
Brinjal, Egg Plant	Solanum melongena L.	भण्टा	33
Cucumber	Cucumus sativus L.	काँक्रो	55
Sponge gourd	Luffa aegyptiace	घिरौला	47
Tomato	Solanum lycopersicum	गोलभेँडा	18
Lettuce	Brassica japonica Thb. Sieb	जिरिको साग	1
Okra, Lady's Finger	Abelmoschus eschulentusL. Moench.	भिण्डी, रामतोरिया	71
Pumpkin	Cucurbita moschata Duchesne.	फर्सि, कद्दु	10
Spine Gourd	Momordica dioica Roxb.	चटेल, झुसे करेला	1
Fruits	फलफूल बालीहरु		
Indian Plum	Zizyphus jujube Mill.	वयर	1
Pomegranate	Punica granatum	अनार	1
Spices	मसला बालीहरु		
Chilli pepper	Capsicum frutescens L.	खुर्सानी	69
Large Cardamom	Amomum subulatum Roxb.	अलैंची	5
Fibers	रेसा बालीहरु		
Hemp	Cannabis sativa L.	भाङ्ग, गाँजा	3
Jute	Corchorus olitorius L.	जुट	6
Forages	घाँसे बालीहरु		
Teosinte Grass	Zea perennis L.	टियोसिन्टे घाँस	1
Crop Wild Relatives	About 20 species	बालीका जंगली नातेदारहरु	50
Others	About 4 species	अन्य	14
Total	**71 species**		6177

3.3 RESEARCHABLE ISSUES AND ACTIVITIES

Researchable issues and activities within the domain of conservation and utilization of summer crops encompass a diverse array of critical concerns and ongoing research efforts. These issues serve as focal points for advancing the knowledge and practices associated with agricultural biodiversity. Major research issues include the development of site-specific crop varieties, the promotion of genetic diversity and the cultivation of polymorphic populations in agricultural fields. Additionally, research activities center around conservation through utilization and product diversification, embracing both static and dynamic conservation approaches and methods. A significant aspect involves enhancing the value of summer crops through breeding and non-breeding methods. The exploration of the potential of summer crop genetic resources is another central research concern. Moreover, mechanisms for safeguarding these resources and establishing links between agrobiodiversity and education, research, nutrition, environment, food, business, and health are integral to the research landscape. Research efforts also address the impact of climate change on summer crops, along with the management of online databases, and the documentation and profiling of these crops, including phenotypic, genotypic, and metabolite aspects. Genetic enhancement, fingerprinting, and the quantification of agrobiodiversity from various angles are also subjects of investigation (Joshi, 2021a).

Research activities are actively pursued within the framework of the Conservation and Utilization of Agricultural Biodiversity (CUAB) project. First part, dedicated to the conservation and utilization of agricultural plant genetic resources (CUAPGR), encompasses a wide array of activities aimed at preserving and enhancing the genetic diversity of agricultural crops. These activities include the exploration, collection, and distribution of germplasm. Seed cleaning, testing, and characterization ensure the quality and viability of the genetic material, while the processing and conservation of seeds in medium- and long-term storage facilities safeguard their long-term availability. The management and reinforcement of various conservation facilities, including the Field Genebank, Agro Gene Sanctuary, Raithane Nursery, and Herbal Conservation Garden, play a crucial role. Regeneration, multiplication, and characterization efforts extend to both agronomic and horticultural crops. Evaluation and pre-breeding activities enhance the genetic potential of these crops, while maintenance efforts focus on rare, unique, non-utilized, farmer-selected, and elite genetic resources. In-vitro conservation is employed for vegetatively propagated and recalcitrant seed crops, and molecular markers aid in the management of agricultural biodiversity. On-farm and in-situ conservation strategies are applied, while documentation and database management ensure the organized storage of critical information. The compilation of a national priority inventory encompasses neglected, underutilized, and wild plant species.

Second part, known as the management of aquatic, livestock, insect, and microbial agricultural genetic resources (MALIM-AGR), addresses diverse aspects. These include updating conservation strategies for aquatic, livestock, insect, and microbial resources, conducting feasibility studies for a mushroom park, establishing an aqua-pond genebank within the Genebank complex, and monitoring the wild bee population’s role in ecological services and agricultural production.

Within this comprehensive research framework, multiple projects are actively contributing to the advancement of knowledge and practices. These projects include the Evolutionary Plant Breeding Project, which focuses on leveraging genetic diversity and evolutionary plant breeding to enhance farmer resilience to climate change, sustainable crop productivity, and nutrition under rainfed conditions. The Rebuilding Local Seed System Project centers on the collection, conservation, and repatriation of native crop seeds in earthquake-affected areas of Nepal. The Local Crop Project aims to integrate traditional crop genetic diversity into technology to buffer against unpredictable environmental changes in the Nepal Himalayas. Lastly, the Indigenous Seed System Project is geared towards improving seed systems to enhance food security for smallholder farmers in Nepal.

3.4 GOOD PRACTICES FOR CONSERVATION OF SUMMER CROPS BIODIVERSITY

National Genebank has implemented a comprehensive array of good practices, totaling 101 in number (Joshi, 2022; Joshi et al., 2020), and many of them are for summer crop biodiversity conservation and utilization (Figure 4). Many of these practices were developed in-house by National Genebank and include the establishment of various conservation banks. Notably, over 100 elite lines of summer crop genetic resources have been identified and shared with farmers, research institutions, and other organizations. A significant achievement is the registration of 19 improved landraces from 8 different crops, facilitating their recognition and protection. This registration process, involving landraces with diverse genetic characteristics, has been formalized through the creation of Schedule D in seed regulation, accompanied by the development of technical guidelines. Consequently, numerous landraces and varieties have been successfully registered under this provision. Some of conservation banks are given in Table 4.

Table 4. Conservation banks for summer crop genetic resources in Nepal

Agro gene sanctuary	**Cryo bank**	**Safety backup**
Agrobiodiversity trail	DNA bank	Safety duplication (black box)
Agro-insect field genebank	Field genebank	School aqua pond genebank
Agro-insect genebank	Forage field genebank	School field genebank
Agro-microbial field genebank	Gaushaalaa	School insect field genebank
Agro-microbial genebank	Herbal conservation garden	School mushroom park
Aqua pond genebank	Heritage site	Seed bank
Botanical garden	Household field genebank	Temple garden, holy garden
City park	Household genebank	Tissue bank
Community aqua pond genebank	Household insect field genebank	Village level community agro insect field genebank
Community field genebank	Household seed bank	Village level community aqua pond genebank
Community forestry	Livestock farm genebank	Village level community genebank
Community genebank	Mushroom park	Village level community field genebank
Community river	Office garden, agro-garden	Village level community livestock farm genebank
Community seed bank	Pollen and organ bank	Village level community seed bank
Conservation village	Protected area	Zoo
Crop specific park	Ramsar site	

In the realm of climate resilience, innovative technologies have been developed, encompassing climate-smart breeding and germplasm enhancement using a climate analog tool, cultivar mixtures, and evolutionary plant populations. Community-based initiatives, such as community seed banks, community field genebanks, and community aqua pond genebanks, have been established to further enhance genetic resources. The genetic improvement of landraces, landrace registration techniques, geographical indication, diversity blocks, diversity fairs, diversity field schools, and pre-breeding programs for the identification of dynamic elite lines have also been instrumental in this regard. Moreover, product diversification strategies have been devised for neglected and underutilized crops, aimed at encouraging conservation through utilization. A notable example is the development of Chino Kutak, a method designed in collaboration with the National Agricultural Engineering Research Center to simplify the processing of proso millet.

Furthermore, National Genebank has made ex-situ materials accessible through online databases, allowing easy searches to identify suitable germplasm. To raise awareness and promote the significance of native AGRs, various occasions have been designated, including the celebration of events such as the National Agrobiodiversity Year, National Agrobiodiversity Week and Day, Agricultural Genetic Resources Conservation Day, and National Genebank Day. These festivities are embraced and commemorated by numerous organizations across the country, further contributing to the conservation and appreciation of agrobiodiversity.

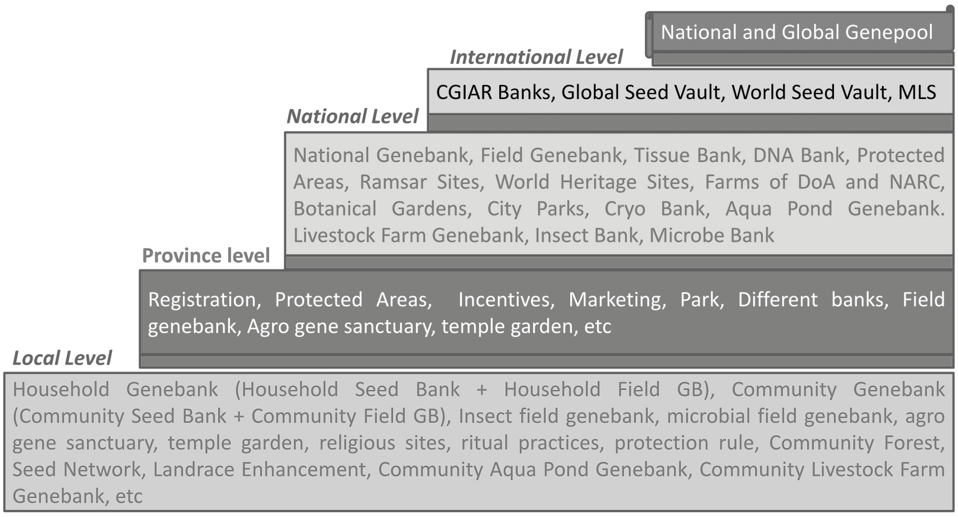

Figure 4. Governance based strategy and methods (good practices & actions) for better management of agrobiodiversity

Source: Joshi et al. (2020), Joshi (2022)

3.5 CURRENT CONSERVATION TECHNOLOGY ADOPTION IN THE NATION

The NAGRC has successfully developed numerous technologies, many of which have been widely embraced throughout the country. Some of these technologies are tailored to specific geographical locations and have found strong acceptance within their designated environments. The online accessibility of germplasm, genetic diversity information, and related data has proven highly valuable, with a substantial number of researchers, students, and farmers utilizing this extensive database. A broad spectrum of stakeholders, including non-governmental organizations (NGOs), international non-governmental organizations (INGOs), government agencies (GOs), farming communities, community-based organizations (CBOs), and private individuals, has actively adopted the technologies generated and pioneered by the National Genebank. Furthermore, select technologies have garnered international recognition and uptake. It is noteworthy that all three tiers of government in Nepal have also integrated specific technologies into their mainstream operations, attesting to the widespread impact and applicability of these innovations.

3.6 ENHANCING CONSERVATION TECHNOLOGY ADOPTION AND ADDRESSING RESEARCH GAPS

Many technologies, such as the Field Genebank, Landrace Registration, Community Seed Bank, and the Promotion of Native and Local Genetic Resources, have been widely embraced and integrated across various regions. However, the adoption of certain technologies has been hindered by factors such as limited awareness and capacity, the development of location-specific solutions, insufficient prioritization by key stakeholders, absence of supportive policies, inadequate investment, and a lack of promotional efforts. Identifying and addressing these barriers is vital in promoting wider technology adoption and ensuring their successful implementation.

Research on native and local summer crop genetic resources remains significantly underexplored. A noteworthy research gap is evident in both basic and applied action research aimed at enhancing the competence of native germplasm. Additionally, areas such as pre-breeding, the utilization of molecular markers, the creation and utilization of searchable databases, nutritional assessments, the amplification of ecological services, the assessment of genetic diversity's impact in agricultural fields, geographical indication strategies, use values, and product diversification all present notable research gaps. Closing these knowledge gaps is pivotal in advancing our understanding of summer crop genetic resources and fostering their sustainable utilization and conservation.

3.7 CHALLENGES IN THE EFFECTIVE EXTENSION OF DEVELOPED TECHNOLOGIES

The National Genebank is at the forefront of technology development related to the conservation and utilization of germplasm. However, several critical issues have hindered the efficient dissemination of these technologies. One of the primary challenges is the insufficient capacity in conservation sciences among stakeholders, limiting their ability to effectively promote and utilize these advancements. Native and local agrobiodiversity has often received low priority, further impeding their widespread adoption. Some technologies, despite their significance, do not yield immediate, tangible benefits, which has curtailed their extension efforts. On the positive side, site-specific germplasm-based technologies developed by the Genebank have demonstrated success in their target locations. Nonetheless, the absence of a searchable database, containing essential germplasm characteristics, remains a significant hurdle for the extensive utilization of ex-situ materials in research, production, and education.

Key problems and challenges include the lack of a web portal and passport application, difficulties encountered in regenerating and multiplying various crops and plants in Khumaltar, limited screening environments, incomplete adaptation of the accessioning system nationwide, the absence of essential legislation and guiding documents, including the Agrobiodiversity Act and relevant policies, as well as the inadequate allocation of in-situ sites for agrobiodiversity. The absence of an emergency fund for urgent maintenance work, poorly managed and inaccessible databases, and the yet-to-be-initiated DOI and DNA barcoding are additional issues. The underutilization of conserved germplasm, insufficiencies in budget allocation, staffing, and the establishment of a cryo bank, inadequacies in mechanization, and the neglect of conservation efforts for aquatic, livestock, insects, microorganisms, and forage AGRs are also significant problems. The conservation of agrobiodiversity, despite its paramount importance, often lacks priority, and many good practices related to its conservation have not been integrated into mainstream agricultural practices. The overreliance on foreign germplasm, limited utilization of germplasm under the ITPGRFA - Multilateral System, genetic erosion in AGRs, issues related to identification and duplicates, and the ineffective functioning of intellectual property rights within AGRs compound the challenges. Furthermore, the uncertain market for native products and the need for more insect, microbe, and bird-friendly production and research areas add to the complex landscape of issues facing the National Genebank's conservation and utilization efforts.

4. CONCLUSION

Many of the summer crop genetic resources (SCGRs) remain under the threat of being lost from agricultural fields. The prevalent practice of monocropping should be revised, and farming methods that promote genetic diversity should be encouraged. Relevant stakeholders should adopt both static and dynamic conservation strategies to ensure the preservation of these resources. Prioritizing the implementation of various good practices, of which 101 good practices have already been identified, is crucial for the long-term conservation and sustainable utilization of SCGRs. Notable among these practices are the establishment of a Field Genebank, Aqua Pond Genebank, Agro-Insect Field Genebank, Evolutionary Crop Population, Forage Field Genebank, Agro Gene Sanctuary, *Raithane* Nursery, School Field Genebank, and Herbal Conservation Garden. Essential routine tasks, such as documentation, germplasm and passport collections, characterization, and database management, should be diligently continued. Red zoning and red listing of SCGRs play a pivotal role in prioritizing and taking action for the conservation of endangered germplasm. Moreover, the collected germplasm has been underutilized in research and education, emphasizing the need to develop site-specific varieties that can compete on a global scale. Effective collaboration among local, provincial, and national-level organizations is essential, and the implementation of various conservation methods should be pursued collectively.

DECLARATION

The authors declare no conflict of interest.

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EFFECTS OF MULCHING MATERIALS ON GROWTH AND YIELD OF BRINJAL

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ABSTRACT

Brinjal; a valuable vegetable, is susceptible to weeds and moisture stress that can hinder growth and yield. Mulching might be a good option to control weeds and moisture to enhance growth and yield. So, an experiment was conducted with five treatments viz. black silver coated mulch (BSCM; 100 gauge), black polythene mulch (BPM; 300 gauge), straw mulch (8 t ha^{-1}), corrugated fiber box mulch (CFBM), and an unmulch group replicated for four times in randomized complete block design at Horticulture Research Station, Pokhara in 2022. Results revealed that BSCM showed the highest marketable yield (23.78 t ha^{-1}) which was statistically similar to straw mulch (20.44 t ha^{-1}) and BPM (19.64 t ha^{-1}) and the lowest (12.1 t ha^{-1}) was observed in the unmulch (12.1 t ha^{-1}). Plant height (134.1 cm), primary root length (40.95 cm), and secondary root numbers (23.25) were observed significantly higher in BPM which was statistically similar ($p>0.05$) with BSCM and straw mulch. The number of branches (7.325), the fruit length (23.2 cm), and fruit diameter (2.5 cm) were found higher in BSCM. Findings suggested that applying different types of mulching materials can effectively enhance the growth and yield of brinjal.

Keywords: Black plastics, Black silver, Brinjal, Pokhara Lurkee, Yield

1. INTRODUCTION

Brinjal, scientifically known as *Solanum melongena* L., is a significant vegetable in the Solanaceae family and is one of the most important vegetable crops predominately grown extensively in tropical and sub-tropical areas throughout the world. It is primarily grown for its unripe fruits, which are used in various culinary preparations, pickling, and dehydrated food industries. Additionally, brinjals are known for their medicinal properties and are particularly rich in vitamin A, making them beneficial for diabetic patients. Although brinjals are technically perennial plants, they are commercially grown as annual crops (Joshi, 2003).

The yield of brinjals in Asia stands at 34.15 t/ha, covering an area of 17,18,049 ha (FAO, 2022). In Nepal, the statistics for brinjal cultivation are 11,292 ha in area, with a total production of 149,075 t, and a productivity of 13.20 t/ha. In the Kaski district of Nepal, brinjal are grown on 125 ha, yielding 2,136 t of produce with a productivity of 17.08 t/ha (MoALD, 2023). The low productivity of brinjal in Nepal is attributed to various biotic and abiotic factors, as well as the absence of suitable cultivars (Joshi, 2003).

Brinjal crops face daily reductions in yield due to the influence of biotic and abiotic factors. Insect pests, such as aphids, brinjal fruit, and shoot borers, are known to affect the crop (Gallo et al., 1988). Other factors like high temperatures, excessive soil humidity, salinity, water stress, and weed competition can lead to significant yield reduction (Attna et al.,

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2023). Weed interference alone has been reported to cause annual crop losses of up to 70%, with a 45% annual loss in sole brinjal crops (Marahatta, 2018). To mitigate these factors, mulching, particularly plastic mulch, has been found effective (Patil et al., 2013). Plastic mulches provide benefits such as weed control, temperature regulation, and reduced salinity, resulting in decreased water loss from the soil (Atta et al., 2023).

Water is a crucial resource in agriculture, and there is often a disparity between the available water and the water required for crop irrigation. Innovative irrigation techniques such as mulching can improve water use efficiency by storing a maximum amount of water in the root zone while minimizing deep percolation losses (El-Beltagi et al., 2022).

In agriculture, two main types of mulches are used: organic mulch, consisting of natural materials like straw, newspaper, dry leaves, sawdust, and compost, and inorganic mulch, which includes materials like plastic mulch, synthetic mulch, and polyethylene film (Memon et al., 2017). Studies have shown a substantial increase in brinjal yield when mulched with materials such as transparent foil (28.3% increase), polyethylene film (15.9% increase), and black polypropylene textile mulch (11.6% increase) compared to conventional cultivation methods (Sowinska et al., 2016). Plastic mulch, in particular, offers advantages like weed control, temperature regulation, and reduced salinity, resulting in less water loss from the soil. Various types of mulches, such as plastic sheets and biodegradable films, are used by farmers to promote plant growth and enhance crop yield.

Research has demonstrated that mulching positively impacts crop growth, yield, and overall cropping outcomes for brinjal cultivation (Ashworth & Harrison, 1983). Grafted brinjals with a 25µ plastic mulch thickness have been found to yield higher produce (Rajasekar et al., 2017). Plastic mulch has been shown to enhance fruit to mature earlier, and higher quality of vegetable crops (Raina et al., 1999; Bharadwaj, 2013).

2. MATERIALS AND METHODS

The experiment was carried out in the vegetable research unit of Horticulture Research Station, Malepatan, Pokhara, Kaski district in western Nepal from February to July 2022. The region lies at the latitude and longitude of 28°13’6.8” and 83°58’27.72” respectively, and a height of 848 meters above sea level. The station has a subtropical humid climate. The soils have a sandy loam texture and are deep and well-drained. The region has an average monthly minimum and maximum temperatures between 13.37 °C in February and 30.64 °C in June and receives a total average rainfall of 74.7 and an average RH was 72.38% within the cultivation period (HRS, 2023).

For the experiment, Pokhara Lurkee brinjal variety was selected. The experiment was laid out in a randomized complete block design (RCBD) with five numbers of treatments (black silver coated mulch (100 gauge), black polythene mulch (300 gauge), straw mulch @ 8 t/ha, corrugated fiber box mulch, control (no mulch) group with four replications. All treatments involved transplanting the brinjal seedling into a raised seedbed. On the last week of February 2022, a nursery bed of 2m long and 1m wide with decomposed FYM (5 kg/m^2) and vermicompost (1 kg/m^2) was mixed with soil, and the elevated nursery bed (15–20 cm) was thoroughly prepared. The seeds were planted in rows at a shallow depth and a distance of 10 cm, 5 cm apart. After that, finely sieved leaf mold was lightly sprinkled on top of the rows of seeds. Seedlings developed after 40 days, which were 10 to 15 cm tall and had three to four leaves, were prepared for transplantation. The plot was supplied with 25 ton/ha farm yard manure and 5 ton/ha vermicompost as basal dose at the time of preparation, and seedlings were transplanted on the field on April 3, 2022. The plot size was 7.4 m^2 and had 60 cm × 60 cm spacing.

Five plants from each plot were taken as sample plants and an average of those was taken as final data from each plot. Growth parameters, assessed at 75 days after transplanting (DAT) and at final harvest, encompassed various aspects of plant development. Plant height was measured with measuring tape from the ground surface to the tip of the plants while stretching. The number of leaves per plant was counted, with only healthy leaves being considered. Leaf area was determined by measuring the length from apex to bale and breadth at three positions on each of five leaves from a single sample plant, multiplying the length and breadth of each leaf to obtain the leaf area. Similarly, the number of branches was recorded, taking into account only healthy branches. After the final harvest, primary root length was measured by uprooting five sample plants and utilizing a measuring tape. Additionally, the number of secondary roots was counted from the same set of uprooted plants.

For yield parameters, measurements were taken to evaluate fruit production. The number of fruits per plant was determined by counting the fruits on five sample plants. Fruit length was gauged by placing a rope alongside the fruit and measuring it with a meter scale. Fruit diameter was measured at three positions on each fruit per sample plant using a digital vernier caliper, with the average diameter calculated thereafter. Fruit yield per plant was obtained by weighing the harvested fruits from all plots using a machine. Moreover, marketable yield per hectare was computed by removing diseased and unsuitable fruits for human consumption and weighing the remainder from each plot using the same weighing machine. After the final data was obtained it was inserted into MS-Excel and analysis of variance (ANOVA) was performed on the data using GENSTAT 15th Edition after ensuring that they met all of the ANOVA assumptions. Duncan's multiple range test (DMRT) was employed to separate the means. The least significant difference (LSD) test at a 5% level of significance was used to assess the significant differences between the types (Gomez & Gomez, 1984).

3. RESULTS

3.1 GROWTH PARAMETER

Plant height

There was a significant difference between the plant height of brinjals with different mulching materials at a p-value of 0.014. Brinjals mulched with black polythene (134.1 cm) had the tallest plant height and brinjals with control (110.6 cm) had the smallest plant height. However, brinjals with straw mulch (121.4 cm) and brinjals with black silver coated mulch (127.5) were statistically at par with both brinjals mulched with black polythene and control. Brinjals mulched with corrugated fiber box shows the same result as that of control which has a lower mean value than brinjals mulched with black polythene, black silver, and straw.

Number of leaves per plant

The effect of mulching materials on brinjal's number of leaves per plant differed significantly at a p-value of 0.017. The highest number of leaves per plant was observed with brinjals mulched with black silver (187.8) which was statistically at par with brinjals mulched with black polythene (178), corrugated fiber box (153.8), and straw (170). The lowest number of leaves per plant was observed in control (110.1).

Leaf area

Leaf area (measured in cm^2) for the different mulching materials was found to be significantly different. Brinjals mulched with black silver had the highest leaf area (401.0 cm^2) as the lowest leaf area was found in control (268.3 cm^2) and was statistically at par with brinjals mulched with corrugated fiber box.

Number of branches

Mulching materials had a significant effect on number of branches. More branch number was found on brinjals mulched with black silver (7.3) and was statistically similar to brinjals mulched with black polythene (6.9) and corrugated fiber box (6.4). Control (5.4) had a smaller number of branches and was statistically at par with brinjals mulched with both straw (6.2) and corrugated fiber box (6.4).

Primary root length

The effect of mulching materials on brinjal's primary root length differed significantly at a p-value of 0.008. The longest primary root was found in brinjals mulched with black silver (41.30 cm) and was statistically at par with all other mulching materials except control (32.80 cm).

Secondary root numbers

The mulching materials significantly impacted the brinjal's secondary root number. More secondary root number was found on brinjals mulched with black silver (25.70) and was significantly at par with brinjals mulched with black polythene (23.25), straw (22.40) & corrugated fiber box (21.75), and fewer secondary root numbers were recorded in control (17.65).

Days to 50% flowering

Days to 50% flowering in brinjals were significantly influenced by the mulching materials. The shortest duration to reach 50% flowering was observed in mulched with black silver (42.75 days), which was statistically different from all other treatments. Black polyethylene (46.0 days) and straw mulch (47.25 days) also showed relatively shorter durations, and they were not significantly different from each other. Corrugated fiber box mulch had a longer duration of 50% flowering (48.75 days), but it was still shorter compared to the control (54.50 days).

Table 1. Effect of mulching materials on plant height, number of leaves per plant, leaf area, number of branches, primary root length, secondary root numbers, and days to 50% flowering of brinjal cultivated at HRS, Malepatan during cropping season 2022

Mulching Materials (Treatments)	**Plant height (cm)**	**Number of leaves per plant**	**Leaf area (cm^2)**	**Number of branches**	**Primary root length (cm)**	**Secondary root numbers**	**Days to 50% flowering (Days)**
Black polythene (300 gauge) mulch	134.1[a]	178.0[a]	366.2[b]	6.925[ab]	40.95[a]	23.25[a]	46.0[c]
Black silver (100 gauge) mulch	127.5[ab]	187.8[a]	401.0[a]	7.325[a]	41.30[a]	25.70[a]	42.75[d]
Corrugated fiber box mulch	113.6[bc]	153.8[a]	292.5[cd]	6.4[b]	39.40[a]	21.75[a]	48.75[b]
Straw mulch	121.4[abc]	170.0[a]	318.8[c]	6.250[b]	40.17[a]	22.40[a]	47.25[bc]
Control (no mulch)	110.6[c]	109.1[b]	268.3[d]	5.450[c]	32.80[b]	17.65[b]	54.50[a]
Grand Mean	121.4	159.9	329.4	6.47	38.92	22.14	47.85
p-value	0.014	0.017	<0.001	0.001	0.008	0.01	<0.001
$LSD_{(0.05)}$	13.52	43.71	28.78	0.770	4.482	3.991	2.332
CV (%)	7.2	17.7	5.7	7.3	7.5	11.6	3.2

Note: LSD= Least Significant Difference, CV= Coefficient of Variation, means in column with the same superscript is not significantly different by DMRT ($p<0.05$).

3.2 YIELD PARAMETERS

Number of fruits per plant

The average number of fruits produced by each plant for the various mulching materials was not significantly different from one another, but the highest number of fruits per plant was found to be in brinjals mulched with straw mulch (42.8), and the lowest number of fruits per plant was found in brinjals mulched with black polythene (30.4).

Fruit length

Mulching materials had a significant effect on brinjal fruit length. Brinjals mulched with black silver had the highest fruit length (23.3 cm) and it is statistically at par with brinjals mulched with straw (20.2 cm), corrugated fiber box (19.3 cm), and black polythene (18.5 cm). The fruit length of the control (17.1 cm) was found to lowest as compared to brinjals with other mulches.

Fruit diameter

There was a significant difference in the fruit diameter of brinjals with different mulching materials. Brinjals mulched with black silver had the largest fruit diameter (2.5 cm), while brinjals in control (no mulch) (2.2 cm) had the smallest fruit diameter. However, brinjals mulched with straw (2.1) were statistically at par with brinjals mulched with black silver, control black polythene (2.15), and corrugated fiber box (2.1).

Fruit yield/plant

The mulching materials significantly impacted the fruit yield per plant of brinjal. The highest fruit yield/plant (0.856 kg) was observed in brinjals mulched with black silver which was statistically at par with brinjals mulched with black polythene (0.707 kg), straw (0.736 kg), and corrugated fiber box (0.655 kg). The lowest fruit yield/plant was found in the control (0.438 kg).

Marketable yield

There was a significant difference between the marketable yield of brinjals on different mulching materials used. Brinjals mulched with black polythene (19.6 t/ha) had the highest marketable yield, while those mulched with black silver (23.7 t/ha) were statistically at par with brinjals mulched with straw (20.4 t/ha) whereas control (12.1 t/ha) had the lowest marketable yield.

Table 2. Effect of mulching materials on fruit length, fruit diameter, number of fruits per plant, fruit yield/plant, and marketable yield of brinjal cultivated at HRS, Malepatan, Nepal during cropping season 2022

Mulching Materials (Treatments)	**Fruit length (cm)**	**Fruit diameter (cm)**	**Number of fruits per plant**	**Fruit yield/ plant (kg)**	**Marketable Yield (ton/ ha)**
Black polythene (300 gauge) mulch	18.5^{b}	2.15^{b}	30.35^{b}	0.707^{a}	19.64^{ab}
Black silver (100 gauge) mulch	23.3^{a}	2.56^{a}	32.05^{ab}	0.856^{a}	23.78^{a}
Corrugated fiber box mulch	19.3^{b}	2.16^{b}	35.25^{ab}	0.655^{ab}	18.19^{b}
Straw mulch	20.2^{ab}	2.27^{b}	42.75^{a}	0.736^{a}	20.44^{ab}
Control (no mulch)	17.1^{b}	2.06^{b}	34^{ab}	0.438^{b}	12.17^{c}
Grand Mean	19.7	2.2	34.9	0.678	18.8
p-value	0.019	0.016	0.150	0.001	0.001
$LSD_{(0.05)}$	3.3	0.273	-	0.156	4.335
CV (%)	11.2	7.9	10.2	14.9	14.9

Note: LSD= Least Significant Difference, CV= Coefficient of Variation, means in column with same superscript is not significantly different by DMRT ($p<0.05$).

4. DISCUSSION

The utilization of mulching materials in brinjal cultivation has demonstrated a significant impact on various growth parameters and ultimately on fruit yield. Ashrafuzzaman et al. (2011) noted that mulching enhanced plant height, primarily attributed to the improved availability of soil moisture and optimal soil temperature. In addition, the conducive microclimate created by mulches facilitated increased leaf area by providing an environment favorable for cell expansion and elongation, as reported by Li et al. (2004). This, in turn, contributed to a higher number of leaves per plant, as observed in the work of Joshi et al. (2019). The research also highlights that the choice of mulching material can influence the vegetative and fruiting characteristics of brinjal plants. Plastic mulch, as shown by

Mahadeen (2014), significantly increased all growth parameters, and ultimately fruit length, diameter, number of fruits and leaves, fruit yield per plant, and marketable yield due to the improvement in moisture conservation and availability in the soil. Similar results were also shown by Mcmillen (2013) due to better moisture conservation and reduced evaporation rates. Furthermore, weed control, facilitated by mulches, as advocated by Viradiya (2013), has a profound impact on yield as it reduces competition for nutrients, space, and light, leading to higher marketable yields. Some free-flying insects need light from the sun to maintain their horizontal orientation while they are in the air; however, when light from the ground enters their body, they are unable to carry on with their regular flight pattern. The typical orientation of flight is disrupted by the light reflection from below when the ground is covered with black silver-coated plastics contributing to higher marketable yield (Shimoda & Honda, 2013). Overall, mulching materials offer an effective means to optimize brinjal cultivation, enhancing plant growth, fruit development, and yield, with silver plastic mulch emerging as a promising choice for improved results.

5. CONCLUSION

In conclusion, the study conducted at the Horticulture Research Station in Malepatan, Nepal, during the 2022 cropping season underscores the significant impact of various mulching materials on brinjal growth and yield. Among the mulching materials tested, black polythene mulch resulted in the tallest plants, while black silver coated mulch demonstrated superior performance in terms of leaf number, leaf area, branches, primary root length, and secondary root numbers. Remarkably, brinjals with black silver-coated mulch produced the longest fruit length and largest fruit diameter. It also achieved the highest fruit yield per plant and marketable yield, followed by straw mulch. Choosing the right mulching material is crucial for successful brinjal cultivation, offering advantages like moisture retention, temperature control, microclimate optimization, and weed suppression, all leading to improved growth and yield. Notably, black silver-coated mulch stands out as a promising choice due to its positive impact on various growth and yield parameters. Further research and field trials are needed to fine-tune these techniques to suit various agricultural contexts, promoting sustainable and efficient brinjal cultivation.

DECLARATION

The authors declare no conflict of interest.

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