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Effect of different doses of nitrogen on growth and yield of maize (*Zea mays*) in Bhadrapur, Jhapa

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ABSTRACT

The aim of the study was to find out the appropriate dose of nitrogen (N) that gives higher productivity and recommend it, as the farmers in Bhadrapur municipality are not aware of the nitrogen dosage due to which they either over-dose or under-dose the maize. A field trial was conducted in a farmer's field to evaluate the effect of different doses of nitrogen on the growth and yield of maize in Bhadrapur, Jhapa, Nepal. Randomized Complete Block Design (RCBD) was used with 7 different treatments which were replicated thrice. The following treatments were used: T1 (Control), T2 (NPK 60:60:60 kg ha^{-1}), T3 (NPK 90:60:60 kg ha^{-1}), T4 (NPK 120:60:60 kg ha^{-1}), T5 (NPK 150:60:60 kg ha^{-1}), T6 (NPK 180:60:60 kg ha^{-1}) and T7 (NPK 210:60:60 kg ha^{-1}). T6 had the tallest (214.45 cm) and the girthiest (2.65 cm) plants which also had a greater number of leaves (13.35) at 60 DAS as compared to others. Similarly, T7 had the longest (22.24 cm) and girthiest (4.98 cm) cobs. T3 had the highest number of lines per cob (16.99). In the case of number of grains per line, T7 had the highest number of grains (37.59). Similarly, in context of thousand kernel weight, grain yield and biological yield, T6 (328.57 gm), T7 (12.22 mt ha^{-1}), and T6 (40.17 mt ha^{-1}) were superior, respectively. T3 had the highest HI (0.32). The Benefit Cost Ratio was seen the highest in T7 with a ratio of 1.5. NPK 180:60:60 kg ha^{-1} can be recommended for foliage production and NPK 210:60:60 kg ha^{-1} can be recommended for grain production as the Benefit Cost Ratio in these fertilizer combinations is comparatively superior.

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1. Introduction

Maize belongs to the family of Poaceae which is a grass family and has a scientific name as Zea mays (Adiaha, 2017). It is one of the most important and versatile emerging crops in the world because of its wider adaptability. It has higher genetic yield potentiality, thus called "The Queen of Cereals" (McKeown, 2002). After wheat, maize is the second most extensively farmed crop in the world, with an estimated 197 million hectares of land cultivated for dry grain each year (Erenstein et al., 2022). According to the estimates, the globe produced 1150.73 million tons of maize in the fiscal year 2022/2023. Of that total, the United States, China and Brazil are the first three highest maize producing countries respectively (Ranum et al., 2014). Nepal produces approximately 1,050 mt of maize seed every year (CDD, 2009). India exports hybrid seeds of maize to Nepal annually which worth 51.5 million US dollars (Sapkota & Pokhrel, 2013). Terai and inner terai have promise for hybrid maize cultivation especially, in the winter season (Dawadi, 2010). Diseases and ineffective crop management are two main biotic and abiotic variables that limit maize productivity. Many diseases can affect maize plants, but in Nepal, bacterial and fungal infections are the most common ones (Subedi, 2015).

With existing crop management techniques, the nation's maize productivity remains low at 2.3 t ha^{-1} (Tiwari et al., 2009). When it comes to high N-demanding crops like maize, N fertilizer is a significant input cost, and yield increases are seen after the application of N fertilizers (Ziadi et al., 2008; Gagnon et al., 2012). The key factor responsible for low yield is found to be the uneven and insufficient use of chemical fertilizers (Shrestha et al., 2013; Devkota et al., 2015). Intensified use of mineral fertilizers and selection of crossovers speak to major pathways to extend maize production in Nepal (Devkota et al., 2015). Low soil fertility and productivity can be attributed to outdated fertilizer dosage recommendations (Thapa, 2021). Due to a lack of knowledge regarding the proper dosage and timing of application of nitrogen fertilizer to hybrid maize varieties, the majority of farmers in Nepal apply N fertilizer randomly, which may be overdosing or under-dosing. However, the hybrid variety that has the right amount of N is the most crucial one to maximize maize yield (Adhikari et al., 2021).

However, studies on varying levels of nitrogenous fertilizer under local environments and soil circumstances have not yet been conducted in specific areas (Adhikari et al., 2021), which also applies to Bhadrapur Municipality. Similarly, research on various doses of nitrogen has been conducted nationally and internationally, but sources of nitrogen such as ammonium nitrate and others have been used. Such sources of nitrogen are very rarely found, non-economical. As well as, they are not very popular among the farmers of the studied locality. Considering all these factors, the research included the use of urea, which is famous among the farmers, cheap and easily available in Bhadrapur Municipality.

When it comes to fertilizers, N is crucial since it plays a key role in the growth and development of crops (Jat et al., 2013). Most frequently, crop productivity is limited by nitrogen. Adding nitrogen is necessary to boost production (Ladha et al., 2005). Likewise, the phosphorus and potassium fertilizers are also equally important as urea, as phosphorus is responsible for DNA and RNA synthesis, respiration as well as photosynthesis (Farzad, 2023). Potassium on the other hand is necessary for stomatal activity, starch synthesis and crop quality (Prajapati and Modi, 2012). Thus, this research focuses on the timely application of nitrogenous as well as phosphorus and potassium fertilizers, which play an important role in maize cultivation. It also focuses on the effect of nitrogen dose on growth and yield parameters, and also the appropriate dose of nitrogen that gives higher yield, which could be recommended to the farmers.

2. Materials and methods

2.1. Experimental site

The experimental setup was carried out in a farmer's field located in Bhadrapur-7, Jhapa, Nepal from 25 February 2024 to 27 June 2024. The climate of this area is tropical. Geographically, it is located at 26° 32′ 31″ North latitude and 88° 5′ 40″ East longitude with an elevation of 91 meters above sea level. From the soil analysis report, the texture was found loamy with the pH of 5.5. Likewise, the analysis result concluded that the total amount of organic matter, nitrogen, P_2O_5 and K_2O were 1.03%, 0.05%, 31.09 kg ha^{-1} and 46.8 kg ha^{-1}, respectively.

2.2. Experimental design

Randomized Complete Block Design (RCBD) was chosen for the field experiment, where seven different doses of nitrogen along with three replications were used. The treatments are listed in the (Table 1). Urea was used as the source of nitrogen for the maize and was collected from the local agrovets along with maize seeds. The size of the individual plot was 7.2 m^2 (3.6m × 2.0m) each. The spacing of maize was 60 cm × 25 cm (Sharma et al., 2019). A g-25 variety of seeds was used for the trial. During field preparation, one-third of N dose and full doses of phosphorus and potassium were applied, and the remaining one-third of N dose was applied in 30 DAS and 55 DAS each, where the leaf count is 6 and 10, respectively.

Table 1. Treatment details

Serial Number	Symbol	Fertilizer dose	
1	T1	Control	(Inamullah et al., 2011)
2	T2	NPK 60:60:60 kg ha^{-1}	(Ojha, 2006)
3	T3	NPK 90:60:60 kg ha^{-1}	(Ojha, 2006)
4	T4	NPK 120:60:60 kg ha^{-1}	(Ojha, 2006)
5	T5	NPK 150:60:60 kg ha^{-1}	(Ojha, 2006)
6	T6	NPK 180:60:60 kg ha^{-1}	(Inamullah et al., 2011)
7	T7	NPK 210:60:60 kg ha^{-1}	(Ahmad et al., 2018)

2.3. Climatic conditions

The graph (Figure 1) describes the temperature and relative humidity (RH) during the research period in Bhadrapur, Jhapa, Nepal. The recorded climatic data revealed that RH was the highest in June (85.29%) and the lowest in April (61.62%). Regarding temperature, the maximum temperature was in April with 37.8°C followed by May with 37.7°C. The minimum temperature was recorded in March with 12.4°C.

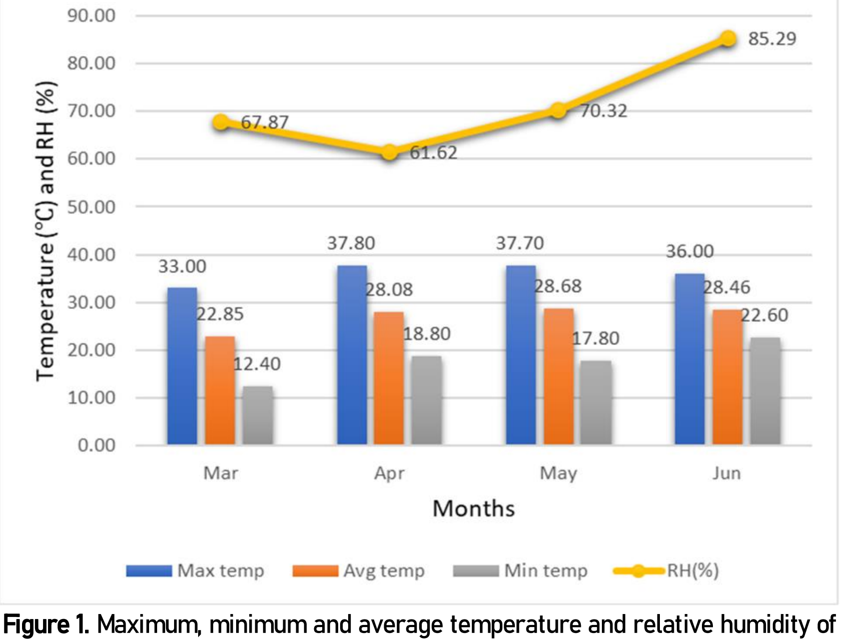

Figure 1. Maximum, minimum and average temperature and relative humidity of research site during research period

The graph (Figure 2) describes the rainfall during the research period in Bhadrapur, Jhapa, Nepal. The maximum rainfall was observed in June with 143.3 mm rainfall followed by May with 88 mm rainfall. Similarly, the accumulated rainfall was the highest in June with 676.51 mm followed by May with 319.6 mm. The reason that May and June have high average rainfall and accumulated rainfall is because monsoon had entered Nepal and it was at its peak during June.

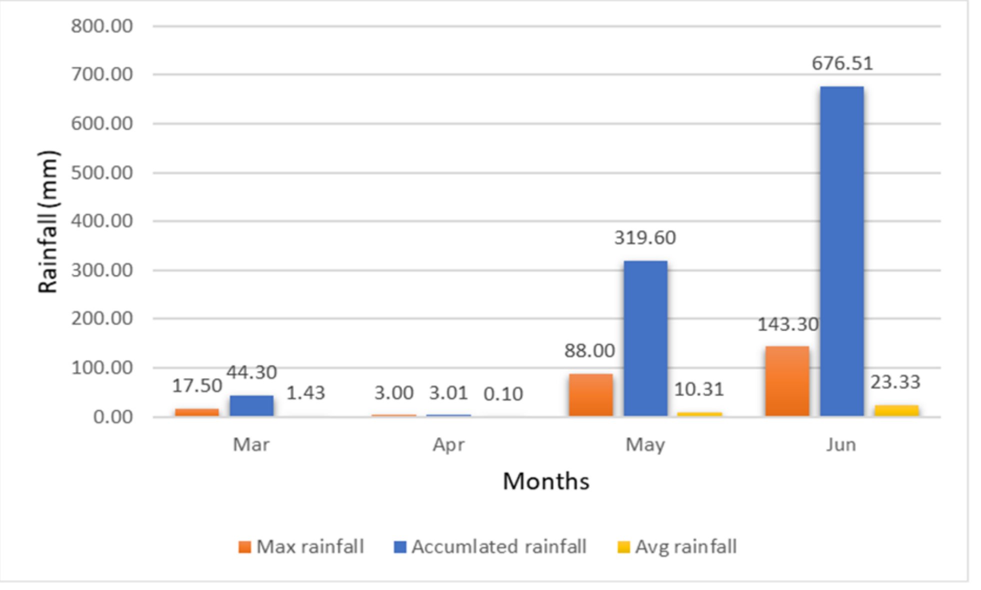

Figure 2. Maximum, accumulated and average rainfall of research site during research period

2.4. Statistical analysis

Data entry and processing were performed using Microsoft Excel, 2019. Analysis of Variance (ANOVA), mean estimation, Post Hoc test and LSD estimation were calculated by using the software, R-Studio, version 4.4.1. The means of the treatments were compared by Duncan's Multiple Range Test (DMRT) at a 5% (0.05) level of significance.

3. Results

Different vegetative, reproductive, yield and yield attributing parameters were recorded and analyzed at different doses of nitrogen. The results are presented in the tables and figures.

3.1. Plant height

No significant differences were seen in plant height between the treatments at 30 DAS. The plot receiving 180 kg N ha^{-1} (T6) had the tallest plants in 45 DAS (117.14 cm) and 60 DAS (214.45 cm) whereas the control had the shortest plants (Table 2).

Table 2. Effect of different doses of nitrogen in plant height of maize in Bhadrapur, Jhapa

Treatment	30 DAS (cm)	45 DAS (cm)	60 DAS (cm)
T1 (0:0:0)	40.97	87.60^{c}	143.26^{d} (11.95)
T2 (60:60:60)	47.32	102.64^{abc}	185.48^{bc} (13.61)
T3 (90:60:60)	48.44	96.00^{bc}	179.65^{c} (13.39)
T4 (120:60:60)	45.63	108.91^{ab}	197.77^{abc} (14.05)
T5 (150:60:60)	48.14	106.02^{ab}	194.92^{abc} (13.96)
T6 (180:60:60)	46.92	117.14^{a}	214.45^{a} (14.64)
T7 (210:60:60)	44.49	99.92^{abc}	200.16^{ab} (14.14)
Grand Mean	45.94	102.60	187.95
SEM (±)	0.77	2.01	2.12
LSD (0.05)	6.32	16.39	17.31 (0.65)
CV %	7.74	8.98	5.17
F- value	1.55^{ns}	3.17*	16.29***

Note: Mean followed by common letter(s) within column are non-significantly different at .05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. Figures in the parenthesis indicate the square root transformed values. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.2. Stem diameter

No significant differences in stem diameter were seen between the treatments at 30 DAS. The plot receiving 180 kg N ha^{-1} (T6) had plants with thick stem diameters in 45 DAS (2.24 cm) and 60 DAS (2.65 cm). Similarly, the control plots (T1) had the thinnest plants in 45 DAS (1.67 cm) and 60 DAS (1.93 cm) (Table 3).

Table 3. Effect of different doses of nitrogen in stem diameter of maize in Bhadrapur, Jhapa

Treatment	30 DAS (cm)	45 DAS (cm)	60 DAS (cm)
T1 (0:0:0)	1.00	1.67^{c}	1.93^{c}
T2 (60:60:60)	1.16	1.94^{b}	2.21^{b}
T3 (90:60:60)	1.13	1.81^{bc}	2.19^{b}
T4 (120:60:60)	1.09	2.03^{b}	2.31^{b}
T5 (150:60:60)	1.12	2.03^{b}	2.35^{b}
T6 (180:60:60)	1.09	2.24^{a}	2.65^{a}
T7 (210:60:60)	1.11	2.02^{b}	2.33^{b}
Grand Mean	1.10	1.96	2.28
SEM (±)	0.01	0.02	0.02
LSD (0.05)	0.14	0.20	0.17
CV %	7.52	5.75	4.38
F- value	1.03^{ns}	7.63**	14.01***

Note: Mean followed by common letter(s) within column are non-significantly different at .05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.3. Number of leaves

The data revealed that there were no significant differences in number a of leaves between treatments at 30 DAS and 45 DAS. At 60 DAS, T2, T4, T5, T6 and T7 were on par, meaning that there were no significant differences in a number of leaves between these treatments. These treatments had the highest number of leaves and T1 (control) and T3 had a lower number of leaves i.e. 11.63 and 11.98 respectively (Table 4).

Table 4. Effect of different doses of nitrogen in leaf count of maize in Bhadrapur, Jhapa

Treatment	30 DAS	45 DAS	60 DAS
T1 (0:0:0)	6.95	8.45	11.63^{b}
T2 (60:60:60)	7.19	9.11	12.68^{a}
T3 (90:60:60)	7.33	8.41	11.98^{b}
T4 (120:60:60)	7.11	9.25	12.87^{a}
T5 (150:60:60)	7.24	9.41	12.75^{a}
T6 (180:60:60)	7.24	9.12	13.35^{a}
T7 (210:60:60)	7.33	8.93	13.21^{a}
Grand Mean	7.20	8.95	12.64
SEM (±)	0.05	0.11	0.08
LSD (0.05)	0.43	0.96	0.69
CV %	3.38	6.07	3.08
F- value	0.90^{ns}	1.51^{ns}	7.73**

Note: Mean followed by common letter(s) within column are non-significantly different at 0.05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.4. Number of cobs per plant

The data revealed that there was no significant difference in a number of cobs per plant. However, the highest number of cobs was seen in T7 (1.05) receiving 210 kg N ha-1and the lowest number of cobs was obtained by T3 and T5 (1.00) receiving 90 kg N ha^{-1} and 150 kg N ha^{-1} (Table 5).

3.5. Length of cob

The data revealed that there was a significant difference in the length of a cob of maize plant. T7 and T6 receiving 210 kg N ha^{-1} and 180 kg N ha^{-1} respectively, had the longest cob of 22.24 cm and 21.72 cm respectively, whereas T1 (control) had the shortest cob measuring 13.20 cm. Similarly, T3, receiving 90 kg N ha^{-1} ranked as the third after T7 and T6 which was in par with T7 and T6 as well as with T4 and T5 which received 120 kg N ha^{-1} and 150 kg N ha^{-1} respectively. T4 and T5 had a shorter length of 20.04 cm and 19.66 cm respectively than T3 (20.88 cm) receiving 90 kg N ha^{-1} (Table 5).

3.6. Diameter of cob

As the dose of the nitrogen increased, the diameter of the cob was also seen increasing. T7 which received 210 kg N ha^{-1} had the highest diameter (4.98 cm), but T3 (4.92 cm), T4 (4.79 cm), T5 (4.75 cm), T6 (4.93 cm) and T7 (4.98 cm), all of them were in par, meaning that there was insignificant difference in diameter between those treatments. T1 (control) had the smallest diameter (3.95 cm) of cob followed by T2 (4.40 cm) (Table 5).

Table 5. Effect of different doses of nitrogen in number of cobs in a plant, length of cob and diameter of cob of maize in Bhadrapur, Jhapa

Treatment	Number of cobs per plant	Length of cob (cm)	Diameter of cob (cm)
T1 (0:0:0)	1.02 (1.23)	13.20^{d} (3.63)	3.95^{c} (2.11)
T2 (60:60:60)	1.03 (1.23)	17.514^{c} (4.18)	4.40^{b} (2.21)
T3 (90:60:60)	1.00 (1.22)	20.88^{ab} (4.57)	4.92^{a} (2.32)
T4 (120:60:60)	1.02 (1.23)	20.04^{b} (4.47)	4.79^{a} (2.30)
T5 (150:60:60)	1.00 (1.22)	19.66^{b} (4.43)	4.75^{a} (2.29)
T6 (180:60:60)	1.02 (1.23)	21.72^{a} (4.66)	4.93^{a} (2.33)
T7 (210:60:60)	1.05 (1.24)	22.24^{a} (4.71)	4.98^{a} (2.34)
Grand Mean	1.02	19.32	4.67
SEM (±)	0.0094	0.17	0.04
LSD (0.05)	0.07 (0.03)	1.42 (0.16)	0.34 (0.07)
CV %	4.23	4.15	4.13
F- value	0.53^{ns}	46.09 ***	11.44 ***

Note: Mean followed by common letter(s) within column are non-significantly different at .05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. Figures in the parenthesis indicate the square root transformed values. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.7. Number of lines in a cob

As the dose of nitrogen increased, the number of lines also increased. T3 receiving 90 kg N ha^{-1} had the highest number of lines per cob (16.99) followed by T7 16.21) and T6 (16.05) which received 210 kg N ha^{-1} and 180 kg N ha^{-1} respectively, but T3, T6 and T7 were at par. Similarly, T6, T7, T2, T4 and T5 were also at par. T1 (control) had the lowest number of lines per cob (12.79) (Table 6).

3.8. Number of grains in a line

As the dose of nitrogen increased, the number of grains in a line also increased. T7 receiving 210 kg N ha^{-1} had the highest number of grains per line (37.59), followed by T6 (35.75), T3 (34.98) and T5 (35.54). These treatments were at par with T7 as well as T4. T4 had 32.48 grains per line. T1 (control) had the lowest number of grains per line (18.76) (Table 6).

3.9. Thousand kernel weight

As the dose of nitrogen increased, the thousand kernel weight also increased. T6 which received 180 kg N ha^{-1} had the highest weight (328.57 g), followed by T7 (322.79 g) and T5 (311.20 g) where, these three treatments were at par. T3 (296.13 g) and T4 (300.39 gm) were at par with T5, T6 and T7 and also with T2 (276.86 g). T1 (control) had the lowest thousand-grain weight of 256.18 g (Table 6).

Table 6. Effect of different doses of nitrogen in number of lines in a cob, number of grains in a line and thousand kernel weight of maize in Bhadrapur, Jhapa

Treatment	Number of lines in a cob	Number of grains in a line	Thousand kernel weight (grams)
T1 (0:0:0)	12.79^{c}	18.76^{d} (4.33)	256.18^{c}
T2 (60:60:60)	15.25^{b}	27.38^{c} (5.22)	276.86^{bc}
T3 (90:60:60)	16.99^{a}	34.98^{ab} (5.91)	296.13^{ab}
T4 (120:60:60)	15.63^{b}	32.48^{b} (5.69)	300.39^{ab}
T5 (150:60:60)	15.93^{b}	33.54^{ab} (5.78)	311.20^{a}
T6 (180:60:60)	16.05^{ab}	35.75^{ab} (5.97)	328.57^{a}
T7 (210:60:60)	16.21^{ab}	37.59^{a} (6.13)	322.79^{a}
Grand Mean	15.55	31.50	298.87
SEM (±)	0.11	0.49	3.67
LSD (0.05)	0.97	4.04 (0.36)	29.96
CV %	3.53	7.21	5.63
F- value	17.59***	28.03***	6.9156 **

Note: Mean followed by common letter(s) within column are non-significantly different at 0.05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. Figures in the parenthesis indicate the square root transformed values. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.10. Grain yield

The data revealed that there was a significant difference in the grain yield of maize plants. As the dose of nitrogen increased, the grain yields also increased significantly. T7, which received 210 kg N ha^{-1}, had the highest yield of 12.22 mt ha^{-1} followed by T6 (10.89 mt ha^{-1}) which received 180 kg N ha^{-1}, where T6 and T7 were at par. Similarly, T3 (10.37 mt ha^{-1}), T4 (9.68 mt ha^{-1}) and T5 (9.50 mt ha^{-1}) were also at par with T6 (10.89 mt ha^{-1}). T1 (control) had the lowest yield with a production of 4.05 mt ha^{-1} (Table 7).

3.11. Biological yield

As the dose of nitrogen increased, the biological yield also increased significantly. T6, which received 180 kg N ha^{-1}, had the highest biological yield of 40.17 mt ha^{-1} followed by T7 (39.74 mt ha^{-1}), which received 210 kg N ha^{-1}. Both of these treatments were at par. T3 (32.80 mt ha^{-1}), T4 (32.22 mt ha^{-1}) and T5 (30.71 mt ha^{-1}), which received 90 kg N ha^{-1}, 120 kg N ha^{-1} and 150 kg N ha^{-1} were at par. Similarly, T3 and T5 were also at par with T2 (27.85 mt ha^{-1}), which received 60 kg N ha^{-1}. T1 (control) had the lowest biological yield of 16.45 mt ha^{-1} (Table 7).

Table 7. Effect of different doses of nitrogen in grain yield, biological yield and Harvest Index (HI) of maize in Bhadrapur, Jhapa

Treatment	Grain yield (mt ha^{-1})	Biological yield (mt ha^{-1})	Harvest index (HI)
T1 (0:0:0)	4.05^{d}	16.45^{d}	0.24^{c}
T2 (60:60:60)	7.50^{c}	27.85^{c}	0.27^{bc}
T3 (90:60:60)	10.37^{b}	32.80^{bc}	0.32^{a}
T4 (120:60:60)	9.68^{b}	32.22^{b}	0.29^{ab}
T5 (150:60:60)	9.50^{b}	30.71^{bc}	0.30^{ab}
T6 (180:60:60)	10.89^{ab}	40.17^{a}	0.27^{bc}
T7 (210:60:60)	12.22^{a}	39.74^{a}	0.30^{ab}
Grand Mean	9.17	31.50	0.28
SEM (±)	0.20	0.56	0.0047
LSD (0.05)	1.68	4.60	0.03
CV %	10.30	8.21	7.58
F- value	24.07***	28.92***	4.55*

Note: Mean followed by common letter(s) within column are non-significantly different at 0.05 based on DMRT. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significance. SEM (±): Standard Error of Mean, LSD: Least Significant Difference, CV: Coefficient of variation

3.12. Harvest index (HI)

As the dose of nitrogen increased, the HI also increased. T3, which received the dose of 90 kg N ha^{-1} had the highest HI of 0.32 followed by T7 (0.30), T5 (0.30) and T4 (0.29), which received the dose of 210 kg N ha^{-1}, 150 kg N ha^{-1} and 120 kg N ha^{-1} respectively. Similarly, T3, T4, T5 and T7 were at par. Likewise, T6 (0.27) and T2 (0.27) were also at par with T4, T5 and T7, and also, with T1 (control). T1 (control) had the lowest HI, which was 0.24 (Table 7).

3.13. Benefit cost ratio (B:C)

The data revealed that there was a significant difference in the B: C ratio in maize cultivation. As the dose of nitrogen increased, the B: C ratio also increased significantly. T7, which received 210 kg N ha^{-1} had the highest B: C ratio of 1.50, followed by T6 (1.35), which received 180 kg N ha^{-1} and T3 (1.33), which received 90 kg N ha^{-1}. T1 (control) had the lowest B: C ratio of 0.60, followed by T2 (0.97), which received 60 kg N ha^{-1}. T1 and T2 were not beneficial in terms of economics as the B: C ratio for these two treatments was less than 1, which indicated the loss (Figure 3).

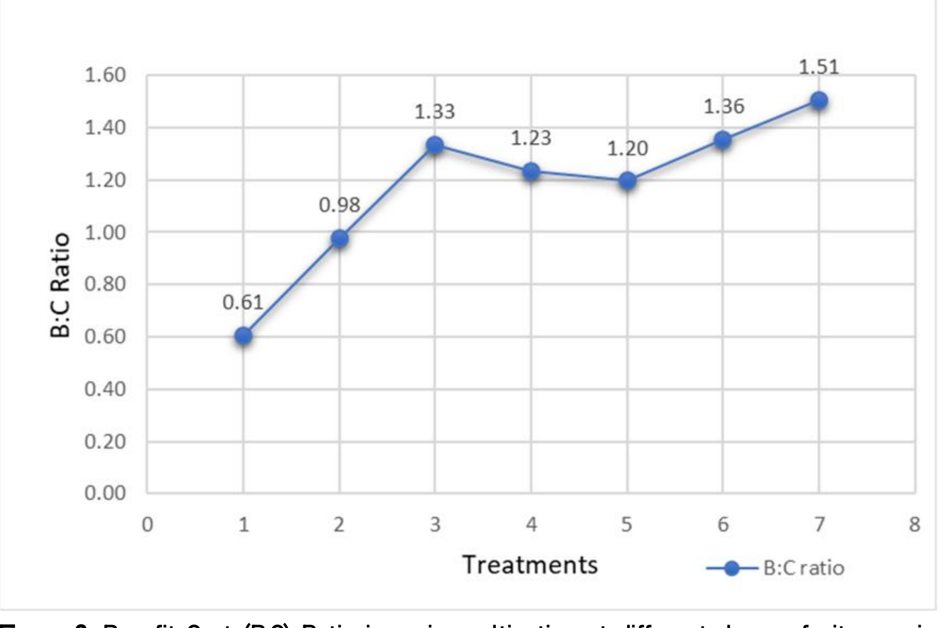

Figure 3. Benefit Cost (B:C) Ratio in maize cultivation at different doses of nitrogen in Bhadrapur, Jhapa

3.14. Regression of grain yield with yield and yield attributing parameters of maize

The relationships between different parameters and grain yield is shown in figure (4), where the relationship between plant height (cm) and yield (mt ha^{-1}) of the plant is shown in graph (a), showing that there was an increment in the yield of maize, when the plant height increased. The graph indicates that, with a unit increment in plant height, the yield increment was 0.0917 tons. A similar type of relationship was found between stem diameter and yield graph (b), as well as between a number of leaves and yield graph (c). With a unit increment in stem diameter and a number of leaves, the yield increment was found to be 8.66 tons and 2.30 tons, respectively.

In the case of number of cobs per plant, though it was not significantly correlated with the grain yield, the graph (d) shows a positive relationship between cob number and grain yield, where unit an increment in cob number resulted in an increment in the yield by 5.504 tons. Graph (e) and graph (f) also show the positive relationship between cob length and grain yield, as well as cob diameter and grain yield, respectively, where, with an increment in cob length and cob diameter by unit, there was an increment in grain yield by 0.845 tons and 6.342 tons, respectively.

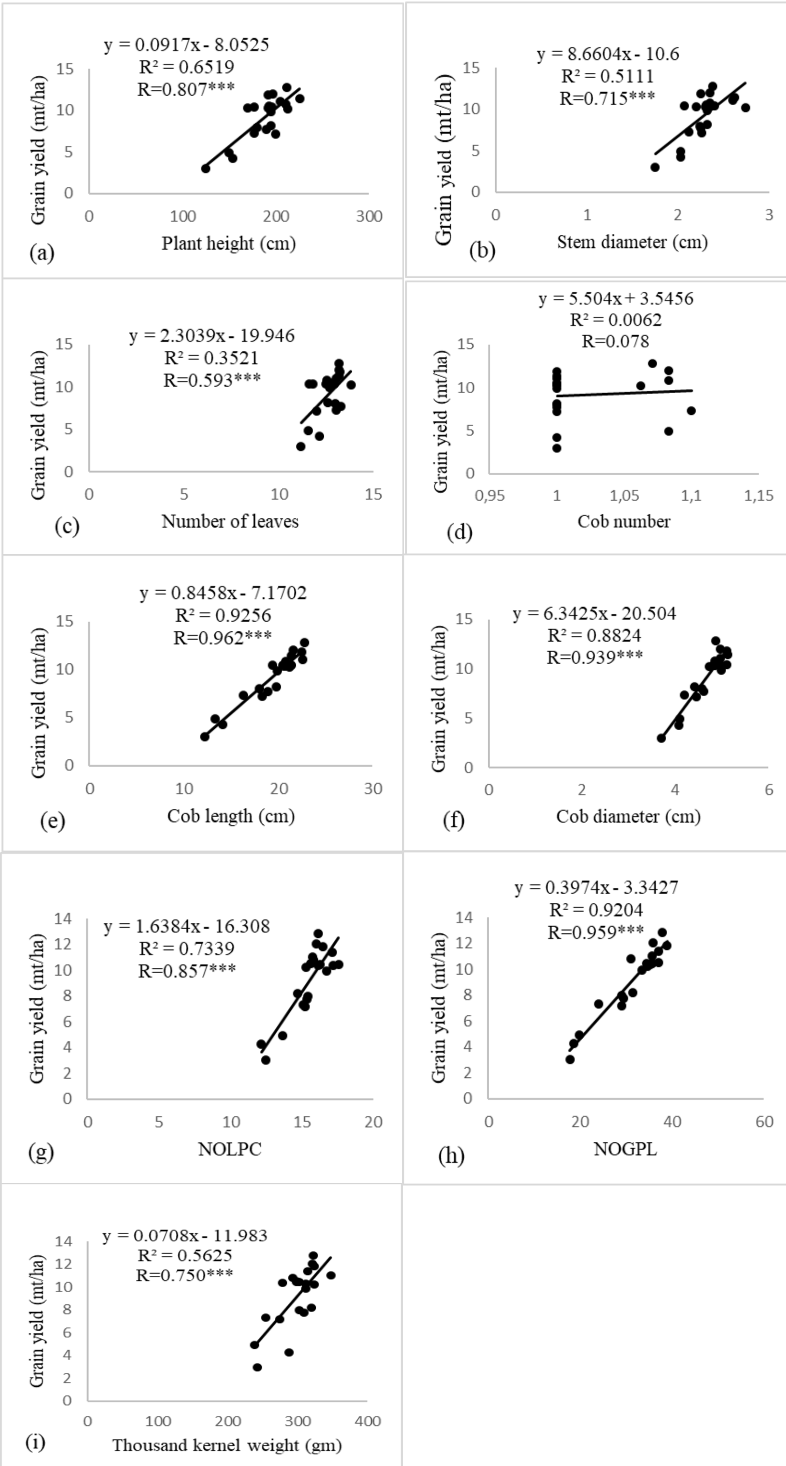

Figure 4. Coefficient of determination (R^2), linear regression equation and scatter diagram showing the fitted simple regression line of Y (yield) on X (Plant height (a), Stem diameter (b), Number of leaves (c), Number of cobs in a plant (d), Length of cob (e), Diameter of cob (f), Number of lines per cob (NOLPC) (g), Number of grains per line (NOGPL)(h), Thousand kernel weight (i).

Likewise, graph (g) and graph (h), also show the positive and direct relationships between a number of lines per cob and grain yield and a number of grains per line and grain yield respectively, where there was an increment of grain yield by 1.638 tons and 0.397 tons with a unit increment in the number of lines per grain and unit increment in the number of grains per line, respectively.

A similar type of positive relationship was found between thousand kernel weight and grain yield, as shown in graph (i). There was an increment in grain yield by 0.070 tons with an increment in weight of thousand grains by 1.0 gram.

4. Discussions

Significant differences were seen in terms of plant height, diameter of stem and number of leaves, especially at 60 DAS. Increased nitrogen levels may lead to increased plant height by promoting cell division, elongation and nucleus formation (Wajid et al., 2007). A higher concentration of N may cause cell division, which in turn is responsible for the gradual increase in stem diameter (Mahdi et al., 2011). A different result was obtained as compared to others in terms of height and diameter of the plant, where the maximum N dose was not the tallest and the girthiest. A similar type of result was obtained by Anwar (2017). It may be due to the fact that a higher accumulation of salt in the soil hinders plants from absorbing water and may have an antagonistic effect. Rather than a high dose of nitrogen, proper timing of the application of nitrogen is what makes the plant grow more in terms of height and diameter. The research conducted by Woldesenbet and Haileyesus, (2016) in southwestern Ethiopia showed that the increased nitrogen levels lead to an increase in the number of leaves. The study also found that no N application resulted in the fewest leaves per plant, while 69 and 92 kg N ha^{-1} resulted in the formation of many leaves per plant. This result is also supported by the experiment done by (Badr and Authman, 2006).

Regarding the number of cobs per plant, research performed by Akbar (2016) in Bandarban Valley reported that the number of ears per plant was not significantly affected by the application of fertilizer which coincides with our findings. Production of cobs in a plant is a genetic factor due to which nitrogen doses did not affect the cob (Inamullah et al., 2011). Similarly, in the case of the length of the cob, the research by Ahmad et al. (2018) concluded that decreasing N levels decreases the cob length. N dose of 180 kg N ha^{-1} had the largest cob length, and the control plot had the lowest cob length. Same was the result of the research conducted by Arif (2015) and it matches our results. (Derby et al., 2004) reported that the probable reason for the increment in the cob length is because the plant utilizes the solar light, assimilates a higher production and its conversion to starches at higher nitrogen dose. The diameter was seen highest in the plot with the highest nitrogen. Same was reported by Adhikari et al. (2021) in Pirthu College, Lamahi, Dang where at 220 kg N ha^{-1}, the cob diameter was larger , while the lowest cob diameter was observed with the N dose of 160 kg N ha^{-1}. The maximum cob diameter was produced at 300 kg N ha^{-1} in comparison to other levels, due to the effect of nitrogen levels on cob diameter (Khan et al., 2011).

An unusual result was obtained where the plot with 90 kg N ha^{-1} had the highest number of grain rows per cob. The number of kernel rows per cob increased with higher doses of N application (Dawadi and Sah, 2012). The study by Khan et al. (2011) found that fertilization with 300 kg N ha^{-1} resulted in the highest number of grain rows per cob, while 75 kg N ha^{-1} resulted in the smallest increment. The study by Woldesenbet and Haileyesus (2016) revealed quite different findings where the amount of nitrogen applied at varying levels did not affect the number of rows per plant. Findings by different researchers are different in this case because the quantity of nitrogen does not affect the kernel rows. The main thing that affects the kernel rows per cob is the timing of the top dressing of nitrogen fertilizer. In the case of a number of kernels per row, the treatment with the highest nitrogen dose had the highest number of grains. The number of kernels per line increased with higher doses of N application (Dawadi and Sah, 2012). The study by Khan et al. (2011) found that fertilization with 300 kg N ha^{-1} resulted in the highest number of grains per line. A similar type of finding was reported by Rahman et al. (2016). As more nitrogen is supplied to the plants, there is less competition for nutrients due to which more biomass is accumulated by plants due to which the number of grains per kernel row increases (Adhikari et al., 2021). With the increasing dose of nitrogen, the thousand kernel weight was also seen increasing. The data of the research conducted by Ahmad et al. (2018) showed that using 180 kg N ha^{-1} resulted in the highest thousand grains weight, followed by 150 kg N ha^{-1}.

The minimum thousand-grain weight was recorded in control. A similar type of result was obtained by Rahman et al. (2016). The reason for the increment of a thousand-grain weight with increasing nitrogen could be because the photosynthesis rates of grains increase (Gökmen et al., 2001). Ağırağaç and Zorer Çelebi (2024) stated in their study that nitrogen positively affects the chlorophyll content in plants.

Like that of a thousand-kernel weight, grain yield was also proportional to the increasing dose of nitrogen. Grain yield depends on the combined effect of individual yield components. Rising nitrogen level corresponds with higher grain yields (Khan et al., 2011). The research by Akbar (2016) showed that when fertilizer application rates increased, maize grain yield rose linearly; the crop that received the maximum RDF (Recommended Dose of Fertilizers) recorded the highest grain yield. The reason for the increment in grain yield with increasing nitrogen dose could be due to the plants do not need to compete for nutrients, thus increases photosynthesis and canopy size. A similar result was obtained in the context of biological yield. The effect of nitrogen on biological yield is significant and with the increase in nitrogen dose, there is also an increment in biological yield in maize crops (Ahmad et al., 2018). The biological yield was the highest with the nitrogen dose of 150 kg N ha^{-1} and was lowest of all with 50 kg N ha^{-1} among three treatments (50, 100 and 150 kg N ha^{-1}) in the research conducted by Rahman et al., (2016). Our result of HI coincides with the result of the research by Dawadi and Sah (2012), where the plot receiving 120 kg N ha^{-1} had the highest HI, followed by 160 kg N ha^{-1} and 200 kg N ha^{-1}. The harvest index demonstrates how well plants function physiologically to convert the percentage of photo assimilation rates to grain yield. The application of various levels of nitrogen has a significant impact on the maize HI (Khan et al., 2011). The reason for the highest HI in T3 is possible due to nitrogen not only initiates grain yield but also initiates vegetative growth. So, in higher doses of nitrogen, the vegetative growth also increased with increasing nitrogen, but the plants with lower nitrogen were able to convert most of their photo-assimilation to grain yield resulting in higher HI (Derby et al., 2004).

It is a brainer that with the increasing nitrogen dose, the cost of cultivation also increases. Likewise, from the result above, with the increasing dose of nitrogen, the grain yield also increases, resulting in an increment in benefit cost ratio with increasing nitrogen dose indicating profitability. A similar result was obtained by Adhikari et al. (2021).

5. Conclusion

A fertilizer dose of NPK 180:60:60 kg ha^{-1} can be suggested to the farmers who cultivate maize for green leaves and fodder for their animals. Similarly, a fertilizer dose of the same i.e. NPK 180:60:60 kg ha^{-1} can be suggested to the farmers who cultivate maize for the grains and higher returns as this dose of fertilizer gives both higher yield and higher B:C ratio. Furthermore, there is no significant difference in yield and BC ratio between T6 and T7. So, T6 can be recommended as it is also important to take care of soil, which can be done by not using higher dose of fertilizers, without having a significant impact on the yield.

Compliance with Ethical Standards

Conflict of interest

The author declare that they do not have any conflict of interest.

Authors' contributions

Khem Raj GHIMIRE: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Resources, Data curation, Writing- Original Draft, Writing- Review and Editing, Visualization, Project administration. **Ravi ACHARYA:** Conceptualization, Methodology, Validation, Visualization, Supervision, Project administration

Ethical approval

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