*Agronomy Journal of Nepal. **7**(1):57-64*
ISSN:2091-0649(Print)
DOI: https://doi.org/10.3126/ajn.v7i1.62084

Effects of Crop Geometry and Split Nitrogen Application on Spring Maize Growth, Yield Components and Yield in Digam, Gulmi, Nepal

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Received: April 25, 2023
Revised: June 5, 2023
Published: July 10, 2023

OPEN ACCESS

The authors declare that there is no conflict of interest.

ABSTRACT

Maize (*Zea mays* L.) is a heavy nutrient feeder that needs optimum spacing and appropriate time to apply nitrogen to get maximum yield. A field study was carried out at Digam, Gulmi, from February to June 2022 to examine the impact of crop geometry and split application of nitrogen on spring maize in two factorial randomized complete block design (RCBD) with four replications. Factor A was the split application of nitrogen; (120 kg ha^{-1}N at the time of sowing) and (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage) and factor B included the three levels of spacing (75 cm x 25 cm, 60 cm x 25 cm and 50 cm x 25 cm). Plant height , stem girth , leaf number, cob girth, thousand grain weight, number of kernel rows per ear, number of kernels per row, and grain yield (3.45 MT ha^{-1}) were all highest for treatment (60 kg ha^{-1}N at sowing + 30 kg ha^{-1}N at knee height + 30 kg ha^{-1}N before tasseling). Likewise, plant height, leaf area index, cob length, cob girth, cob weight, thousand grain weight, number of kernels per row, grain yield (3.04 MT ha^{-1}) and harvest index were highest in plant spaced at (75 cm x 25 cm), while the number of kernel rows per ear was highest in plants spaced at (60 cm x 25 cm). The lowest value of all parameters was found in plants at treatments; (120 kg ha^{-1}N at the time of sowing) and (50 cm x 25cm*)*. Similarly, the treatment (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage) combined with spacing of (60cm x 25cm) was found to have a significant effect on grain yield (3.99 MT ha^{-1}) which was statistically at par to the treatments, (60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1} N before tasseling stage) combined with spacing of (75 cm x 25 cm) (3.95 MT ha^{-1}) . Thus, for the optimum and sustainable production of the spring maize, crop geometry of (75 cm x 25 cm) or (60 cm x 25 cm) can be recommended with three splits application of nitrogen at Digam, Gulmi.

Keywords: Maize, Spacing, Split application of nitrogen, Yield

How to cite this article:
Ghimire P, S Sharma, K Gyawali and P Bhusal. 2023. Effects of Crop Geometry and Split Nitrogen Application on Spring Maize Growth, Yield Components and Yield in Digam, Gulmi, Nepal. Agronomy Journal of Nepal. 7(1):57-64. DOI: https://doi.org/10.3126/ajn.v7i1.62084

INTRODUCTION

Maize (*Zea mays* L.), also known as corn, is a versatile cereal grain cultivated around the world for over nine thousand years, initially by indigenous peoples in southern Mexico (Matsuoka et al 2002). Its adaptability makes it one of the most widely grown crops, thriving in temperate, subtropical, and tropical regions. Maize varieties include field corn, high-oil maize, waxy maize, and quality protein maize, serving as a crucial source of food, animal feed, and industrial raw materials for billions of people (ICAR 2022). Maize, also called the 4F plant, is used for food, feed, fodder, and fuel. It is a multi-purpose and multi-income commodity. Globally, maize covers 193.7 million hectares, yielding nearly 1147.7 million metric tons, with an average productivity of 5.75 MT/ha (FAO 2020). Its usage is diverse, with 61% for feed, 17% for food, and 22% for industrial purposes. Maize plays a vital role in the agricultural economy, contributing significantly to various sectors, including feed, starch, and biofuel. Its extensive applications, contributing to over three thousand goods, highlight its economic importance (ICAR 2022). It is the most dominant cereal crop in Nepal, coming in second to paddy in terms of area (9,79,776 ha) and production (29,97,733 metric tonnes), with a productivity of 3.06 tonnes per hectare (MoALD 2021). In different regions of Nepal, maize serves as a food staple in mid-hills and high hills and as animal feed in the terai and inner terai. However, in the western terai plain, there is a significant fallow period between winter crop harvesting and rice planting. This period can be utilized for spring maize cultivation, especially in areas with available irrigation water. Despite the potential, farmers lack knowledge regarding optimal crop management, including fertilizer application and plant population (Ghimire et al 2016). To address this gap, the current research focuses on providing valuable insights to farmers in Digam, Gulmi, specifically concerning crop density and the optimal number of split applications of Nitrogen for spring maize. The study aims to enhance spring maize productivity by optimizing crop geometry and nitrogen application, offering practical guidelines for local farmers.

MATERIALS AND METHODS

Experimental site

This experiment was carried out at Chatrakot rural municipality-4, Digam, Gulmi, from February to June 2022. Digam is located at latitude: 27 °58′12" north and longitude: 83°21′21" east and at an altitude of 746 masl.

Soil properties

For the routine soil test, soil analysis was done before conducting the research by taking samples randomly from each replication. A soil kit box was used for the analysis. The shovel was used to collect soil samples from 0 to 15 cm deep. The collected samples were dried, and made fine.

Table 1. **Chemical analysis of soil**

S.N	Soil properties	Values	Methods
1	pH	6.7	Soil kit-box method
2	Nitrogen %	Medium	Soil kit-box method
3	Soil available phosphorous	Medium	Soil kit-box method
4	Soil available potassium	Low	Soil kit-box method

Experiment design

A two-factorial, randomized complete block design with four replications and six treatments was used to conduct the experiment. Factor A was the split application of nitrogen; (120 kg ha^{-1}N at the time of sowing) and (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage) and Factor B was the three levels of spacing (75 cm x25 cm, 60 cm x25 cm and 50 cm x25 cm).

Table 2. Treatment combination

Factor A: Split application of nitrogen	
1	120 kg ha^{-1}N at the time of sowing (A1)
2	60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage (A2)
Factor B: Spacing	
1	75 cm x25 cm (B1)
2	60 cm x 25 cm (B2)
3	50 cm x 25 cm (B3)

Plot size, layout and crop sowing

There were 24 plots each measuring 3 m x2.75 m (8.25 m^2) with a total of 24 plots. Plots were separated by 50 cm. Plants were arranged inside the plots according to the treatments from the research. Five plants were taken as samples from each plot. Seed treated with Bavistin (2g kg^{-1} of seed) was sown with a help of jab-planter after final land preparation. Sowing was done on February 27, 2022.

General cultural practices

The field was plowed with a mini-tiller 15 days before seed sowing to bring the soil under good tilth. The FYM @5 kg per plot area (8.25 m^2) was applied to all experimental plots. During the first land preparation, it was uniformly mixed into the soil. The recommended dose of NPK used was 120:60:40 N:P_2O_5:K_2O kg ha^{-1} (AITC 2078). The first manual weeding was done when the plants reached a knee-high stage. After that, a second manual weeding along with earthing up was performed thirty days after the first weeding. Harvesting was done on June 27, 2022, manually.

Observation recorded

A biometrical observation like plant height, number of leaves, and leaf area index; phenological observations like days to 50% tasseling, days to 50% silking, and yield-attributing characteristics like cob length, number of kernel rows per cob, number of kernels per row, thousand grain weight, grain yield and harvest index were calculated. Grain yield (MT ha^{-1}) was calculated using the following formula:

$$Yield\left(\frac{Kg}{ha}\right) = \frac{10000}{A \times B} \times \frac{C \times R \times K \times TGW}{1000 \times 1000}$$

Where,
A = Row-to-Row spacing (m)
B = Plant-to-Plant spacing (m)
C = Number of cobs per plant
R = Number of rows per cob
K = Number of kernels per kernel row
TGW= Thousand grain weight (g)

The harvest index (%) was calculated by using the formula given below:

$$HI\ (\%) = \frac{EY}{BY} \times 100$$

Where,
HI = Harvest index
EY = Economic yield (Mt ha^{-1})
BY = Biological yield (Mt ha^{-1})

Leaf area index (LAI) was measured by given formulae;

LAI = Leaf area / Spacing

Where,
Leaf area = Leaf length x leaf breadth x K
and K = Correction factor (0.776)

STATISTICAL ANALYSIS

The observed data were entered into Microsoft Excel 2010 for analysis in R-studio. A mean comparison using Duncan's Multiple Range Test (DMRT) was performed on the studied data at a 5% level of significance.

RESULTS AND DISCUSSION

Effect on growth characters

Plant height

The taller (144.27 cm) plant height was recorded from the treatment, (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage), which was significantly higher than the treatment (120 kg ha^{-1}N at the time of sowing) (133.7 cm). The availability of sufficient nitrogen at different stages of maize growth would be a contributing factor for the increase in plant height with more nitrogen; nitrogen promotes plant growth and lengthens internodes, which led to a gradual increase in plant height (Adhikari et al 2016). Furthermore, according to Hammad et al (2011), nitrogen can be applied in three splits to grow maize plants to their maximum height. Similarly, altering spacing had a significant effect on plant height as well. It is noteworthy that the highest plant height of 149.58 cm was measured at a spacing of 75 cm x 25 cm. The tallest plants grow in the broader crop geometry, which may be due to access to nitrogen supply (N) at different stages of top dressing rather than more plants at a higher density and closer spacing (Katwal et al 2018). There was no significant interaction effect on plant height between the split application of nitrogen and crop geometry.

Number of leaves per plant

Application of 60 kg ha^{-1}N at sowing time + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage produced the significantly highest number of leaves per plant. When maize received the most divided nitrogen treatments, the number of leaves per plant increased significantly. The delayed vegetative and reproductive development stages were the cause of this (Amanullah et al 2009). There was no significant variation on the number of leaves per plant due to different spacings. Also, there was no significant interaction effect between the split application of nitrogen and crop geometry on the number of leaves per plant.

Leaf area index

There was no significant variation in the leaf area index of maize due to split of application of nitrogen, but the leaf area index of maize was found to be significantly ($p< 0.001$) influenced by different spacings (Table 3). The maximum (0.35) leaf area index was recorded for the plants spaced at 75 cm x 25 cm and the minimum (0.21) was measured for the plants spaced at 50 cm x 25 cm. The outcome is consistent with the findings of Imran et al (2015), who found that the greatest leaf area index was obtained from the lowest plant density and the minimum from the highest plant density. There was no significant interaction effect in number of leaves per plant between the split application of nitrogen and crop geometry.

Days to tasseling and silking

The days to 50% tasseling and 50% silking were significantly ($p <0.05$) influenced by split application of nitrogen but was not significantly influenced by different spacing (Table 3). The treatment (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage) had the most days to 50% tasseling and 50% silking (59 days and 65 days respectively). The nitrogen applied in three splits had prolonged the vegetative growth, which resulted in a higher yield (Rizwan et al 2003). Plant density had no significant effect on the tasseling and silking of maize, according to Gaire et al (2020). There was no significant interaction effect on the number of leaves per plant between the split application of nitrogen and crop geometry.

Table 3. Growth attributing and phenological characters of maize influenced by split application of nitrogen and crop geometry at Digam, Gulmi, 2022

Treatments	Plant height (cm)	Number of leaves per plant	Leaf area index	Days to 50% tasseling (DAS)	Days to 50% silking (DAS)
Split application of nitrogen					
120 kg ha^{-1}N at the time of sowing	133.70^{b}	11.00^{b}	0.28	58.00^{b}	64.00^{b}
60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage	144.27^{a}	12.00^{a}	0.29	59.00^{a}	65.00^{a}
F-test	***	***	ns	*	*
Spacing					
75 cm x25 cm	149.58^{a}	11.00	0.35^{a}	59.00	65.00
60 cm x25 cm	135.83^{b}	12.00	0.28^{b}	59.00	65.00
50cm x25 cm	131.55^{b}	11.00	0.21^{c}	58.00	64.00
F-test	***	ns	***	ns	ns
Interaction (A x B)	ns	ns	ns	ns	ns
CV, %	3.95	5.65	15.51	1.22	1.11
Grand Mean	138.98	11.22	0.28	58.67	64.67

Note: The common letter(s) within the column indicate non-significant difference based on Duncan's Multiple Range Test (DMRT) at 0.05 level of significance, * significant at 5% level of significance ** significant at 1% level of significance, *** significant at 0.1% level of significance (CV – Coefficient of Variation), DAS: Days After Sowing, NS: Non-significant

Effect on yield and yield attributing characters

Yield and yield-attributing characteristics were found to increase with increased inter-row spacing and split nitrogenous fertilizer application. Thousand grain weight, number of kernel rows per ear, number of kernels per row, and grain yield were found to be maximum for the treatment (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage). Likewise, cob length, cob girth, cob weight, thousand grain weight, number of kernels per row, grain yield, and harvest index were highest in plants spaced at (75 cm x25 cm), while the number of kernel rows per ear was found to be greatest in plants spaced at (60 cm x 25 cm). Thousand grain weight, number of kernels per row, and grain yield were found to be influenced by the interaction between both factors.

Cob length

The cob length was significantly influenced by different spacing but not by the split application of nitrogen (Table 4). The greatest cob length was recorded from the plants spaced at 60 cm x 25 cm, which was statistically similar to the treatment 75cm x 25cm but significantly higher than the treatment 50cm x 25cm. The cob length tends to increase with an increase in row spacing (Koirala et al 2020).

Number of kernel rows per ear

The highest number of kernel rows per ear (12.75) was recorded for treatment (60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage), which was statistically significant at 1%. The finding is in agreement with the results of Adhikari et al (2016), who claimed that split nitrogen treatment had a considerable impact on all of the kernel rows per ear. The highest (13.08) number of kernel rows per ear was recorded for the treatment, (60 cm x25 cm), which was statistically similar to the treatment, (75 cm x25 cm) (12.43) and significantly higher than the treatment, (50 cm x25 cm) (10.90). This result is in accordance with the finding of Koirala et al (2020). They stated that different row spacing influences the number of rows per cob and discovered that the highest number of rows per cob (12.7) was significantly lower than row spacing (75 cm x 25 cm), which was statistically equal to row spacing (60 cm x 25 cm) (12.5), followed by row spacing (45 cm x 25 cm) (12.1), and the lowest number of rows per ear was discovered in broadcast (11.7).

Number of kernels per row

For treatment (60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height + 30 kg ha^{-1} N at tasseling stage), the highest (26.18) number of kernels per row was noted. The split nitrogen treatment had a considerable impact on the quantity of kernels per row (Adhikari et al 2016). The largest number of kernels per row was seen for the treatment, (75 cm x 25 cm) (24.21), which was statistically similar to the treatment, (60 cm x 25 cm) (24.19), and significantly greater than the treatment, (50 cm x 25 cm) (23.15). The interaction between split application of nitrogen and crop geometry had significant impact on number of kernels per row (Table 5). The treatments (60 kg ha^{-1} N at sowing + 30 kg ha^{-1} N at knee height stage + 30 ha^{-1} N before tasseling stage) in combination with (75 cm x 25 cm) spacing produced the highest number of kernels per row (26.58), and the treatments (120 kg ha^{-1} N at sowing) in combination with (50 cm x 25 cm) spacing produced the lowest (20.43).

Thousand grain weight

The treatment (60 kg ha^{-1}N at sowing + 30 kg ha^{-1}N at knee height + 30 kg ha^{-1} N before tasseling stage) had the highest thousand grain weight (272.83 g), which was significantly higher than the treatment (120 kg ha^{-1}N at sowing) (253.66 g). The greatest thousand grain weight is obtained with split nitrogen application, which may be because nitrogen is more readily available to the maize plant and percolates less, improving nitrogen usage efficiency (Anwar et al 2017 and Radma and Dagash 2013). The plants spaced at 75 cm x 25 cm produced the highest (295.63 g) thousand grain weight, while the plants spaced (50 cm x 25 cm) produced the lowest (242.25 g). Low grain weight in densely populated plants was likely caused by a lack of photosynthates available for grain development as a result of high interspecific competition, which led to a low rate of photosynthesis and a high rate of respiration due to increased mutual shading (Zamir et al 2011). The interaction between split application of nitrogen and crop geometry had significant influence on thousand grain weight (Table 5). The maximum (327.50 g) thousand grain weight was obtained for treatments (60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1} N before tasseling stage) combined with spacing of 75 cm x 25 cm and the lowest (236.00 g) was recorded for the treatments (120 kg ha^{-1} N at the time of sowing) and (50 cm x 25 cm).

Grain yield

Grain yield significantly varied as a result of split nitrogen application and spacing and their interaction (Table 4). The treatment that generated the maximum (3.45 MT ha-1) grain yield was (60 kg ha^{-1} N at sowing + 30 kg ha^{-1} N at knee height + 30 kg ha^{-1} N before tasseling). It is not advisable to apply a full dose of nitrogen fertilizer at once since the plant cannot consume the entire amount of fertilizer at once, which results in losses. It is recommended to apply N in splits rather than as a single application at the time of planting to increase N use efficiency and yield (Rozas et al 2004). The maximum (3.04 MT ha^{-1}) grain yield was recorded for the treatment, (75 cm x 25 cm), which was similar to the treatment, (60 cm x 25 cm) (3.04 MT ha^{-1}) and significantly higher than the treatment (50 cm x 25 cm) (1.95 MT ha^{-1}).

The findings are constant with those of Abuzar et al (2011), who discovered that the lowest grain yield occurred at the highest population. The grain yield was significantly affected by the interaction between split application of nitrogen and crop geometry (Table 5). The treatments (60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1} N before tasseling stage) combined with spacing of (60 cm x 25 cm) produced the highest (3.99 MT ha^{-1}) grain yield, which was statistically at par with the treatments (60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1} N before tasseling stage) combined with spacing of 75 cm x 25 cm) (3.95 MT ha^{-1}).

Harvest index

The harvest index (Table 4) was significantly influenced at 1% level of significance for crop geometry but was not significantly influenced by the split of application of nitrogen. The maximum (37.40 %) harvest index was recorded for treatment, (75 cm x 25 cm), which was similar to the treatment, (60 cm x 25 cm) (36.88 %) and significantly higher than the treatment, (50 cm x 25 cm) (36.04 %). There was no significant change observed due to interaction between different row spacing and split application of nitrogen (Koirala et al 2020).

Table 4. Yield and yield attributes of maize influenced by different split application of nitrogen and crop geometry at Digam, Gulmi, 2022

Treatments	Cob length (cm)	No. ofkernel rows per ear	No. of kernels per row	Thousand grain weight(g)	Grain yield (MT ha^{-1})	Harvest index(%)	Biological yield (MT ha^{-1})
Split application of nitrogen							
120 kg ha^{-1}N at the time of sowing	16.41	11.52^{b}	21.52^{b}	253.66^{b}	1.90^{b}	36.7	5.16^{b}
60 kg ha^{-1}N at the time of sowing + 30 kg ha^{-1}N at knee height stage + 30 kg ha^{-1}N before tasseling stage	16.58	12.75^{a}	26.18^{a}	272.83^{a}	3.45^{a}	36.7	9.37^{a}
f-test	ns	**	***	**	***	ns	***
Spacing							
75cmx25cm	16.80^{a}	12.43^{a}	24.21^{a}	295.63^{a}	3.04^{a}	37.40^{a}	8.12^{a}
60cm x25cm	17.45^{a}	13.08^{a}	24.19^{a}	251.88^{b}	3.04^{a}	36.88^{a}	8.26^{a}
50cm x25cm	15.24^{b}	10.90^{b}	23.15^{b}	242.25^{b}	1.95^{b}	36.04^{b}	5.42^{b}
F-test	**	**	***	***	***	**	***
CV (%)	6.31	7.93	2.08	5.04	10.69	2.00	11.58
Grand Mean	16.49	12.13	23.85	263.25	2.68	36.77	7.27

Note: The common letter(s) within the column indicate non-significant difference based on Duncan's Multiple Range Test (DMRT) at 0.05 level of significance, * significant at 5% level of significance ** significant at 1% level of significance, *** significant at 0.1% level of significance (CV – Coefficient of Variation), DAS: Days After Sowing, NS: Non-significant

Table 5. Number of kernels per row,thousand grain weight and grain yield as influenced by the interaction between different time of application of nitrogen and crop geometry at Digam, Gulmi, 2022

Treatments	No. of kernels per row	Thousand grain weight (g)	Grain yield (MT ha^{-1})
Interaction of two factors (A x B)			
(120 kg ha^{-1} N at the time of sowing) x (75 cm x 25 cm)	21.85^{b}	263.75^{b}	2.13^{b}
(120 kg ha^{-1} N at the time of sowing) x (60 cm x 25 cm)	22.28^{b}	248.75^{bc}	2.09^{b}
(120 kg ha^{-1} N at the time of sowing) x (50 cm x 25 cm)	20.43^{c}	248.50^{bc}	1.48^{c}
(60kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1} N before tasselings tage) x (75 cm x 25 cm)	26.58^{a}	327.50^{a}	3.95^{a}
(60kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30kg ha^{-1}N before tasseling stage) x (60 cm x 25 cm)	26.10^{a}	225.00^{bc}	3.99^{a}
(60 kg ha^{-1} N at the time of sowing + 30 kg ha^{-1} N at knee height stage + 30 kg ha^{-1}N before tasseling stage) x (50 cm x 25 cm)	25.88^{a}	236.00^{c}	2.41^{b}
F-test	*	***	**
CV (%)	2.08	5.04	10.69
Grand mean	23.85	263.25	2.68

Note: The common letter(s) within the column indicate non-significant difference based on Duncan's Multiple Range Test (DMRT) at 0.05 level of significance, * significant at 5% level of significance ** significant at 1% level of significance, *** significant at 0.1% level of significance (CV – Coefficient of Variation), DAS: Days After Sowing, NS: Non-significant

CONCLUSION

The finding of the study showed that the significantly highest grain yield obtained on treatment (60kg ha^{-1} N at the time of sowing + 30kg ha^{-1} N at kneeheight stage + 30kg ha^{-1} N before tasseling stage) and also under spacing of 60 cm × 25 cm and 75 cm × 25 cm. Hence, we can conclude that the yield of the spring maize can be maximized by sowing the maize at spacing of 75 cm x 25 cm or 60 cm x 25 cm with three splits application of nitrogen at Digam, Gulmi. This study was conducted in only one location and season, and hence may not be applicable to all agroecological zones. Thus, this trial should be replicated in different agroecological zones for further validation.

ACKNOWLEDGMENTS

The Prime Minister's Agriculture Modernization Project (PMAMP) and Agriculture and Forestry University (AFU), who provided funds for the project, are acknowledged with sincere gratitude from the authors. The author especially wants to thank Assistant Professor, Mr. Ananta Prakash Subedi for playing the role of advisor during the research period. The author also expresses heartfelt gratitude to the farmers and all the helping hands in the region.

AUTHOR’S CONTRIBUTION

Praju Ghimire served as the principal researcher throughout the study, conceptualizing the research design and overseeing the cultivation and harvesting processes. Shikha Sharma helped her during data collection and analysis, contributing significantly to the research process. Kabiraj Gyawali and Pooja Bhusal provided valuable suggestions during the manuscript preparation, enhancing the overall quality of the paper. All authors participated in proofreading and made necessary amendments to the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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