Nepal Agriculture Research Journal
Vol. 15, No. 1, pp. 136-151, 2023
DOI: https://doi.org/10.3126/narj.v15i1.51723

Performance of hybrid maize at different nitrogen levels in spring season at Badhaiyatal area of Bardiya District, Lumbini Province, Nepal

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ARTICLE INFO

Research Paper

Received: July 21, 2022
Revised: November 12, 2022
Accepted: January 23, 2023
Published: February 01, 2023

Contents available at
http://www/sasnepal.org.np

Published by Society of Agricultural Scientists Nepal (SAS-Nepal).

ABSTRACT
Blanket recommendation of nitrogen (N) for maize would not be applicable as the new high yielding hybrids have been grown in Nepal. A field experiment was carried out during spring season at Badhaiyatal, Bardiya to determine optimum N level for hybrid maize. The treatments consisted of three commercial maize hybrids namely Rampur hybrid-10, Rajkumar and Pioneer-3522 and four N levels i.e., 150 kg ha^{-1}, 175 kg ha^{-1}, 200 kg ha^{-1} and 225 kg ha^{-1}. The experiment was carried out in split-plot design with maize hybrids as main plot factor and N levels as sub plot factor in three replications. Results revealed that all yield attributes were significantly ($p>0.05$) influenced by variety and nitrogen levels except number of ears harvested per hectare. The grain yields with N level @ 225 kg ha^{-1} (8.69 t ha^{-1}) and @ 200 kg ha^{-1}(8.39 t ha^{-1}) were statistically similar but higher than remaining N levels. The higher yield with higher N level was because of significantly ($p>0.05$) higher leaf area index (4.67 at 75 Days After Sowing, plant height (248.50 cm at 75 DAS), number of kernels per ear (467), ear length (18.59 cm), ear circumference (15.16 cm) and shelling percentage (70.68%). All three maize hybrids: Pioneer 3522 (8.46 tha^{-1}), Rajkumar (8.05 t ha^{-1}) and Rampur hybrid-10 (7.63 t ha^{-1}) were found similar in grain yield. The yield attributes viz., ear length, and ear circumference, number of kernels per ear showed positive correlation with grain yield. Therefore, application of N@ 200 kg ha^{-1} for the maize hybrids during spring season is suggested for Bardiya.

Keywords: Spring maize, Nitrogen, Grain yield, Yield attributes, Variety

Cited as: Adhikari M, SK Sah, B Ghimire and P Neupane. 2023. Performance of hybrid maize at different nitrogen levels in spring season at Badhaiyatal area of Bardiya District, Lumbini Province, Nepal. Nepal Agriculture Research Journal **15**(1): 136-151. DOI: https://doi.org/10.3126/narj.v15i1.51723

INTRODUCTION

Maize (*Zea mays* L) is one of the most grown crop in the world after rice and wheat, ranking first in terms of production (Souki et al 2011). It is also known as the "queen of cereals" (Begam et al 2018). To increase the maize production, the technology of hybrid has been introduced in Nepal. However, there is a lack of site-specific hybrids in Nepal (Kandel and Shrestha 2020). Despite high potential uses and export demand, average maize productivity at the farmer level is quite low (2.84 t ha^{-1}) in comparison to the attainable yield (5.7 t ha^{-1}) (MoALD 2020). There is a considerable yield gap of 4.43 t ha^{-1} in hybrid maize as the attainable yield is 7.27 t ha^{-1} and the national average is just 2.84 t ha^{-1} (Ghimire et al 2016). One of the reasons of the lower yield of maize is due to lower use of nitrogen (N) fertliser (Asghar et al 2010, Khanal et al 2017). Farmers do not apply enough fertilizer to newly introduced hybrid varieties (Devkota et al 2016). With the use of hybrid maize varieties, the level of N requirement becomes higher, but maize crops are usually known to be grown under nutrition limitation in Nepal.

Application of low N resulted in decreased maize growth and productivity (Adhikary and Adhikary 2013). An optimum amount and efficient time of nitrogen application can increase applied nitrogen recovery up to 58–70% and thus increase yield and grain quality of the crop (Abebe and Feyisa 2017).There is little information regarding the nitrogen requirement for these newly introduced hybrids in local conditions. Therefore, in present investigation we carried out a study to identify optimum nitrogen dose for maize hybrids especially at agroclimatic conditions of Bardiya District and similar other locations.

MATERIALS AND METHODS

Field research was conducted during spring season from February to June, 2021 with crop duration of four months at Kanthapur, Badhaiyatal, Bardiya, situated at 28°11'13.7"N and 81°25'26.0"E geographical coordinates about 150 m above the sea level. The average minimum to maximum temperatures for the cropping duration were from 19.8 to 33.3°C, respectively. The total rainfall recorded during the crop period was 326.3 mm. The average annual rainfall of Bardiya is 1033 mm. The maximum relative humidity (RH %) for the cropping period was 80%, whereas the minimum was 55%.

The soil pH was found neutral at both 0–15 cm (7.0) and 15–30 cm (7.5) soil depth. Similarly, soil organic matter was 0.69% and 0.89% at 0–15 cm and 15–30 cm depths, respectively. Total nitrogen at 0-15 cm (0.03%) and 15-30 cm (0.04%) soil depths was low. Available phosphorus (51.53 kg ha^{-1}) was found to be medium at 0-15 cm depth and high at 15-30 cm depth (87.60 kg ha^{-1}). Similarly, available potassium was high (410.91 kg ha^{-1}) at 0–15 cm and low (213.07 kg ha^{-1}) at 15–30 cm depths of the soil.

The experiment was carried out in a split plot design with three replications. The main plot factor was the maize variety, constituting three hybrid varieties, V1 (Rampur hybrid 10), V2 (Rajkumar) and V3 (Pioneer 3522). Rajkumar and Pioneer-3522 were selected as maize hybrids since these single cross hybrids were popular among the farmers of Bardiya district. Similarly, the sub plot factor was nitrogen levels: N1 (150 kg ha^{-1}), N2 (175 kg ha^{-1}), N3 (200 kg ha^{-1}) and N4 (225 kg ha^{-1}). The size of the individual plot was 3 m × 3 m (9 m^2). Row spacing was maintained at 60 cm apart with 20 cm intra row spacing.

Land preparation was carried out two weeks before maize sowing. Farm Yard Manure (FYM) was incorporated @ 10 t ha^{-1} during final land preparation. The experiment was carried out in irrigated conditions. Pre-sowing irrigation was done for better germination of seeds. The full doses of phosphorus and potassium fertilizers were applied @ 60 kg P_2O_5 and 40 kg K_2O per hectare as basal applications. A total of five irrigation was done after seed sowing throughout the crop duration. Irrigation was done after emergence, followed by irrigation at the seedling stage, knee-height stage, tasseling stage, and silking stage.

Data on plant height, leaf number, and leaf area index (LAI) at 30 DAS, 45 DAS, 60 DAS, and at 75 DAS were taken. The phenological observations viz., days to 80% tasseling and days to 80% silking were taken. The non-destructive row sampling technique was used for estimating the leaf area index. The leaf area index was estimated using a formula (Eq. 1).

$$\text{Leaf area index} = \frac{\text{Leaf area,cm}^2}{\text{Land area,cm}^2} \times 0.75 \qquad \text{(Eq. 1)}$$

Number of kernels per ear, number of kernel rows per ear, ear length, ear circumference, 1000 kernels weight, length of filled ear, length of sterile ear, sterility percentage were recorded (Eq. 2).

$$\text{Sterility percentage} = \frac{\text{Sterile ear length (cm)}}{\text{Total ear length (cm)}} \times 100 \qquad \text{(Eq. 2)}$$

Five randomly selected ears were weighed with grains. All grains were shelled out and the weight of grain was taken and the shelling percentage was calculated using following formula (Eq. 3).

$$\text{Shelling percentage} = \frac{\text{Grain yield (kg)}}{\text{Ear yield (kg)}} \times 100 \qquad \text{(Eq. 3)}$$

Biological yield, stover yield, and grain yield were taken from net plot area. The harvested crop was thoroughly dried, then threshed, sun-dried, cleaned, and its final grain weight was recorded. The moisture content of grain was recorded using a multi-crop moisture meter. The following formula was used to calculate grain yield at 14% moisture content (Eq. 4).

$$\text{Grain yield } \left(\frac{\text{kg}}{\text{ha}}\right) \text{ at 14\% moisture} = \frac{(100-\text{M}) \times \text{Net plot yield (kg)} \times 10000 \text{ m}^2}{(100-14) \times \text{Net plot area,m}^2} \qquad \text{(Eq. 4)}$$

Where M is the grain moisture content in percentage.
Net plot area: 4.68 m^2

Similarly, harvest index (HI) was calculated using the following formula (Eq. 5).

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Grain yield+stover yield}} \qquad \text{(Eq. 5)}$$

Data entry and analysis were done using MS-Excel 2019, R studio version 4. 1.1 was used for data analysis, and Duncan's Multiple Range TEST (DMRT) at a 0.05 probability level was used for mean separation. Similarly, the analysis of variance (ANOVA) procedure as described by Gomez and Gomez (1984) for split plot design studies was employed to statistically examine the data collected. The Fisher's Least Significant Difference (LSD) procedure used by Obi (1986) was also used for treatment mean separation for the significant difference at the 5% probability level.

RESULTS

Plant height

The mean plant height was 65.55 cm at 30 DAS and increased to 240.23 cm at 75 DAS (Table 1). Variety didn`t govern the plant height at harvest. The plant height was significantly

(0.05) influenced by nitrogen levels at 30 DAS, 45 DAS, 60 DAS and 75 DAS. Tallest plant height at 75 DAS was observed with 225 kg ha^{-1} (248.50 cm) followed by 200 kg ha^{-1} (242.32 cm), 175 kg ha^{-1} (235.84 cm) and 150 kg ha^{-1} (234.25 cm), respectively (Table 1).

Table 1. Plant height (cm) of spring maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	**Plant height (cm)**			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Variety				
Rampur Hybrid 10	62.65	88.81	183.58^{b}	237.37
Rajkumar	66.32	96.30	202.08^{a}	243.48
Pioneer 3522	67.69	92.15	204.83^{a}	239.83
LSD (0.05)	6.36	13.39	8.04	13.45
F test	Ns	Ns	**	Ns
Sem (±)	1.50	2.16	6.67	1.77
CV (%)	8.60	12.8	3.60	4.90
Nitrogen Level				
150 kg ha^{-1}	59.97^{c}	86.57^{b}	181.57^{c}	234.25^{b}
175 kg ha^{-1}	61.75^{bc}	89.84^{b}	194.46^{bc}	235.84^{b}
200 kg ha^{-1}	68.10^{ab}	92.90^{ab}	198.08^{b}	242.32^{ab}
225 kg ha^{-1}	72.38^{a}	100.38^{a}	213.20^{a}	248.50^{a}
LSD (0.05)	6.37	8.67	15.03	7.96
F test	**	*	**	**
Sem (±)	2.86	2.94	6.50	3.26
CV (%)	9.80	9.50	7.70	3.30
Grand Mean	65.55	92.42	196.83	240.23

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and *P<0.05, **P<0.01 and ***P<0.001

Leaf Number

The grand mean number of leaves was 6.59 at 30 DAS, 8.70 at 45 DAS and 11.71 at 75 DAS (**Table 2**).

Table 2. Number of leaves of spring maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	**Number of leaves**			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Variety				
Rampur Hybrid 10	7.33^{a}	9.28	11.26^{a}	12.18
Rajkumar	6.48^{b}	8.76	10.65^{ab}	11.68
Pioneer 3522	5.96^{c}	8.06	10.25^{b}	11.28
LSD (0.05)	0.48	1.04	0.72	1.27
F test	**	Ns	*	Ns
Sem (±)	0.39	0.35	0.29	0.26
CV (%)	6.50	10.60	6.00	9.60
Nitrogen Level				
150 kg ha^{-1}	6.48	8.28^{b}	9.91^{c}	10.97^{b}
175 kg ha^{-1}	6.42	8.84^{a}	10.68^{b}	11.95^{a}
200 kg ha^{-1}	6.64	8.64^{ab}	10.86^{ab}	11.80^{a}
225 kg ha^{-1}	6.82	9.04^{a}	11.42^{a}	12.13^{a}
LSD (0.05)	0.38	0.43	0.59	0.77
F test	Ns	*	***	*
Sem (±)	0.08	0.16	0.31	0.25
CV (%)	5.90	5.10	5.60	6.70
Grand Mean	6.59	8.70	10.72	11.71

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and *P<0.05, **P<0.01 and ***P<0.001.

Number of leaves was not significantly (0.05) influenced by variety at 75 DAS. Statistically non-significant but slightly higher number of leaves was observed in Rampur hybrid 10 (12.18) than Rajkumar (11.68) and Pioneer 3522 (11.28). Similarly, nitrogen levels had significant (0.05) influence on number of leaves. Highest number of leaves was observed with nitrogen level 225 kg ha^{-1} (12.13), 200 kg ha^{-1} (11.80) and 175 kg ha^{-1} (11.95), which are statistically at par and lowest with 150 kg ha^{-1} (10.97).

Leaf Area Index

The grand mean value of leaf area index (LAI) increased from 0.57 at 30 DAS to 4.36 at 75 DAS (Table 3). Leaf area index was significantly influenced by variety at 45 DAS, 60 DAS and 75 DAS. Significantly (0.05) higher leaf area index was observed at 75 DAS in Pioneer 3522 (4.52) followed by Rajkumar (4.34) than Rampur hybrid 10 (4.23). Similarly, leaf area index was significantly (0.05) influenced by nitrogen levels at all days after sowing (DAS). Similarly, statistically higher leaf area index was observed with nitrogen level 225 kg ha^{-1} (4.67) followed by 200 kg ha^{-1} (4.43) and 175 kg ha^{-1} (4.30) than 150 kg ha^{-1} (4.06).

Table 3. Leaf area index (LAI) of spring maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	**Leaf Area Index (LAI)**			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
Variety				
Rampur Hybrid 10	0.57	2.17^{b}	2.93^{b}	4.23^{b}
Rajkumar	0.56	2.67^{a}	3.17^{a}	4.34^{ab}
Pioneer 3522	0.60	2.43^{ab}	3.03^{ab}	4.52^{a}
LSD (0.05)	0.12	0.37	0.15	0.21
F test	Ns	*	*	*
Sem (±)	0.01	0.14	0.06	0.08
CV (%)	19.60	13.50	4.40	4.40
Nitrogen Level				
150 kg ha^{-1}	0.44^{c}	2.20^{b}	2.84^{b}	4.06^{c}
175 kg ha^{-1}	0.51^{bc}	2.14^{b}	2.97^{b}	4.30^{bc}
200 kg ha^{-1}	0.64^{ab}	2.50^{ab}	3.06^{ab}	4.43^{ab}
225 kg ha^{-1}	0.70^{a}	2.86^{a}	3.30^{a}	4.67^{a}
LSD (0.05)	0.13	0.47	0.24	0.31
F test	**	*	**	**
Sem (±)	0.05	0.16	0.09	0.12
CV (%)	23.60	19.90	8.20	7.30
Grand Mean	0.57	2.42	3.04	4.36

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and * $P<0.05$, ** $P<0.01$ and *** $P<0.001$

Phenological Observation

The mean days to tasseling, silking was 64.13 days and 67.66 days, respectively in the experiment (Table 4). The days to tasseling and silking was influenced by variety as well as nitrogen levels. Significant (0.01) earlier days to tasseling and silking was observed in Rajkumar than Pioneer 3522 and Rampur hybrid 10. Days to tasseling and silking was significantly (0.01) earlier with nitrogen level 225 kg ha^{-1} than nitrogen level 150 kg ha^{-1}. The mean days of anthesis silking interval was 3.52 days in the experiment (Table 4). Statistically non-significant anthesis silking interval was observed as influenced by variety. The anthesis silking interval was found significantly higher with 150 kg ha^{-1} (4 days) and 175 kg ha^{-1} (3.88 days) than 225 kg ha^{-1} (3 days) and 200 kg ha^{-1} (3.22 days).

Table 4. Days to tasseling and silking of spring maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	Days to Tasseling	Days to Silking	Anthesis Silking Interval (ASI)
Variety			
Rampur Hybrid 10	64.75^{b}	68.33^{c}	3.58
Rajkumar	63.33^{a}	66.91^{a}	3.58
Pioneer 3522	64.33^{b}	67.75^{b}	3.41
LSD (0.05)	0.59	0.46	0.49
F test	**	**	Ns
Sem (±)	0.17	0.41	0.05
CV (%)	0.80	0.60	12.50
Nitrogen Level			
150 kg ha^{-1}	65.33^{c}	69.33^{b}	4.00^{b}
175 kg ha^{-1}	64.55^{bc}	68.44^{b}	3.88^{b}
200 kg ha^{-1}	63.55^{ab}	66.55^{a}	3.00^{a}
225 kg ha^{-1}	63.11^{a}	66.33^{a}	3.22^{a}
LSD (0.05)	1.14	1.08	0.40
F test	**	***	***
Sem (±)	0.28	0.73	0.24
CV (%)	1.80	1.60	11.60
Grand Mean	64.13	67.66	3.52

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and $^{*}P<0.05$, $^{**}P<0.01$ and $^{***}P<0.001$

Number of Kernels per ear

The average number of kernels per ear was 437.3 (Table 5). Both variety and nitrogen levels had a significant (0.05) impact on kernels per ear. Statistically (0.05) higher numbers of kernels per ear were observed in Pioneer 3522 (500) and Rajkumar (454), which are statistically at par with Rampur hybrid 10 (358). Kernels per ear were also significantly influenced by nitrogen levels. With nitrogen levels of 225 kg ha-1 (467), the number of kernels per ear was significantly higher (0.01), followed by 200 kg ha^{-1} (442), 175 kg ha^{-1} (427), and 150 kg ha^{-1} (413).

Number of Kernel rows per ear

The mean number of kernel rows per ear was (15.31), ranging from 13.90 to 16.63 (Table 5). Variety significantly (0.01) influenced kernel rows per ear. Statistically, a greater number of kernel rows per ear were observed in Pioneer-3522 than in Rajkumar (15.40) and least in Rampur hybrid 10 (13.90). Similarly, kernel rows per ear were not statistically (0.05) influenced by nitrogen levels. However, a statistically non-significant but slightly greater number of kernel rows were observed with nitrogen levels of 225 kg ha^{-1} (15.51) than 200 kg ha^{-1} (15.33) than 175 kg ha^{-1} (15.28) and 150 kg ha^{-1} (15.11).

Thousand kernels weight

The mean thousand kernel weight observed was 340.26 g (Table 5). The number of thousand kernels weight was significantly (0.01) influenced by variety. Rampur hybrid 10 (377 g) had a statistically higher thousand kernel weight than Rajkumar (338 g) and Pioneer 3522 (306 g). There was no significant (0.05) difference in thousand kernel weight (g) as influenced by nitrogen levels. The nitrogen level 225 kg ha^{-1} (349 g) produced slightly more thousand kernels weight (g) than the nitrogen levels 200 kg ha^{-1} (345 g), 200 kg ha^{-1} (337 g), and 250 kg ha^{-1} (330 g).

Ear length

The average ear length was observed to be 17.79 cm, ranging from 16.77 cm to 18.78 cm (Table 5). Observation data was not significantly (0.05) influenced by variety. However, a statistically non-significant but slightly longer ear length was observed in variety Rajkumar (18.78 cm) than in Rampur hybrid 10 (17.32 cm) and shorter in Pioneer 3522 (17.30 cm). Similarly, ear length was significantly (0.01) influenced by nitrogen levels. Statistically, longer ear length was observed with nitrogen level 225 kg ha^{-1} (18.59 cm), followed by 200 kg ha^{-1} (18.38 cm) and 175 kg ha^{-1} (17.44 cm) and shorter with nitrogen level 150 kg ha^{-1} (16.77 cm).

Ear circumference

The average ear circumference was observed to be 14.87 cm, ranging from 14.22 cm to 15.21 cm (Table 5). There was a significant (0.01) difference in ear circumference as influenced by both variety and nitrogen levels. The Rajkumar variety (15.21 cm) and Pioneer 3522 (15.18 cm) had statistically (0.01) higher ear circumferences than the Rampur hybrid 10 (14.22 cm), which had statistically equal ear circumferences. Similarly, nitrogen levels of 225 kg ha^{-1} (15.16 cm) resulted in significantly (0.05) higher ear circumference, followed by 200 kg ha^{-1} (14.88 cm), 175 kg ha^{-1} (14.87 cm), and 150 kg ha^{-1} (14.58 cm).

Table 5. Yield component of spring maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	Number of kernels per ear	1000 kernels weight (g)	Number of kernel rows per ear	Ear length (cm)	Ear circumference (cm)
Variety					
Rampur Hybrid 10	358^{b}	377^{a}	13.90^{c}	17.32	14.22^{b}
Rajkumar	454^{a}	338^{b}	15.40^{b}	18.78	15.21^{a}
Pioneer 3522	500^{a}	306^{c}	16.63^{a}	17.30	15.18^{a}
LSD (0.05)	74.68	23.30	1.16	2.16	0.48
F test	*	**	**	Ns	**
Sem (±)	41.71	20.47	0.79	0.49	0.133
CV (%)	15.10	6.00	6.70	10.70	2.90
Nitrogen Level					
150 kg ha^{-1}	413^{b}	330	15.11	16.77^{c}	14.58^{b}
175 kg ha^{-1}	427^{b}	337	15.28	17.44^{bc}	14.87^{ab}
200 kg ha^{-1}	442^{ab}	345	15.33	18.38^{ab}	14.88^{ab}
225 kg ha^{-1}	467^{a}	349	15.51	18.59^{a}	15.16^{a}
LSD (0.05)	28.20	18.62	0.735	0.99	0.349
F test	**	Ns	Ns	**	*
Sem (±)	11.51	4.305	0.082	0.42	0.11
CV (%)	6.51	5.52	4.80	5.60	2.40
Grand Mean	437.30	340.26	15.31	17.79	14.87

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and $^{*}P<0.05$, $^{**}P<0.01$ and $^{***}P<0.001$

Grain Yield

The average grain yield of spring maize was 8.04 t ha^{-1} (Table 6). The grain yield was not influenced by variety. However, it was significantly (p>0.01) influenced by nitrogen levels. Rampur hybrid-10 had a statistically similar but slightly lower grain yield (7.63 t ha^{-1}) than Rajkumar (8.05 t ha^{-1}). The highest grain yield was observed in Pioneer 3522 (8.46 t ha^{-1}). The grain yield was highest at nitrogen level of 225 kg ha^{-1} (8.66 t ha^{-1}) and it was statistically similar with N level of 200 kg ha^{-1} (8.39 t ha^{-1}) and significantly(p>0.01) higher than N levels of 175 kg ha^{-1} (7.82 t ha^{-1}) and 150 kg ha^{-1} (7.33 t ha^{-1}).The highest nitrogen level of 225 kg ha^{-1} could increase the yield by 18.46% compared to 150 kg ha^{-1}. Further, there was no significant interaction effect of maize varieties and nitrogen levels on grain yield of spring maize.

Relationship between Ear length and Grain yield

The regression equation shows the relationship between the grain yield (kg ha^{-1}) and ear length of maize hybrids. A significant (0.01) positive correlation of ear length was observed with grain yield (r = 0.43**). The difference in grain yield is due to differences in ear length by 18.89% (Figure 1).

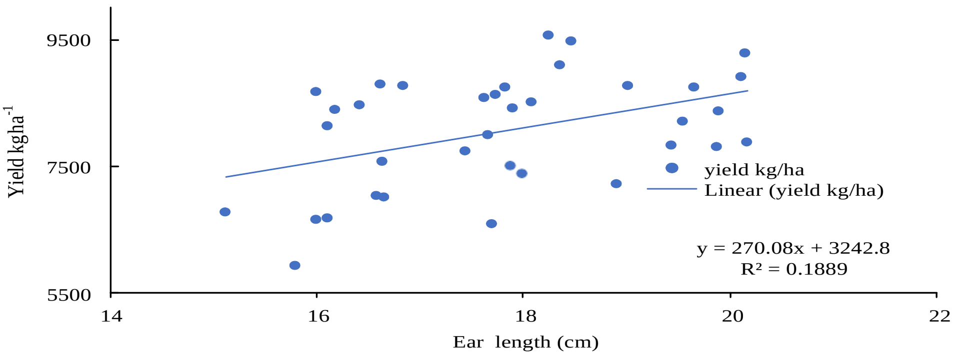

Figure 1. Simple linear regression between the grain yield and ear length of Spring hybrid maize at Badhaiyatal, Bardiya, Nepal, 2021

Relationship between Ear circumference and Grain yield

The regression equation shows the relationship between the grain yield (kg ha^{-1}) with ear circumference of maize hybrids. A significant (0.01) positive correlation of ear circumference was observed with grain yield (r = 0.52**). The difference in grain yield is due to differences in ear circumference by 26.67% (Figure 2).

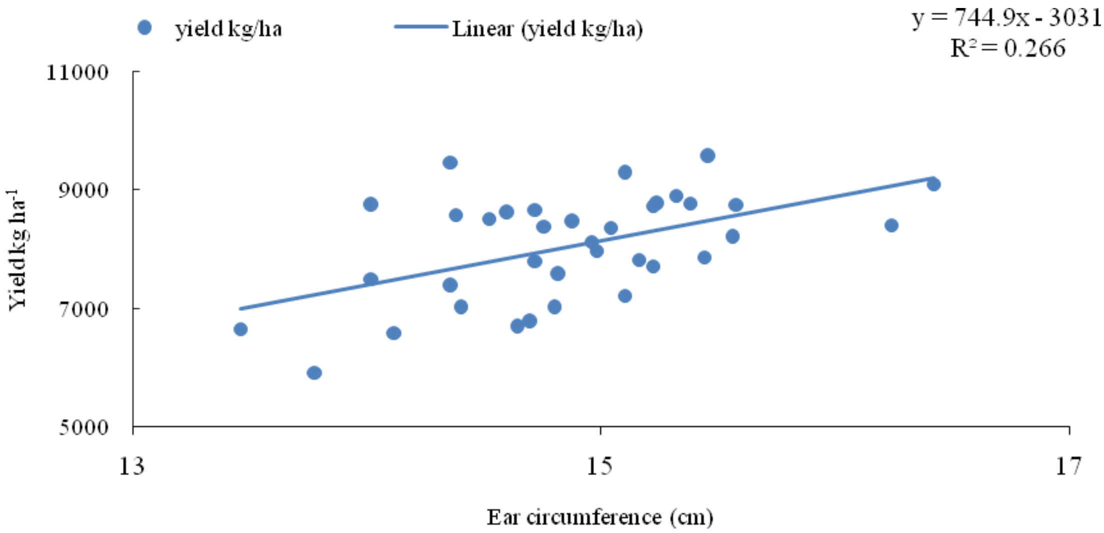

Figure 2. Simple linear regression between the grain yield and ear circumference of Spring hybrid maize at Badhaiyatal, Bardiya, Nepal, 2021

Relationship between number of Kernels per Ear and Grain yield

The regression equation shows the relationship between the grain yield (kg ha^{-1}) and number of kernels per ear of maize hybrids. The yield attribute, number of kernels per ear showed a significant (0.01) positive correlation with grain yield (r = 0.51**). Number of kernels per ear had 26.41% determination on grain yield (Figure 3).

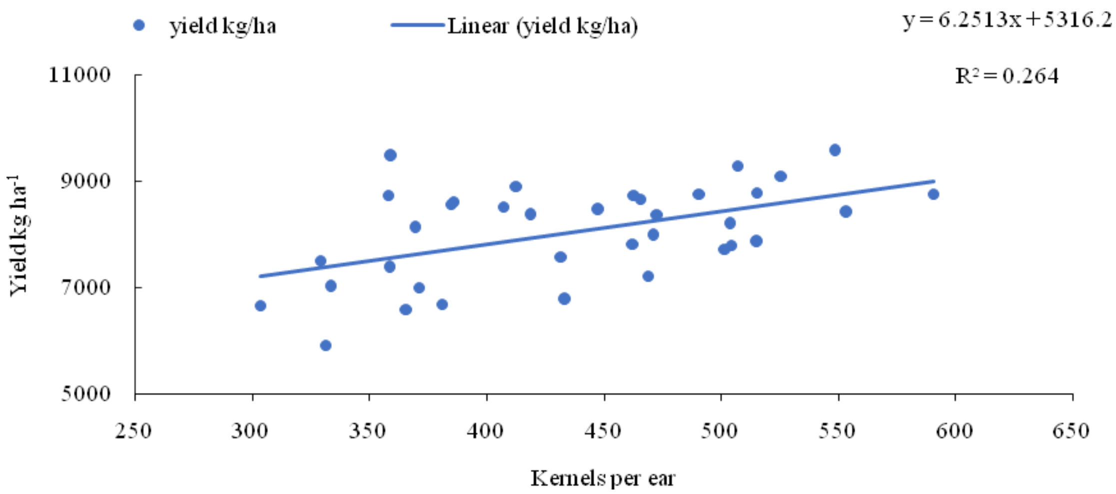

Figure 3. Simple linear regression between the grain yield and number of kernels per ear of spring hybrid maize at Badhaiyatal, Bardiya, Nepal, 2021

Stover yield

Stover yield was significantly (0.05) influenced by variety, but it was not significantly (0.05) influenced by nitrogen levels. Stover yield was highest in Rampur hybrid 10 (13525 kg ha^{-1}), followed by Rajkumar (12185 kg ha^{-1}) and lowest in Pioneer 3522 (9977 kg ha^{-1}). It might be due to the higher number of leaves and a genetic trait for thick stems. Similarly, stover yield was not significantly (0.05) influenced by nitrogen levels. However, a slightly higher stover yield was observed with a nitrogen level of 225 kg ha^{-1} (12125 kg ha^{-1}) and the lowest with a nitrogen level of 150 kg ha^{-1} (11397 kg ha^{-1}).

Harvest index

The average harvest index of spring hybrid maize observed in the experiment was 0.40 (Table 6). Both variety and nitrogen levels had a significant (0.05) influence on the harvest index of spring maize. A significantly (0.05) higher harvest index was observed in Pioneer 3522 (0.45) and the lowest in the remaining two varieties, i.e., Rampur hybrid-10 (0.36) and Rajkumar (0.40), which were significantly (0.05) at par. Similarly, a significantly (0.001) higher harvest index was observed with nitrogen levels of 225 kg ha^{-1} (0.42) and 200 kg ha^{-1} (0.41), which were significantly at par. The lowest harvest index was observed with nitrogen levels of 175 kg ha^{-1} (0.397) and 150 kg ha^{-1} (0.392), which were significantly (0.001) at par.

Shelling percentage

The average shelling percentage was 69.47 % and was significantly (0.05) influenced by variety (Table 6). Statistically (0.05) higher shelling percentages were observed in Rampur hybrid 10 (71.04%) and Pioneer 3522 (70.13%), which were significantly at par. The lower shelling percentage was observed in Rajkumar (67.23%). Nitrogen levels were significantly (0.05) influenced by shelling percentage. A nitrogen level of 225 kg ha^{-1} (70.68%) resulted in a statistically (0.05) higher shelling percentage, followed by 200 kg ha^{-1} (70.37%) and 175 kg ha^{-1} (68.54%). The lower shelling percentage was observed with a nitrogen level of 150 kg ha^{-1} (68.27%).

Sterility percentage

The average sterility percentage was observed at 15.76% (Table 6). Both hybrid variety and nitrogen levels had no effect on the sterility percentage. However, a statistically non-significant (0.05) but slightly higher sterility percentage was observed in Rajkumar (16.96%) than in Rampur hybrid 10 (16.41%) and Pioneer 3522 (13.91%). Nitrogen levels of 150 kg ha^{-1} (16.67%) had a statistically non-significant (0.05) but slightly higher sterility percentage than 200 kg ha^{-1} (15.90%) and 175 kg ha^{-1} (15.90%). The lower sterility percentage was observed with a nitrogen level of 225 ha^{-1} (14.57%).

Table 6. Yield attributing traits and yield of spring hybrid maize as influenced by varieties and nitrogen levels at Bardiya, Nepal, 2021

Treatments	**Yield (t ha^{-1})**	**Stover yield (kg ha^{-1})**	**Harvest index**	**Shelling Percentage**	**Sterility percentage**
Variety					
Rampur Hybrid 10	7.63	13525^{a}	0.36^{b}	71.04^{a}	16.41
Rajkumar	8.05	12185^{ab}	0.40^{b}	67.23^{b}	16.96
Pioneer 3522	8.46	9977^{b}	0.45^{a}	70.13^{a}	13.91
LSD (0.05)	0.97	2470.32	0.04	2.65	5.35
F test	Ns	*	*	*	Ns
SEm (±)	0.23	1034.35	0.028	1.14	0.93
CV (%)	10.70	18.30	10.80	3.40	30.00
Nitrogen Level					
150 kg ha^{-1}	7.31^{c}	11397	0.392^{b}	68.27^{c}	16.67
175 kg ha^{-1}	7.82^{bc}	12069	0.397^{b}	68.54^{bc}	15.90
200 kg ha^{-1}	8.39^{ab}	11991	0.41^{a}	70.37^{ab}	15.90
225 kg ha^{-1}	8.66^{a}	12125	0.42^{a}	70.68^{a}	14.57
LSD (0.05)	0.63	837.3	0.01	1.84	2.08
F test	**	Ns	***	*	Ns
SEm (±)	0.30	168.36	0.007	0.61	0.43
CV (%)	7.92	7.10	3.70	2.70	13.30
Grand Mean	8.04	11895.50	0.40	69.47	15.76

Treatment means followed by common letter (s) within column are not significantly different from each other based on DMRT 0.05. Ns indicates non significance and *P<0.05, **P<0.01 and ***P<0.001

DISCUSSION

Growth of spring hybrid maize

Plant height was not significantly (0.05) influenced at 75 DAS by variety (Table 1). It may be due to the fact that all tested varieties were hybrids with the heterotic effect of rapid growth rate. This finding is similar to the findings of Enujeke et al (2013) who also showed that in an experiment with various varieties of maize; plant height had no direct relationship with variety at 75 days after sowing. The non-significant plant height of all hybrid varieties tested has a similar effect on grain yield. The number of leaves of spring maize was found to be significant at 30 DAS and 60 DAS (Table 2) as influenced by variety. It might be due to genetic characteristics and the different growth rates of the varieties tested. It was not significant on other days after sowing, i.e., 45 DAS and 75 DAS. It might be due to similar genetic characteristics for bearing leaves. This finding is in line with the findings of Karn et al. (2019).

Leaf area index (LAI) was significantly (0.05) influenced by variety at 75 DAS (Table 3). It might be due to the difference in leaf number, longer length, and wider breadth of genotypes of individual hybrids. A higher index of leaf area was observed in Pioneer 3522 than in Rajkumar and Rampur hybrid 10, which may be due to its longer and wider leaves. This finding is consistent with those of (Karnet al 2019, Sajjan et al 2002). A higher leaf area index increases photosynthetic area, chlorophyll content, and biomass assimilate storage, all of which increase available translocate for grain yield.

Variety had a significant (0.01) influence on tasseling and silking days (Table 4). However, anthesis silking interval (ASI) was not significantly (0.05) influenced by variety. This might be due to genetic characteristics of earlier days to maturity and rapid growth rates. This is similar to the findings of Adhikari et al (2021). Dhakal et al (2017) also reported similar results of a significant influence of variety on tasseling and silking. Earlier tasseling and silking cause earlier physiological maturity in spring maize.

Yields attributes and yield of spring hybrid maize

Variety was found to have a significant (0.05) influence on yield attributing characters such as number of kernels per ear, thousand kernels weight, cob circumference, number of kernel rows per ear, and shelling percentage, whereas number of ears harvested per hector, cob length, and sterility percentage were found to be non-significant (Tables 5 and 6).

The higher number of kernels per ear in Pioneer 3522 than in Rajkumar and Rampur hybrid 10 may be due to its better capacity to convert photosynthetase into sink, resulting in a greater number of kernels per ear than the Nepali hybrid. Similar findings were observed by Adhikari et al (2021) and Karn et al (2019). The higher number of kernels per cob results in a higher grain yield in Pioneer 3522 than in other varieties.

The higher thousand kernel weight observed in Rampur hybrid 10 than in Rajkumar and Pioneer 3522 might be due to its genetic potential for large kernel size and better performance under genotypic environment interaction (Table 5). Similarly, higher cob circumference and kernel rows in Pioneer 3522 than in other varieties might be due to a higher leaf area index for more accumulation of biomass and a better capacity to convert photosynthesis into a sink, which increased both cob circumference and number of kernel rows. This finding is similar to the findings of Karn et al (2019) and Koirala et al (2020). Higher cob circumference and the number of kernel rows per ear support a numerically higher grain yield in Pioneer 3522.

Grain yield was found to be non-significant as influenced by variety (Table 6). This might be due to the similar genetic potential of both multinationals (Rajkumar and Pioneer 3522) and the newly released Nepali hybrid (Rampur hybrid 10). This finding is in agreement with the findings of Paudel (2009). All three hybrids tested have similar grain yields in the spring season.

Growth of spring hybrid maize at different nitrogen levels

Plant height was significantly (0.05) influenced by nitrogen levels at all days after sowing (DAS) observations (Table 1). Taller plant height with a nitrogen level of 225 kg ha^{-1} at all days after sowing might be due to the fact that with the higher dose of nitrogen application, the cell division, cell elongation, nucleus formation, green foliage, and thus the chlorophyll content increase, which increases the rate of photosynthesis and extension of the stem, resulting in increased plant height (Diallo et al 1997, Thakur et al 1998). This finding is consistent with those of Abubakar et al (2019), Karn et al (2019) and Worku et al (2020). Thus, plant height increases with an increase in nitrogen level, resulting in higher grain yield.

Leaf number was significant (0.05) as influenced by nitrogen levels at 75 DAS (Table 2). With a nitrogen level of 225 kg ha^{-1} on all days after sowing, a greater number of leaves were observed, which may be due to nitrogen availability for cell division, nucleus formation, and chlorophyll synthesis, which increased the rate of photosynthesis for a greater number of leaf extension. This is all in agreement with the findings of Imran et al (2015). Thus, the number of leaves increases with an increase in nitrogen level, which increases the photosynthetic leaf area index, resulting in a higher grain yield.

Leaf area index (LAI) was observed to be significantly (0.01) influenced by nitrogen levels (Table 3). The higher leaf area index with a nitrogen level of 225 kg ha^{-1} might be due to increased nitrogen supply for leaf emergence and extension to its maximum length and breadth and a higher number of leaves. All these were in agreement with the findings of Imran et al (2015). The leaf area index increased in a linear fashion as the nitrogen level increased.

Days to tasseling, days to silking and anthesis silking interval (ASI) were significantly (0.05) influenced by nitrogen levels (Table 4). Earlier days to tasseling and silking were observed with a nitrogen level of 225 kg ha^{-1}, which might be due to sufficient nitrogen availability for rapid vegetative growth and quick entry into the reproductive phase. More number of days to tasseling and silking was observed with nitrogen levels of 150 kg ha^{-1}, which may be due to insufficient nitrogen for cell growth and development, slowing plant vegetative growth and a delayed reproductive phase. Similar findings were observed by Dawadi and Sah (2012) Rai (1961) and Yadav (1990). Early tasseling and silking shorten the vegetative stage and increase the grain filling duration in spring maize, increasing grain yield with an increase in nitrogen level.

Yields attributes and yield of maize genotypes at different nitrogen levels

Yield attributes viz., number of kernels per ear, ear length, ear circumference, and shelling percentage, were significantly (0.05) influenced by nitrogen levels, but thousand kernel weight, number of kernel rows per ear, and sterility percentage were not significantly influenced by nitrogen levels (Table 5 and Table 6).

A higher number of kernels per ear were observed with a nitrogen level of 225 kg ha^{-1} (Table 5). It might be due to better translocation of photosynthates to the sink, which increased the number of kernels per ear. With an increase in nitrogen level, the numbers of kernels per ear increased from 150 kg ha^{-1} to 225 kg ha^{-1} as maize hybrids are responsive to nitrogenous fertilizer and have a better capacity to convert photosynthetates. Similar results were obtained by Gungula et al (2003), Majid et al (2017) and Wajid et al (2007), who found the increase in kernels per ear correlated with the increase in N level. Turgut (2000) also observed a significant number of kernels per ear with increased nitrogen level and found a maximum number with a nitrogen level of 280 kg ha^{-1}. Thus, the number of kernels per ear increases with an increase in nitrogen level, which increases final grain yield.

Ear length was significantly (0.01) influenced by nitrogen levels (Table 5). Longer ear length was observed with a nitrogen level of 225 kg ha^{-1} than with other levels of nitrogen. It may be due to the higher accumulation of biomass and translocation into the sink (ear). Pokhrel et al (2009) noted the longest cob length with a nitrogen level of 210 kg ha^{-1}. Longer ear length with an increase in nitrogen level results in higher grain yield.

Similarly, higher ear circumference was observed with increasing nitrogen levels and was found higher at nitrogen levels of 225 kg ha^{-1}. It might be due to rapid nucleus formation, cell division, and cell elongation that ultimately support longer ear length and higher ear circumference. Similarly, a positive correlation between the level of nitrogen and the circumference of cob was reported by Ahmad et al (2018), Santos et al (2002) and Amanullah et al (2016). An increase in ear circumference with a higher nitrogen level results in a higher yield of spring maize.

The shelling percentage of spring maize was significantly (0.05) influenced by nitrogen levels (Table 6). A higher shelling percentage was observed with a nitrogen level of 225 kg ha^{-1} followed by 200 kg ha^{-1} than with other levels of nitrogen. This is due to better conversion of assimilate into sink (kernels) due to a longer grain filling period with these nitrogen levels. This finding is in line with the findings of Amanullah et al (2016). Thus, an increase in shelling percentage with a higher nitrogen level ultimately increases grain yield.

There was a significant ($p<0.01$) effect on grain yield as influenced by nitrogen levels. Higher grain yields were observed with nitrogen levels of 225 kg ha^{-1}, followed by 200 kg ha^{-1} (Table 6). This is possible due to a significantly higher number of kernels per ear, longer ear length, ear circumference, and shelling percentage (Table 5 and Table 6). It is obvious that grain yield increases with increasing levels of nitrogen, as nitrogen increases chlorophyll synthesis, cell division, and optimum utilization of solar light. Higher assimilate production and its conversion to starch result in higher grain yield. Sharifi et al (2016) also reported the highest grain yield with the application of 225 kg N ha^{-1}. Similar findings were also observed by Adhikari et al (2021). A better yielding nitrogen level of 225 kg ha^{-1} could increase the yield by 18.46% compared to 150 kg ha^{-1}. Among the nitrogen levels used in the experiment, nitrogen level 225 kg ha^{-1} produced the highest grain yield whereas nitrogen level of 200 kg ha^{-1} produced similar grain yield in spring maize of the Bardiya-like climate in Nepal. Therefore, it is suggested that farmers in Bardiya should use a nitrogen level between 200 kg ha^{-1} and 225 kg ha^{-1} for a higher grain yield of spring maize.

CONCLUSION

Different levels of N affect yield and yield attributes significantly. The highest grain yield was observed at 225 kg N ha^{-1}. The present recommendation of 180 kg ha^{-1} of nitrogen is not sufficient to get an optimum yield of hybrid maize. The application of N level 200 kg ha^{-1} ensures higher grain yield similar to 225 kg ha^{-1}. However, all tested hybrid varieties showed similar grain yield. Eventually all hybrids with dose of 200 kg N ha^{-1} are suggested for farmers in Bardiya and similar climatic conditions. Besides, this study needs further study for recommendation of specific N level for particular hybrid variety.

Acknowledgements

We would like to express our sincere gratitude to the Agriculture and Forestry University, and Prof. Shrawan Kumar Sah for continuous support and guidance during the research period. Financial support for this study was obtained from Prime Minister Agriculture Modernization Project (PMAMP).

Authors' Contributions

All authors listed have made a substantial, direct and intellectual contribution to the experimentation, data recording, and analysis and manuscript preparation.

Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

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