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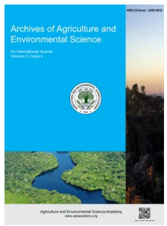

ORIGINAL RESEARCH ARTICLE

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Effect of nitrogen levels on growth and yield of popcorn maize (*Zea mays* var. everta) in Mid Hills, Parbat District, Nepal

Bamdev Regmi[1*], Bidya Ojha[1], Govinda Prasad Sharma[2], Babu Ram Khanal[3] and Dhan Bahadur Thapa[4]

[1]Bachelor in Agriculture, Agriculture and Forestry University, Department of Agriculture, Nepal
[2]Secretary, Ministry of Forests and Environment, Government of Nepal
[3]Associate Professor, Department of Soil Science and Agri Engineering, Agriculture and Forestry University, Nepal
[4]Senior Agricultural officer, Prime Minister Agriculture Modernization Project, Project Implementation Unit, Parbat, Nepal
[*]Corresponding author's E-mail: thebamdevregmi@gmail.com

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ABSTRACT

A field experiment was conducted from March to July 2020 to investigate the impact of varying nitrogen levels on the growth and yield of popcorn maize in Parbat. The experiment was laid out in single factorial Randomized Complete Block Design (RCBD) comprising nine levels of nitrogen: 0, 50, 75, 100, 120, 125, 150, 175 and 200 kg ha^{-1} as treatment with three replications. "Lumle Yellow" variety was cultivated in an acidic (pH 4.9) clay loam soil with moderate levels of total nitrogen (0.19%), high levels of available phosphorus (126.6 kg ha^{-1}), potassium (427.68 kg ha^{-1}), and moderate organic matter content (4.36%). The findings showed that an increased N-level significantly increased plant height and the leaf area index, reaching a maximum at 175 kg N ha^{-1}. While number of cob plant^{-1} and kernel row cob^{-1} were non-significant, yield attributing parameters such as cob length, cob diameter, number of kernel rows^{-1}, thousand grain weight, and grain yield were significant and determined to be maximum at 150 kg N ha^{-1}. With subsequent increases in N to 175 and 200 kg N ha^{-1}, the yield-attributing features did not show an increase. The highest grain yield (4.97 Mt ha^{-1}) produced from 150 kg N ha^{-1} was 98 percent higher than the yield obtained from control (2.5 Mt ha^{-1}) and 28 percent higher as compared to lowest level of N (50 kg ha^{-1}). However, reduction in grain yield was found with increase in N levels above 150 kg ha^{-1}.

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INTRODUCTION

Globally, maize is the third most extensively produced cereal after wheat and rice. Grown maize are classified as dent, pop, flour, flint, sweet, and waxy corns based on its agricultural application (Jugenheimer, 1976; Russell & Hallauer, 1980). Popcorn's ability to pop stems from a unique combination of morphological features that set it apart from other varieties of corn. Popcorn, or maize as it is scientifically called *Zea mays var. everta*, is a type of corn that belongs to the grass family. Popcorn is nutritious and one of the most popular snack foods in the world due to high fiber content and low energy. Of the six forms of maize/corn, only popcorn pops. The other five types are pod, sweet, flour, dent, and flint (Schepers, 1990). Three parts make up a whole grain of popcorn: the germ, endosperm, and pericarp (sometimes called the hull). The conditions for popcorn growth are comparable to those for dent corn, however popcorn is less resilient to harsh weather (Ziegler, 2001). Parbat district lies in mid hills of Nepal. About 32.50% (42,540) population are dependent on agriculture for their livelihood (MoALD, 2022). About 53.26% (28592 ha) land is arable, of which 45.02% (24171 ha) are under cultivation (MoALD, 2022). With a yield of 2.59 Mt ha^{-1}, Parbat district produces 35,500 Mt of maize across 13,700 ha (MoALD, 2022). Majority of people cultivated maize in the summer season (February to July). The productivity of maize (2.59 Mt ha^{-1}) in the Parbat district lags behind the national average (3.10 Mt ha^{-1}) (MoALD, 2022). Major varieties of maize grown in the Parbat district are Manakamana-3, Arun-2 and local varieties. The economic and nutritional value of popcorn in Nepali commercial marketplaces and the significance of popcorn maize as a snack meal are unknown to the farmers in the Parbat district. The maize productivity is highly dependent on chemical fertilizer. A higher yield can be achieved by applying the right amount of nutrients at the right time using the optimal application technique (USDA, 2020). Among these, N is one of the important elements reported for high maize production. Applying enough N at the right time—during crop growth,—and at the right rate results in the highest fertilizer use efficiency and the lowest chance of loss (Stark and Richards, 2008). A study in North China Plain reported loss of around 25% of the reactive nitrogen where farmers applied 300–350 kg N ha^{-1} $season^{-1}$ or even more N fertilizer to meet the food need (Zhang *et al*., 2019).

Among the maize growing areas of Parbat district, Phalewas is a potential area for maize and maize seed production. The Parbat district has witnessed a steady increase in interest in cultivating an enhanced hybrid commercial popcorn (*Z. mays everta*) because of the possibility of greater financial returns compared to the native variety and common corn (AKC, 2019). People do not know how to choose popcorn varieties with high yields or how to manage them, including when to plant, how much fertilizer to use, and how much planting density. Although popcorn is only produced in small quantities in Nepal as a garden crop, demand for it is rising in the domestic market. A large amount of popcorn is consumed in hotels, restaurants, cafes, movie halls, and similar places. Technology improvement is therefore required to maintain and cultivate the popcorn crop in a way that aids in production. In addition, farmers struggle with a number of issues related to irrigation, fertilizer application, soil moisture, daylight hours, and meteorological conditions, all of which have an adverse effect on the productivity and production of popcorn. As a result, the current study helps farmers understand the relative value of growing popcorn maize in arid lowlands. Multiple studies have indicated that the placement of nitrogen fertilizers often has beneficial and significant impacts at different crop growth stages increasing crop growth and production (Adhikari *et al*., 2021; Hammad *et al*., 2022). Likewise, Omar *et al.* (2022) in his studies mentioned the prosect of increase in nutritional value of maize with good N fertilization practice. However, Tamang *et al.* (2024) in his studies pointed forward the concept of threshold, beyond which additional nitrogen does not improve the yield further and might even decline. Henceforth, this study attempts to evaluate how varying amounts of nitrogen fertilizer application can increase popcorn maize productivity by relating phenological and yield-related characteristics.

MATERIALS AND METHODS

A field experiment was conducted from March to July 2020 at Phalewas Municipality-Mudikuwa, Parbat district which is situated at an elevation of 640–2266 meters above mean sea level and is geographically located at 28.190 North latitude and 83.670 East longitude. The average maximum temperature of 30°C and minimum temperature of 9°C were recorded in 2020. The relative humidity varied between 42% in April and 89% in July. The three different seasons of the sub-tropical climate are the rainy monsoon (June-October), the chilly winter (November-February), and the pleasant spring (March-May). Before the experiment, soil samples were taken from each replication a depth of 0 to 15 cm using a shovel. The samples were then analyzed for soil properties, such as available potassium (427.68 kg ha^{-1}), total nitrogen (0.19%), soil type (a clay loam with pH 4.9), and organic matter (4.36%). The experiment was conducted in Randomized Complete Block Design (RCBD) with 9 different doses of nitrogen (0, 50, 75, 100, 120, 125, 150, 175 and 200) N kg ha^{-1} as a treatment with three replications. Each treatment had single row of 12 plants each with spacing row to row of 50 cm and plant to plant of 20 cm and plot size 3×2.6 m^2. *Z. mays var. everta*—Lumle yellow popcorn, was used in the study. It was produced in Gandaki Province, Lumle, Kaski, by the Directorate of Agricultural Research (DoAR) of Nepal Agriculture Research Council (NARC), appropriate for the mid-hill region. A mini-tiller was used to plough the field 15 days before seeding in order to achieve a good tilth. Muriate of Potash (MOP), urea, and Single Super Phosphate (SSP) served as a source of potassium, nitrogen, and phosphate respectively. For each treatment, the recommended amounts of phosphatic and potassic fertilizers, 60 and 40 kg ha^{-1} respectively, were computed and weighed individually. The total amount of nitrogen (N) for each plot was divided into three equal parts. Full dose of phosphorus (P) and potassium (K) and one third of N were applied as basal dose 5 cm apart from maize row at 5 cm depth and second split dose of N was applied as side-dress (top dress) at knee high stage and finally last dose was side dressed at tasseling stage. First hand weeding and earthing up were done at 30 Days After Sowing (DAS) and second-hand weeding were performed at 60 DAS. First irrigation was done at knee high stage and the second irrigation was not needed as the crop growing period fell under rainy season.

RESULTS AND DISCUSSION

Biometric observations

Effect on plant height: Plant height tended to increase as the N rate increased because N promoted vegetative growth in the maize and similar results were reported in Gökmen *et al*. (2001; Türk & Alagöz (2018). The trend of increase in plant height showed better performance in N175 but at 45 DAS, plant height was insignificant, which might be due to effect of initial soil fertility, low moisture and less N uptake. Similar findings were reported in studies of Karki *et al*. (2020). The highest plant height (266 cm) at 120 DAS was obtained in N175 which was significant with control and N50. Iqbal *et al*. (2015) also concluded an increased plant height with an increasing N level up to 180 kg ha^{-1}. The higher plant height was obtained from 175 and 200 kg N ha^{-1} (266 and 263 cm) which were similar to previous studies (Gözübenli & Konukan, 2010 ;Türk & Alagöz, 2018). However, plant height at 200 kg N ha^{-1} was found decreased which might be due to N toxicity. Since the soil already had moderate level of total N before the treatment application, addition of high levels of N might have exceeded the metabolic capability to assimilate NH_4 which could decrease the plant growth. The results were also in accordance with the studies of Huffman (1989). Similarly, the maximum ear height (162 cm) was also found in N175 and similar result was observed in other treatments except control in which the lowest ear height of 137 cm was reported.

Effect on leaf area index: It was observed that Leaf Area Index (LAI) at 45 DAS was not influenced by N levels, it may be due to indigenous soil productivity while the result was significantly influenced at 60, 75 and 90 DAS by nitrogen levels. The studies were similar to that of Gaire *et al.* (2020) in maize where LAI at 30 DAS were found insignificant compared to 60 and 90 DAS. The highest LAI was obtained at 90 DAS as 6.24 in N175 which is statistically similar with N150 (6.21) followed by N200 (6.15). Increase in Leaf area index with increasing effect of N fertilizer were reported by Jasemi *et al.* (2013) and Arif (2015). The increase in leaf area with increased N rates agreed with the findings of Jasemi *et al.* (2013); Shrestha *et al.* (2018) that N influences increased leaf production and elongation.

Effect on phenology

Days to 50% emergence: N levels had no significant impact on days to 50% emergence (Table 3). The mean of 50% emergence of popcorn maize seedlings was found as 11.81 days. This result showed that seeds used their own stored food supplies during germination and did not rely as much on outside nutrition. Binder *et al.* (2000) and Hammad *et al.* (2013) reported similar results of emergence count per unit area.

Table 1. Effect of nitrogen levels on plant height and ear height of yellow Lumle popcorn (*Z. mays var. everta*) at Mudikuwa, Parbat, 2020.

Treatments (kg ha^{-1})	Plant height (cm)					Ear height (cm)
	45DAS	60DAS	75DAS	90DAS	120DAS	
N0	26.61	82^{d}	157^{e}	228^{c}	240^{c}	137^{b}
N50	26.75	90^{cd}	176^{d}	237de	249^{bc}	149^{ab}
N75	28.13	90^{cd}	181^{d}	240^{b}	253^{abc}	154^{a}
N100	29.00	100^{abc}	186^{cd}	241^{b}	262^{ab}	156^{a}
N120	28.93	94^{bc}	191^{bcd}	245^{ab}	261^{ab}	154^{a}
N125	28.46	100^{abc}	201^{abc}	253^{a}	261^{ab}	158^{a}
N150	32.26	108^{a}	203^{ab}	252^{a}	263^{ab}	155^{a}
N175	31.93	107^{a}	210^{a}	254^{a}	266^{a}	162^{a}
N200	32.50	103^{ab}	205^{ab}	255^{a}	263^{ab}	158^{a}
SEm(±)	0.49	1.15	1.89	1.31	1.62	1.97
CV (%)	8.76	6.15	5.16	2.30	3.23	5.02
LSD (0.05)	4.45^{NS}	10.34**	16.97**	9.76**	14.42*	13.38*

Note: *Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT test.) **,* indicates 1% and 5%, level of significance respectively.*

Table 2. Effect of nitrogen levels on leaf area index (LAI) of yellow Lumle popcorn (*Z. mays var. everta*) at Mudikuwa, Parbat, 2020.

Treatments (kgha^{-1})	Leaf Area Index			
	@ 45 DAS	@ 60 DAS	@ 75 DAS	@ 90 DAS
N0	0.38	2.13^{c}	3.34^{c}	4.40^{c}
N50	0.39	2.45^{b}	3.67^{c}	5.47^{b}
N75	0.44	2.52^{ab}	4.18^{b}	5.98^{a}
N100	0.46	2.50^{ab}	4.33^{b}	6.04^{a}
N120	0.46	2.60^{ab}	4.34^{a}	6.13^{a}
N125	0.48	2.63^{ab}	4.36^{b}	6.17^{a}
N150	0.48	2.67^{ab}	4.38^{b}	6.21^{a}
N175	0.49	2.72^{ab}	4.62^{a}	6.24^{a}
N200	0.51	2.73^{a}	4.64^{a}	6.15^{a}
SEm(±)	0.011	0.03	0.02	0.05
CV (%)	13.12	6.23	3.15	4.71
LSD (0.05)	0.10^{NS}	0.27**	0.23**	0.47**

Note: *Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT test.*

Table 3. Effect of nitrogen levels on crop phenology of popcorn maize at Mudikuwa, Parbat, 2020.

Treatments (kg ha^{-1})	Days to 50% emergence	Days to 50% tasseling	Days to 50% silking	Days to physiological maturity	SFD	ASI
N0	12	86.00^{a}	91^{a}	119^{d}	33.00^{e}	5
N50	12	84.66^{ab}	89^{ab}	120^{d}	35.34^{cde}	4.34
N75	11.67	84.00^{ab}	88^{bc}	120.34^{cd}	36.34^{cde}	4
N100	11.67	83.67^{abc}	88^{bc}	122.67^{abc}	39.00^{bcd}	4.34
N120	12	82.33^{bcde}	86^{cde}	121.33^{bcd}	39.00^{bcd}	3.67
N125	12	83.00^{bcd}	87^{bcd}	123.34^{ab}	40.34^{abc}	4
N150	12	81.00^{cde}	85de	124.34^{a}	43.34^{ab}	4
N175	11.34	80.33^{de}	84.34^{e}	124.34^{a}	44.00^{a}	4
N200	11.67	80.00^{e}	83.67^{e}	124.34^{a}	44.34^{a}	3.67
SEm(±)	0.18	0.30	0.27	0.28	0.47	0.14
CV (%)	7.93	1.92	1.67	1.2	6.26	19.01
LSD (0.05)	0.88^{NS}	2.52**	2.51**	2.53**	4.26**	1.35^{NS}

Note**:** *Means followed by the common letter(s) within each column are not significantly different at 5% level of significance by DMRT test.*

Days to 50% tasseling: The days to 50% tasseling were significantly affected by N levels (Table 3). The days to 50% tasseling decreased with increasing N levels from 0 kg ha^{-1}to 200 kg ha^{-1}. Similar results were found in the studies of Adhikari *et al.* (2021) in hybrid maize varieties where an increased in N level from 160 kg ha^{-1} to 220 kg ha^{-1} decreased the tasseling. Days to 50% tasseling was found significantly earlier in N200 (80 days) and N175 (80.33 days) and were at par. It was significantly higher in N0 (86 days) followed by N75 (84.66 days) and N50 (84 days). Higher N doses increased the tasseling earliness due to increased vegetative development. When compared to control, improved vegetative structures (plant height, number of leaves, and canopy) encouraged the early production of tassel under greater N dosages. Dawadi & Sah (2012) also found N application and its increased rate caused tasseling and silking in the maize.

Days to 50% silking: The effect of N management practices on days to silking was significant (Table 3). Silking was found earlier in N200 (83.67 days) which was found statistically similar at N175 (84.34 days) followed by N150. Days to silking was found the longest in control (91 days) and the result was found at par with N50 (89 days). Application of 200 kg N ha^{-1} resulted in earlier silking by 7.33 days as compared to no N application. Higher N application reduces the days to silking in maize because of increased vegetative growth and early initiation of reproductive growth. These outcomes concur with those of Dawadi & Sah (2012) who reported that the increasing N levels from 120 kg ha^{-1} to 200 kg ha^{-1} reduced the days for silking. Gökmen *et al.* (2001) observed decreased silking days with increasing N doses from 0 to 250 kg ha^{-1} N application. Similarly, Rai (1961) and Gaire *et al.* (2020) also reported that higher application of N dose induced early tasseling and silking stage of maize.

Days to physiological maturity: Levels of N altered with the number of days count to physiological maturity (Table 3). Earlier maturity was associated with no N treatment (119 days) and statistically similar with N50 (120 days) followed by N75 (120.34 days). The lengthiest period needed to reach physiological maturity was found in 150, 175, and 200 kg N ha^{-1} (124.34 days) and also statistically at par with 125 kg N ha^{-1} (123.34 days). The above results are in line with the findings of Gaire *et al.* (2020) who reported the shortest period to physiological development (119 days) obtained under 30 kg N ha^{-1}and the longest physiological maturity days (123.17 days) under 90 and 120 kg N ha^{-1}. Similar findings were reported by Shrestha *et al.* (2018). Delayed in maturity at a higher N dose possibly led to its role in staying green. It delays the senescence of leaves and increases the succulence of plants. The earlier maturity with control potentially imparted stress to the crop owing to the deficiency of N. According to Gungula *et al.* (2007), low synthesis and translocation of cytokinin and an elevated ABA content are likely linked to early senescence and short vegetative development stages in cases of N deficit.

Anthesis silking interval: Anthesis Silking Interval (ASI) is one of the very important aspects of maize growing. Higher ASI interval means pollen shedding takes earlier than silk emergence. Therefore, lower ASI is necessary for pollen reception by silk and a higher number of kernel formation in maize. An increase in N levels did not affect the anthesis silking interval (Table 3). However, ASI was found earlier in N200 kg N ha^{-1} (3.67 days), a similar result was obtained in treatment with 120 kg N ha^{-1} and found the longest in 0 kg N ha^{-1}(5 days) in contrast to other levels of N. When maize is planted with increased N, the earliness in tasseling and silking eventually reduces the ASI. This could be because higher N levels induce earliness and accelerate growth of plant. The above findings are in accordance with Hammad *et al.* (2011) who also observed decreasing ASI with higher N levels.

Seed fill duration: Seed Fill Duration (SFD) is the period between anthesis and physiological maturity. In general, longer SFD increases the size of the kernel as plants get more time to accumulate photosynthates in the sink. There was a significant effect of nitrogen on SFD (Table 3). The increment in the rate of nitrogen increased the SFD. The highest SFD (44.30 days) was found in N200 which was followed by N175 (44 days). The lowest SFD (33 days) was observed in the control plot which was statistically similar to N50 (35.34 days) and N75 (36.34 days).

Table 4. Effect of nitrogen levels on cob length, cob diameter, number of kernel row and kernel per row of popcorn maize (*Z. mays var. everta)* at Mudikuwa, Parbat, 2020.

Treatment (kgha^{-1})	Cob length (cm)	Cob diameter (cm)	Kernel row cob^{-1}	kernel row^{-1}	Shelling percentage
N0	14.73^{c}	3.38^{d}	12.8	26.50^{e}	72.23^{b}
N50	15.53^{b}	3.49^{c}	13.20	30.00^{d}	75.49^{ab}
N75	15.73^{b}	3.54^{bc}	13.20	31.06^{cd}	77.53^{a}
N100	15.80^{b}	3.56^{bc}	13.60	31.00^{cd}	77.47^{a}
N120	16.17^{ab}	3.58^{bc}	13.47	32.40^{bc}	75.97^{a}
N125	16.06^{ab}	3.60^{ab}	14.00	33.20^{ab}	75.97^{ab}
N150	16.80^{a}	3.68^{a}	14.27	34.46^{a}	77.90^{a}
N175	16.06^{ab}	3.59^{ab}	14.00	33.80^{ab}	78.88^{a}
N200	16.02^{ab}	3.57^{bc}	13.2	32.93^{ab}	79.18^{a}
SEm(±)	0.84	0.01	0.12	0.20	0.47
CV (%)	2.77	1.65	4.73	3.32	3.15
LSD (0.05)	0.76**	0.10**	1.11	1.82**	4.20*

Note: *Means followed by the common letter within each column are not significantly different at 5% level of significance by DMRT test. **,* indicates 1% and 5%, level of significance respectively.*

Effect on yield attributes

Cob length: A significant variation in cob length was observed between the varying N levels in popcorn (Table 4). Cob length was the longest under N150 (16.80cm) which was similar to N120 (16.17cm) followed by N125 (16.06 cm), N175 (16.06 cm), and N200 (16.02 cm). The shortest cob length (14.73 cm) was observed under the control plot followed by N50 (15.53 cm), N75 (15.73 cm), and N100 (15.80 cm) respectively. The above findings are consistent with those of Gungula *et al.* (2007), who reported that cob length increased as N levels rose, peaking at 120 kg N ha^{-1}. Similarly, a direct relation between the level of N and the length of cob was reported by Turgut (2000); Santos *et al*. (2002) and Ahmad *et al.* (2018). The likely cause of the larger cob length at a higher N level could be the best possible use of solar energy, increased assimilation of photosynthates, and its conversion to starches, as reported by Derby *et al*. (2004).

Cob diameter: Cob diameter was also found significantly influenced by distinct N levels (Table 4). Cob diameter increased significantly with increased N levels up to 150kg ha^{-1}. The N level of 150 kg ha^{-1} produced a greater cob diameter (3.68 cm) which was similar to N125 (3.60cm) followed by N levels of N175 and N200 with 3.59 cm and 3.57 cm respectively. Similarly, a notable increase in cob diameter was seen by Saleem *et al.* (2017) as the amount of N increased. Since there was enough N available, which is necessary for cell division and elongation, a higher dose of N treatment might have resulted in a higher cob diameter. Gul *et al.* (2016) reported significant improvement in the number of rows cob^{-1} and cob diameter with an increase in fertility level. The study also suggests findings of Gungula *et al.* (2007).

Kernel rows cob^{-1}: The number of kernel rows cob^{-1} was not influenced by N levels (Table 4). However, the number of kernel rows rose with increased levels of N from N0 to N150 and reduced on further increasing doses. It was found to be the highest in N150 (14.34). The lowest number of kernel rows was found in the control plot (12.8). The trend of increasing the number of kernel rows with increasing doses of N application was obtained only up to 150 kg N ha^{-1}. Adhikari *et al.* (2021) produced similar findings, showing that hybrid maize varieties kernel row^{-1} showed the least amount of variation (12.98) at 160 kg N ha^{-1}. At larger levels, up to 220 kg N ha^{-1}, the results were comparable. Higher levels of N fertilizer increased the rate of photosynthesis, enzymes, and chlorophyll. Consequently, as the level of N grows, so does the number of kernel rows ear^{-1}. A similar result was also obtained by Gaire *et al.* (2020) with N levels up to 120 kg ha^{-1} and Arif (2015) with 210 kg ha^{-1} N level.

Kernel row^{-1}: The significant response of N levels in the number of kernels row^{-1} was observed (Table 4). Each increment in N levels from 0 to 150 kg N ha^{-1} significantly increased the number of kernel row^{-1} and started to decrease on the above doses. It was found to be the highest in N150 (34.46) and at par with N175 (33.80), N125 (33.20), and N200 (32.93) and was lowest at N0 (26.50) followed by N50 (33.00). The higher number of kernel row^{-1} was also because of a more assimilated supply at higher doses of N. The findings support the studies of Karki *et al.* (2020).

Shelling percentage: Table 4 shows the shelling % as an effect of N level. The maximum shelling percentage (77.6%) was obtained with 200 kg N ha^{-1}, and this result was rather similar to other treatments. Raising the amount of N improved nutrient absorption and encouraged photosynthetic translocation from source to sink, which increased the number of kernels row^{-1} and the number of kernel rows cob^{-1}, raising the percentage of shelling.

Yield data

Thousand grain weight: Thousand-grain weight (TGW) in g is influenced significantly by N levels and is presented in Table 5. The result indicates that the highest (TGW) was found in N150 and similar results were obtained in N125 (183.10g) followed by N175 (181.89 g), N200 (181.87 g), and 100 kg Nha^{-1}(181.81 g). Jasemi *et al*. (2013) obtained similar results with maximum TGW at 150 kg Nha^{-1}. The lowest TGW (163.52 g) was found in the control plot and was statistically at par with N50 (169.02 g). Gökmen *et al.* (2001) reported the increase in TGW with the increasing dose of N due to a higher amount of photosynthates in the grains. Similar outcomes were reported by Adhikari *et al.* (2021).

Table 5. Effect of nitrogen levels on Thousand Grain Weight (TGW), grain yield, and harvest index of popcorn maize (*Z. mays var. everta*) in Mudikuwa, Parbat, 2020.

Treatments (kg ha^{-1})	TGW (g)	Grain yield (mt.ha^{-1})	Harvest index (H.I)
N0	163.52^{d}	2.50^{d}	0.23^{d}
N50	169.02^{cd}	3.62^{c}	0.27^{cd}
N75	173.31^{bcd}	3.66^{c}	0.29^{bc}
N100	181.81^{ab}	4.19^{bc}	0.28^{bc}
N120	175.45^{bc}	4.48^{ab}	0.30^{abc}
N125	183.10^{ab}	4.84^{ab}	0.32^{ab}
N150	186.79^{a}	4.97^{a}	0.29^{bc}
N175	181.89^{ab}	4.65$_{ab}$	0.34^{a}
N200	181.87^{ab}	4.75^{ab}	0.32^{ab}
SEm(±)	1.23	0.08	0.0048
CV (%)	3.63	10.43	8.56
LSD (0.05)	11.14**	0.75**	0.04**

Note: *Means followed by the common letter within each column are not significantly different at 5% level of significance by DMRT test.*

Grain yield: Table 5 demonstrates the effect of different doses of N application on grain yield (mt ha^{-1}). The result indicated that the highest grain yield (4.97 mt ha^{-1}) was obtained under the application of 150kg Nha^{-1}which was similar to N125 (4.84 mt ha^{-1}), N200 (4.75 mt ha^{-}1), N175 (4.65 mt ha^{-1}) and N120 (4.48 mt ha^{-1}). Similarly, the lowest grain yield was observed under control (2.50 mt ha^{-1}) followed by treatment N50 (3.62 mt ha^{-1}) and N75 (3.66 mt ha^{-1}). Up to 150 kg N ha^{-1}, N application greatly boosted grain output; afterward, higher levels to 175 and 200 kg N ha^{-1} did not increase grain yield but were at par. Similar outcomes were seen in research by Dawadi and Sah (2012), where an application of 200 kg N ha^{-1} yielded a grain yield that was higher than that of 120 kg N ha^{-1} application, but at par with that of 160 kg N ha^{-1} application. The reason could be due to the nitrogen use efficiency which is linked with grain yield that decreased with an increase in N level. The study is also supported by findings of Gheith *et al.* (2022). Similar results were noted by Amanullah (2014) who found a negative correlation between an increase in nitrogen rate and nitrogen use efficiency over two years. Increment in yield over control was maximum at N150 (98 %) which was similar to N125 (93%).

Harvest index: The results indicated that an increment in N level gave significant ($p<0.01$) results with harvest index as presented in table 5. The highest harvest index (0.34) was found under N175 which was at par with N200 and N125 (0.32) and the lowest harvest index (0.23) was found under N0 (0.23) and followed by N50 (0.27). Similar findings were found in Amanullah (2014) research, which showed a positive relationship between the harvest index and higher N rate of up to 150 kg ha^{-1}.

Conclusion

The growth, grain production, and yield-related attributes of Lumle yellow popcorn maize were significantly impacted by the application of nitrogen fertilizer. In Lumle yellow popcorn (*Z. mays everta*), the application of nitrogen fertilizer at a rate of 150 kg ha^{-1} increased the yield attributing variables—number of kernel rows^{-1}, cob length, thousand-grain weight, cob diameter, and consequently grain yield—however, couldn't increase above the rate of 150 kg ha^{-1}. The inability to achieve better results with higher nitrogen rates could also suggest that the crop's capacity to utilize nitrogen effectively has been maximized at 150 kg ha^{-1}. Excessive nitrogen beyond this point may not be efficiently used by the plants and could potentially lead to environmental issues or reduced economic efficiency. Accordingly, the study demonstrated that popcorn output could be optimized with fertilization of 150 kg ha^{-1} by applying a basal dose at sowing and a split dose at critical crop stages, like tasseling and knee-high.

DECLARATIONS

Author contribution statement

Conceptualization: B.R. and B.K.; Methodology: B.R.; Software and validation: B.R., B.K. and G.S.; Formal analysis and investigation: B.R., B.O and G.S; Resources: B.R. and B.O; Data curation: B.R and G.S.; Writing—original draft preparation: B.R.; Writing—review and editing: B.O., G.S, D.T and B.R; Visualization: B.R.; Supervision: G.S, D.T. and B.K; Project administration: D.T.; Funding acquisition: B.R. All authors have read and agreed to the published version of the manuscript.

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