Agraarteadus
2 • XXXII • 2021 289–295

Journal of Agricultural Science
2 • XXXII • 2021 289–295

GENOTYPE AND NITROGEN EFFECTS ON GRAIN YIELD AND YIELD-RELATED TRAITS OF MAIZE (*Zea mays* L.) HYBRIDS

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Saabunud: Received: 01.11.2021

Aktsepteeritud: Accepted: 17.12.2021

Avaldatudveebis: Published online: 18.12.2021

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Keywords: grain yield, growth, hybrids, maize, nitrogen.

DOI: 10.15159/jas.21.37

ABSTRACT. Genotype and nitrogen application are important determinants of grain yield in maize. This experiment was carried out in split-plot design with two factors (maize hybrids as the main factor and nitrogen rates as the sub factor) arranged in randomized complete block design (RCBD) with three replications. The maize hybrids including Rampur Hybrid-2, Rampur Hybrid-4 and Rampur Hybrid-6 were main plots, and four nitrogen rates of 0, 140,160, and 180 kg N ha^{-1} were sub-plot. Results revealed that hybrids had significant effects on the days to 50% tasselling, cob circumference, number of kernel rows per cob and grain yield. Similarly, nitrogen rates had significant effects on all parameters except on the days to 50% tasselling and silking. The highest values of cob length (18.31 cm), no of kernel rows per cob (13.22), no of kernels per cob (33.36), cob circumference (13.90 cm) was recorded from the plot fertilized with 180 kg N ha^{-1}. Rampur Hybrid-2 produced the highest yield (6.19 t ha^{-1}), whereas the lowest yield was found in Rampur Hybrid-6. Similarly, 180 kg N ha^{-1} produced a significantly higher yield (7.06 t ha^{-1}) which was followed by 160 kg ha^{-1} (6.71 t ha^{-1}), 140 kg ha^{-1} (6.30 t ha^{-1}) and the lowest yield (3.93 t ha^{-1}) with 0 kg N ha^{-1}. Therefore, among the hybrids evaluated, Rampur Hybrid-2 could be an appropriate hybrid variety for the cultivation at Dang district and similar conditions in Nepal. This study suggests that maize production can be maximized by cultivating Rampur Hybrid-2 with the use of 180 kg N ha^{-1} in the inner Terai region of Nepal.

Introduction

In terms of area and productivity, maize is Nepal's second most important crop after rice. In Nepal, the maize production area is currently 8.915 million hectares with a productivity of 2.50 t ha^{-1} (MOAD, 2016). According to Oad *et al*. (2004), the biggest obstacles to boosting grain yield, include an insufficient supply of fertilizers. Among the plant nutrients, nitrogen (N) management is one of the most essential factors for increasing crop yield and profitability (Amanullah, 2016). N is the most yield-restraining nutrient in crop production worldwide Guo *et al.* (2016). Nitrogen is a major component of amino acids, which function as the building blocks of proteins. It is a vital nutrient for maize, and its role in photosynthesis and other biological activities such as water and mineral absorption, vacuole storage, and xylem transport is a key determinant of grain yield (Asibi *et al*., 2019). Nitrogen (N) fertilizer affects dry matter production in maize via regulating leaf area development, leaf area maintenance, photosynthetic ability, and, as a result, yield, and grain quality (Muchow, Sinclair, 1994). Nitrogen improves grain yield in all hybrids, mostly by increasing the number of kernels, which increases productivity (Uribelarrea *et al*., 2004; Khaliq *et al*., 2009). Nitrogen (N) deficit results in pale, yellowish-green maize plants with thin stalks. Because nitrogen is a mobile nutrient in plants, symptoms appear first on the older, lower leaves and proceed up the plant if the deficiency is not corrected. A V-shaped yellowing appears on leaves, starting at the tip and moving down the midrib toward the leaf base (Sawyer, 2004). The increase in maize grain production after nitrogen fertilization is mostly due to an increase in the number of ears per plant, total dry matter distributed to the grain, and average ear weighing (Nxumalo *et al*., 1993). Hybrid maize varieties are more nitrogen-responsive than local varieties of maize (Shrestha *et al*., 2018b). Maize grain production and quality are affected by nitrogen application rate and fertilizer N source. In hybrid maize varieties, nitrogen fertilizer at a rate of 150 kg ha^{-1} enhanced grain production and yield attributing factors such as the number of cobs per hectare and thousand-grain weight (Sharma *et al*., 2019). Urea is becoming more popular because it offers several advantages over other forms of nitrogen fertilizer in terms of manufacturing, transportation, and marketing (Biswas, Ma, 2016). Another source of N is Di-ammonium phosphate.

Crop yield is also heavily influenced by variety. To acquire the best yield, cultivars that are suitable to specific agro-ecological locations, seasons, and maturity should be chosen (Adhikari *et al*., 2021). The reason for differences in grain yield and yield attributing traits among the maize genotypes was due to their variation in their genetic makeup. Prasai *et al*. (2015) reported significant differences among maize cultivars for grain yield and yield attributing traits. Dhakal *et al*. (2017) observed the difference in the days to tasseling and silking among maize genotypes. Shrestha *et al*. (2021) found that promising maize hybrids namely KWM-91 × KWM-93 produced the maximum values of grain yield (9.99 t ha^{-1}) followed by KWM-93 × KWM-91 (9.63 t ha^{-1}) and KWM-92 × KWM-93 (9.40 t ha^{-1}) at Khumaltar, Lalitpur, Nepal. Similarly, Kandel and Shrestha (2020) found that their two years of field experiments showed that P3396, Shresta, and Rampur Hybrid 6 in 2018 and P3396, Shresta, and Ganga Kaveri in 2019 was promising maize hybrid in inner terai condition in Nepal.

The hybrid variety with appropriate nitrogen doses is most important to maximize maize yield. The optimum N fertilizer rates and maize hybrids have not been determined for the newly developed hybrids in the district. Therefore, this study was carried out to determine the optimum nitrogen rates and maize hybrid.

Table 1. Physico-chemical properties of the soil of the experimental location

S.N.	Properties	Content	Category
1	Physical properties		
	Sand (%)	21.6	
	Silt (%)	58.80	
	Clay (%)	19.60	
	Soil texture		Silt loam
2	Chemical properties		
	pH	6.67	Slightly Acidic
	Total Nitrogen (%)	0.10	Medium
	Available Phosphorus (P_2O_5 kg ha^{-1})	45	Medium
	Available Potassium (K_2O kg ha^{-1})	190.78	Medium
	Organic matter (%)	2.1	Low

Materials and Methods

Experimental location

The experiment was conducted in Lamahi municipality, Dang district in Lumbini province of the inner Terai region of Nepal from June to September 2017. Geographically, it is located at 27.9904° N Latitude and 82.3018° E Longitude and has an elevation of 725 masl. The Physico-chemical properties of the soil of the experimental site are given in Table 1. The meteorological data for the growing season of 2017 is presented in Figure 1.

The soil analysis results showed (Table 1) the soil was silt loam, pH 6.67 and low in organic matter (2.1%).

Plant materials

The plant materials used in the experiment were received from National Maize Research Program, Rampur, Chitwan, Nepal. The details of plant materials are given in Table 2. These three maize hybrids are recommended for the Terai region of Nepal. The experimental location is in the Terai region of Nepal. These hybrids were favoured for cultivation because of their higher productivity by farmers. The effects of different rates of nitrogen on these maize hybrids were not evaluated in Lamahi, Dang district; therefore, these hybrids were selected for this study.

Table 2. The details of maize hybrids used in the experiment

S. N.	Name of hybrids	Parentage	Type
1	Rampur Hybrid-2	RML-4/NML-2	Single crops hybrid
2	Rampur Hybrid-4	RML-32/RML-17	Single crops hybrid
3	Rampur Hybrid-6	RML-4/RML-17	Single crops hybrid

Experimental design and cultural practices

Twelve treatments were laid out in a split-plot design with two factors (Hybrids as the main factor and nitrogen rates as the subfactor) arranged in a randomized complete block design (RCBD) with three replications. The maize hybrids of Rampur Hybrid-2, Rampur Hybrid-4 and Rampur Hybrid-6 were main plots, and four nitrogen rates of 0, 140,160, and 180 kg N ha^{-1} were sub-plot. Field data were collected from the two middle rows of each plot leaving the outside rows and a distance of 25 cm at the ends of each middle row to serve as borders. Each plot size measured 2.4 m × 4 m (9.6 m^2) consisting of four rows of 0.60 m apart and 4 m in length. The individual plots and replication were separated by 0.5 m. We tested four levels of N (0, 140, 160 and 180 kg N ha^{-1}) on three maize hybrids (Rampur Hybrid-2, Rampur Hybrid-4, and Rampur Hybrid-6).

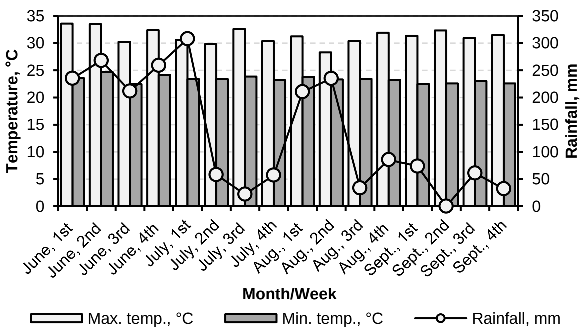

Figure 1. Climatic records of the experimental location

The fertilizer was applied into soil rowsby hands. The nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) were applied via Urea, Diammonium Phosphate (DAP), and Muriate of Potash (MOP). Half dose of the Nitrogen (0, 70, 80 and 90 kg N ha^{-1}) and a full dose of phosphorus (60 kg P_2O_5 ha^{-1}) and potassium (40 kg K_2O ha^{-1}) were applied at the basal dose at the time of seed sowing. The remaining N was applied in two splits; first dose (0, 35, 40, and 45 kg N ha^{-1}) at six-leaf stages and second dose (0, 35, 40, and 45 kg N ha^{-1}) at the ten-leaf stage. During the maize growing season, two manual weeding and hoeing operations were carried out. On 18 days after sowing, the first weeding was done, and 36 days later, the second weeding was done. Irrigation was used at three different periods of growth: knee-high stage, tasseling stage, and milking stage. Other crop management practices such as irrigation and pest management were carried out as per the recommendation of the National Maize Research Program (NMRP) Rampur, Chitwan, Nepal.

Data collection and observations

Field data were collected from the two middle rows of each plot leaving the outside rows and a distance of 25 cm at the ends of each middle row to serve as borders. Data obtained included days to 50% silking, days to 50% tasseling, plant height, cob length, and cob circumference, ear weight, kernel rows per cob, and the number of kernels per row. The moisture content was determined on all harvested cobs in representative cobs (central two rows). Wile-Model 55-Grain Moisture Meter was used to take the reading on the moisture content of grain.

The following formula (Eq.1) was used to compute grain yield (t ha^{-1}) at 12% moisture content using fresh ear weight:

$$GY = \frac{FW \times (100 - GMP) \times S \times 10\,000}{(100 - DMP) \times NPA}, \qquad (1)$$

where
GY – grain yield, kg ha^{-1};
FW – fresh weight of ear in kg per plot at harvest, kg $plot^{-1}$;
GMP – grain moisture percentage at harvest, %;
DMP – desired moisture percentage, *i.e.*, 12%;
NPA – net harvest plot area, m^2;
S – shelling coefficient, *i.e.*, 0.8.

Grain yield was converted to t ha^{-1} from kg ha^{-1}.

Data analysis

All collected data were entered into Microsoft Excel 2016 and analyzed by using GENSTAT (version14th edition; VSN International, Hemel Hempstead,UK). All the data collected were statistically analyzed using the analysis of variance (ANOVA) procedure described by Gomez and Gomez (1984) for Split plot design experiments. Separation of treatment means for the significant difference was performed by using the Fisher's least significant difference (LSD) procedure at 0.05 probability level (Obi, 1986).

Results and Discussion

Effect of genotypes

The plant height, days to 50% silking, cob length, and no. of kernels per row were non-significant. The plant height varied from 167.03 (Rampur Hybrid-4) to 168.08 (Rampur Hybrid-6) and days to 50% silking varied from 61 days (Rampur Hybrid-4) to 63.17 (Rampur Hybrid-2). The cob length differed from 16.32 cm (Rampur Hybrid-6) to 16.49 cm (Rampur Hybrid-2). The number of kernels per row varied from 29.10 (Rampur Hybrid-4) to 31.93 (Rampur Hybrid-2). The days to 50% tasselling, cob circumference, no. of kernel rows per cob and grain yield were found significant (Table 3). Significantly, the maximum days to 50% tasselling was found in Rampur Hybrid-2 (58.67 days) and the minimum days to 50% tasselling (58 days) in Rampur Hybrid-6. The cob circumference was significantly biggest (13.61 cm) in Rampur Hybrid-2 and the smallest (13.09 cm) in Rampur Hybrid-4. The maximum no. of kernel rows per cob was found in Rampur Hybrid-2 (13.36) and the minimum no. of kernel rows per cob (13.07) in Rampur Hybrid-6. The maximum grain yield was found in Rampur Hybrid-2 (6.19 t ha^{-1}) and Rampur Hybrid 6 produced the minimum grain yield (5.80 t ha^{-1}) (Table 4).

Table 3. Mean squares from ANOVA for grain yield and other agronomic traits of maize hybrids

Sources	df	Plant height, cm	Days to 50% tasselling	Days to 50% silking	Cob length, cm	Cob circum-ference, cm	No. of kernel rows per cob	No. of kernels per row	Grain yield, t ha^{-1}
Replication	2	6.04	14.08**	23.69	0.17	1.88*	0.94	0.90	0.01
Hybrid (H)	2	4.20	7.58*	15.44	0.10	0.80	3.83	30.16	0.44
Error (a)	4	60.21	0.66	5.23	2.46	0.25	0.64	37.09	0.11
Nitrogen (N)	3	2462.35**	2.54	7.29	25.66**	2.95**	1.65*	56.59**	17.94**
H × N	6	12.36	0.76	1.18	1.06*	0.05	0.88	0.65	0.006
Error (b)	18	17.60	1.13	4.27	0.33	0.15	0.45	3.10	0.03
Total	35								

df – degree of freedom, * statistically significant at the level of 0.05, ** statistically significant at level 0.01

The above ANOVA (Table 3) showed that days to 50% tasselling was significant with the use of genotype. The use of genotypes showed the non-significant for the plant height, days to 50% silking, cob circumference, no. of kernel rows per cob, no. of kernels per row and grain yield. The days to 50% tasselling, days to 50% silking were non-significant with the application of nitrogen. The no. of kernel rows per cob showed a significant effect with the application of nitrogen. The traits namely plant height, cob circumference, cob length, no. of kernels per row and grain yield were found highly significant for plant height, cob circumference, no. of kernels per row and grain yield. The interaction (nitrogen × genotype) effect for cob length was found significant but non-significant for plant height, days to 50% tasselling, and days to 50% silking, cob circumference, no. of kernel rows per cob, no. of kernels per row and grain yield.

Table 4. Effect of various levels of nitrogen and genotypes on growth, grain yield and yield attributing traits in maize hybrids

Traits	Plant height, cm	Days to 50% tasselling	Days to 50% silking	Cob length, cm	Cob circumference, cm	No. of kernel rows per cob	No. of kernels per row	Grain yield, t ha^{-1}
				Maize hybrids				
Rampur Hybrid-2	167.07	58.67^{a}	63.17	16.49	13.61^{a}	13.36^{a}	31.93	6.19^{a}
Rampur Hybrid-4	167.03	57.08^{b}	61.00	16.48	13.09^{b}	12.27^{b}	29.10	5.99^{b}
Rampur Hybrid-6	168.08	58.00^{ab}	62.66	16.32	13.37^{ab}	13.07^{a}	31.75	5.80^{c}
CV%	4.64	1.41	3.67	9.56	3.78	6.24	19.69	5.54
P value	0.93	0.02	0.16	0.959	0.02	0.05	0.51	0.04
LSD (0.05)	–	0.93	–	–	0.35	0.59	–	0.18
				Nitrogen levels				
N @ 0 kg ha^{-1} (Control)	147.07^{d}	58.55	63.55	14.28^{cd}	12.60^{c}	12.27^{b}	27.53^{c}	3.93^{d}
N @ 140 kg ha^{-1}	161.71^{c}	58.11	62	16.12^{c}	13.24^{b}	13.03^{a}	30.71^{b}	6.30^{c}
N @ 160 kg ha^{-1}	176.08^{b}	57.66	62.11	17.01^{ab}	13.68^{a}	13.07^{a}	32.11^{ab}	6.71^{b}
N @ 180 kg ha^{-1}	184.71^{a}	57.33	61.44	18.31^{a}	13.90^{a}	13.22^{a}	33.36^{a}	7.06^{a}
CV%	2.51	1.84	3.32	3.51	2.95	5.22	5.70	3.17
P value	0.00	0.12	0.20	0.00	0.00	0.03	0.00	0.00
LSD (0.05)	4.16	–	–	0.99	0.39	0.67	1.75	0.19

Means with the same letter in the column are not significantly different at P = 0.05 by DMRT. LSD –least significant difference, and CV – coefficient of variance

Effect of nitrogen levels

Nitrogen levels showed no significant differences for days to 50% tasselling and days to 50% silking. Plant height, cob length, cob circumference, no. of kernel rows per cob, no. of kernels per row and grain yield were significantly affected by different levels of nitrogen (Table 3). The plant height (184.71 cm) was significantly highest with the application of nitrogen level of 180 kg N ha^{-1} and the lowest plant height (147.07 cm) was produced with the application of 0 kg N ha^{-1}. The plant height significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1}. Significantly longest cob length (18.31cm) was recorded with the application of a nitrogen level of 180 kg N ha^{-1} and the lowest cob length (14.28 cm) was produced with the application of 0 kg N ha^{-1}. The cob length significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1}. The cob circumference (184.71 cm) was the biggest with the application of nitrogen level of 180 kg N ha^{-1} and the smallest cob circumference (147.07 cm) was produced with the application of 0 kg N ha^{-1}. The cob circumference significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1}. The maximum no. of kernel rows per cob (13.22) was recorded with the application of nitrogen level of 180 kg N ha^{-1} and the minimum no. of kernel rows per cob (12.27) was produced with the application of 0 kg N ha^{-1}. No. of kernel rows per cob significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1}. The no. of kernels per row (33.36) was the maximum with the application of nitrogen level of 180 kg N ha^{-1} and the minimum no. of kernels per row (27.53) was produced with the application of 0 kg N ha^{-1}. The no. of kernels per row significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1}. The grain yield (7.06 t ha^{-1}) was the highest under nitrogen level of 180 kg N ha^{-1} and the lowest (3.93 t ha^{-1}) was produced under 0 kg N ha^{-1} The grain yield significantly increased with the increase in the rate of nitrogen from 0 to 180 kg ha^{-1} (Table 4).

Correlation study

Estimates of the phenotypic correlation for traits are shown in Table 5. Grain yield was negatively correlated with days to 50% tasselling (r = –0.253) and days to 50% silking (r = –0.291). Days to 50% tasselling were positively correlated with days to 50% silking (r = 0.73**). Grain yield was positively and significantly correlated with plant height (r = 0.883**), cob length (r = 0.812**), cob circumference (r = 0.689**), No. of kernel rows per cob (r = 0.397*), No. of kernels per row (r = 0.593**).

Table 5. Pearson's correlation coefficient among growth, grain yield and its attributing traits of maize hybrids

Traits	PH	TD	SD	CL	CC	NKRPC	NKR	GY
PH	1							
TD	–0.297	1						
SD	–0.222	0.73**	1					
CL	0.805**	–0.177	–0.214	1				
CC	0.659**	–0.005	–0.045	0.500**	1			
NKRPC	0.362*	0.043	–0.092	0.166	0.430**	1		
NKR	0.587**	–0.375*	–0.461**	0.433**	0.444**	0.078	1	
GY	0.883**	–0.253	–0.291	0.812**	0.689**	0.397*	0.593**	1

PH–plant height, cm; TD– days to 50% tasselling; SD–days to 50% silking; CL–cob length, cm, CC–cob circumference, cm, NKRPC – no. of kernel row per cob, NKR– no. of kernels per row, GY– grain yield, t ha^{-1}. * – significant at P <0.05, ** – significant at P <0.01

Discussion

Hybrid maize is a heavy feeder with a higher nutritional response (Sarkar *et al*., 2000). Commercial maize hybrids demand high nitrogen levels and fertile soils, according to Muza *et al*. (2004) and Shrestha *et al.* (2018a), hybrids respond well to nitrogen fertilizer. The highest grain yield (7.06 tha^{-1}) was obtained when the nitrogen level was 180 kg N ha^{-1}, whereas the lowest grain yield (3.93 t ha^{-1}) was obtained when the nitrogen level was zero kg N ha^{-1}. Increased nitrogen rate from 0 to 180 kg ha^{-1} resulted in a considerable increase in grain yield (Table 4). Maize received increased nutrition because of nitrogen application, resulting in higher grain production. The increased grain production due to nitrogen application could be linked to the plant's enhanced growth. The increased growth resulted in a significant rise in yield parameters such as the number of cobs per plant, grains per cob, cob length and girth, and test weight, all of which contributed to a higher grain yield with nitrogen application. Sahoo and Mahapatra (2004) have also reported on the favourable effects of nitrogen on maize grain yield. The results of this experiment showed a positive response of various yield attributes to increased nitrogen fertilization, which was consistent with the findings of several researchers (Chillar, Kumar, 2006; Bindhani *et al*., 2007; Prodhan *et al*., 2007) who found a higher green cob yield with increased nitrogen application. Nitrogen has a major effect on the crop's vegetative and reproductive growth. Increased nitrogen rates improved yield attributes, which could be related to the fact that nitrogen treatment to maize plants kept the leaves greener for longer, allowing for more dry matter accumulation and so improving yield attributes (Asaduzzaman *et al*., 2014)

Various hybrids differed in terms of growth, yield, and yield-related traits. The grain yields of the hybrids were different. Of all the hybrids, Rampur Hybrid-2 (6.19 t ha^{-1}) produced the maximum grain yield. The findings of Kandel *et al.* (2018) and Prasai *et al.* (2015), who reported considerable differences in grain yield between maize varieties, are supported by these data. Differences in days to tasselling and silking among maize genotypes were found by Prasai *et al.* (2014), Dhakal *et al.* (2017). Hussain *et al*. (2011) found that maize varieties differed in plant height. Maize genotypes had distinct genetic makeup, resulting in variation in grain yields in different locations. The most important and complex quantitative trait in maize is grain yield, which is affected by numerous genes. Both genetic and environmental factors may have contributed to the increase in maize yield under varied environmental conditions. Researchers have found a lot of variation in maize populations, including top-crosses and open-pollinated cultivars (Sampoux *et al.,* 1989). These findings are consistent with those of Grzesiak (2001), who found significant genotypic variability across maize genotypes grown in various locations.

The correlation coefficient is used to measure the degree of relationship as well as the degree of interconnection between traits (Bocanski *et al*., 2009; Nagabhushan *et al*., 2011). Selection based on yield components is thought to be more successful than selection based solely on yield (Shamsuddin, Ali, 1989). Plant height, ear height, and the number of kernel rows per ear all indicate a positive and significant correlation with maize grain yield, according to the study (Sadek *et al*., 2006). Grain yield was negatively correlated with days to 50% tasselling and days to 50%silking. Grain yield and days to blooming have a significant negative correlation, according to De Souza *et al.* (1997). Grain yield was positively correlated with plant height, cob length, cob circumference, number of kernel rows per cob, and number of kernels per row. Alvi *et al*. (2003) and Nzuve *et al*. (2014) reported similar findings. There was a positive correlation between days to 50% tasselling and days to 50% silking. This result is similar to the findings of Chase and Nanda (1967). If these traits have a strong and positive correlation, it means that genotypes are being chosen for grain yield indirectly.

Conclusion

Nitrogen fertilizer had profound effects on growth, grain yield and yield attributing traits of hybrids of maize. Nitrogen rate @180 kg ha^{-1} produced the higher grain yield in Rampur Hybrid-2. Therefore, the use of this level of nitrogen in this hybrid is beneficial to get the higher maize production.

Funding

The Institute of Agriculture and Animal Science, Prithu Technical College, Dang, Nepal supported the financial support for this research

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

GP, MB – Carry out experiment, collection, analysis and interpretation of data and wrote the manuscript;
MM, DJ – Provided guidance of experiment, critical revision of the manuscript and wrote the manuscript;
JS – Critical revision of the manuscript, data analysis and wrote the manuscript;
All the authors read and approved the final manuscript.

References

Adhikari, K., Bhandari, S., Aryal, K., Mahato, M., Shrestha, J. 2021. Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. – Journal of Agriculture and Natural Resources, 4(2):48–62. DOI: 10.3126/janr.v4i2.33656

Alvi, M.B., Rafique, M., Shafique, M., Hussain, A., Mohmood, T., Sarwar, M. 2003. Characters association and path analysis of grain yield and yield components in maize. – Pakistan Journal of

Biological Science, 6(2):136–138. DOI: 10.3923/pjbs.2003.136.138

Amanullah.2016. Rate and timing of nitrogen application influence partial factor productivity and agronomic NUE of maize (*Zea mays* L) planted at low and high densities on calcareous soil in northwest Pakistan. – Journal of Plant Nutrition, 39:683–690. DOI: 10.1080/01904167.2015.1087031

Asaduzzaman, Md., Biswas, M., Nazrul Islam, Md., Rahman, Md.M., Begum, R., Sarkar, Md.A.R., Asaduzzaman, Md. 2014. Variety and N-fertilizer rate influence the growth, yield and yield parameters of baby corn (*Zea mays* L.). – Journal of Agricultural Science, 6(3):118–131. DOI: 10.5539/jas.v6n3p118

Asibi, A.E., Chai, Q., Coulter, J.A. 2019. Mechanisms of nitrogen use in maize. – Agronomy, 9(12):775. DOI: 10.3390/agronomy9120775

Bindhani, A., Barik, K.C., Garnayak, L.M., Mahapatra, P.K. 2007. Nitrogen management in baby corn (*Zea mays* L.). – Indian Journal of Agronomy, 52:135–138.

Biswas, D.K., Ma, B.L. 2016. Effect of nitrogen rate and fertilizer nitrogen source on physiology, yield, grain quality, and nitrogen use efficiency in corn. – Canadian Journal of Plant Science, 96(3):392–403.

Bocanski, J., Srećkov, Z., Nastasić, A. 2009. Genetic and phenotypic relationship between grain yield and components of grain yield of maize (*Zea mays* L.). – Genetika, 41(2):145–154. DOI: 10.2298/GENSR0902145B

Chase, S.S., Nanda, D.K.1967. Number of leaves and maturity classification in *Zea mays* L. – Crop Science, 7:431–433.

Chillar, R.K., Kumar, A. 2006. Growth and yield behaviour of sweet corn (*Zea mays* L. saccharata) under varying plant population and nitrogen level. In Extended Summaries of Golden Jubilee National Symposium on conservation Agriculture and Environment. Held during 26–28 October, 2006, Banaras Hindu University, Varanasi, India, pp. 277–278.

De Souza, O.I., Egli, D.B., Bruening, W.P. 1997. Water stress during seed filling and leaf senescence in Soybean. – Agronomy Journal, 89(5):807–812. DOI: 10.2134/agronj1997.00021962008900050015x

Dhakal, B., Shrestha, K.P., Joshi, B.P., Shrestha, J. 2017. Evaluation of early maize genotypes for grain yield and agro-morphological traits. – Journal of Maize Research and Development, 3(1):67–76. DOI: 10.3126/jmrd.v3i1.18923

Gomez, K.A., Gomez, A.A. 1984. Statistical procedures for agricultural research. 2nd ed. – New York. John Wesley and Sons, 680p.

Grzesiak, S. 2001. Genotypic variation between maize (*Zea mays* L.) single-cross hybrids in response to drought stress. – Acta Physiologiae Plantarium, 23(4):443–456.

Guo, C., Li, P., Lu, J., Ren, T., Cong, R., Li, X. 2016. Application of controlled release urea in rice: reducing environmental risk while increasing grain yield and improving nitrogen use efficiency. – Communications in Soil Science and Plant Analysis, 47: 1176–1183. DOI: 10.1080/00103624.2016.1166235

Hussain, N., Khan, M.Y., Baloch, M.S. 2011. Screening of maize varieties for grain yield at Dera Ismail Khan. – The Journal of Animal and Plant Sciences, 21(3):626–628.

Kandel, B.P., Shrestha, K. 2020. Performance evaluation of maize hybrids in inner-plains of Nepal. – Heliyon, 6(12):e05542.

Kandel, B.P., Adhikari, N.R., Adhikari, B.B., Tripathi, M. 2018. Performance of hybrid maize in Chitwan Nepal. – Bangladesh Journal of Plant Breeding and Genetics, 31:43–51.

Khaliq, T., Ahmad, A., Hussain, A., Ali, M.A. 2009. Maize hybrids response to nitrogen rates at multiple locations in semiarid environment. – Pakistan Journal of Botany, 41(1):207–224.

MOAD.2016. Food and Nutrition Security: A Status Report. Reported by Ministry of Agricultural Development and Central Bureau of Statistics to the Food and Agricultural Organizations, Nepal.

Muchow, R.C., Sinclair, T.R. 1994. Nitrogen response of leaf photosynthesis and canopy radiation use efficiency in field-grown maize and sorghum. – Crop Science, 34(3):721–727. DOI: 10.2135/cropsci1994.0011183X003400030022x

Muza, L., Waddington, S.R., Banziger, M. 2004. Preliminary results on the response of nitrogen use efficient OPV and hybrid maize to N fertilizer on smallholder fields in Zimbawe. – In: Integrated approaches to higher maize productivity in the new millennium: Proceedings of the seventh eastern and southern Africa regional maize conference, Nairobi, Kenya, CIMMYT African Livelihoods Program, p. 245.

Nagabhushan, N.M., Mallikarjuna, C.H., Shashibhaskar, M.S., Prahalada, G.D. 2011. Genetic variability and correlation studies for yield and related characters in single cross hybrids of maize (*Zea mays* L.). – Current Biotica, 5:157–163.

Nxumalo, E.M., Pali-Shikhulu, J., Dlamini, S.M. 1993. Assessment of nitrogen fertilizer use in commercial hybrids. SADC-Land and Water Research Programme. – Proceedings of the Fourth Annual Scientific Conference, Windhoek, Namibia, p. 322–329.

Nzuve, F., Githiri, S., Mukunya, D.M., Gethi, J. 2014. Genetic variability and correlation studies of grain yield and related agronomic traits in maize. – Journal of Agricultural Science, 6(9):166–176. DOI:10.5539/jas.v6n9p166

Oad, F.C., Buriro, U.A., Agha, S.K. 2004. Effect of organic and inorganic fertilizer application on maize fodder production. – Asian Journal of Plant Sciences, 3:375–377. DOI: 10.3923/ajps.2004.375.377

Obi, I.U.1986. Statistical methods of detecting differences between treatment means. – SNAAP press limited, Enugu, Nigeria, 45p.

Prasai, H.K., Sharma, S., Kushwaha, U.K.S., Joshi, B.P. 2014. Varietal improvement of early maize for far western hills of Nepal. – Proceedings of the 27th National Summer Crops Workshop,Vol.II, held on18–20th April,2013 at National Maize Research Program, Rampur, Chitwan, Nepal, p.174–177.

Prasai, H.K., Kushwaha, U.K.S., Joshi, B.P., Shrestha, J. 2015.Performance evaluation of early maize genotypes in far western hills of Nepal. – Journal of Maize Research and Development, 1(1):106–111. DOI: 10.3126/jmrd.v1i1.14248

Prodhan, H.S., Bala, S., Khoyumthem, P. 2007. Response to rate of nitrogen and effect of plant density on yield of baby corn. – Journal of Interacademicia, 11:265–269.

Sadek, S.E., Ahmed, M.A., Abd El-Ghaney, H.M. 2006. Correlation and path coefficient analysis in five parents inbred lines and their six white maize (*Zea mays* L.) single crosses developed and grown in Egypt. – Journal of Applied Sciences Research, 2(3):159–167.

Sahoo, S.C., Mahapatra, P.K. 2004. Response of sweet corn (*Zea mays* L.) to nitrogen levels and plant population. – Indian Journal of Agricultural Sciences, 74(6):337–338.

Sampoux, J.P., Gallais, A., Lefort-Buson, M. 1989.S1 value combined with topcross value for forage maize selection. – Agronomie, 9(5):511–520.

Sarkar, A.K., Singh, K.P., Singh, B.P., Singh, R.P. 2000. Long term effects of fertilizers, manures and amendments on crop production and soil fertility. – Technical Bulletin of Soil Science and Agricultural Chemistry (BAU) No.2/2000, pp. 31–45.

Sawyer, J. 2004. Integrated pest management, nutrient deficiencies and application injuries in field crops. – Unpublished report IPM, 42, IOWA State University, USA.

Shamsuddin, A.K.M., Ali, M.M. 1989. Genotypic and phenotypic correlation and path analysis in spring wheat. – Bangladesh Journal of Agricultural Science, 16(1):75–78.

Sharma, R., Adhikari, P., Shrestha, J., Acharya, B.P. 2019. Response of maize (*Zea mays* L.) hybrids to different levels of nitrogen. – Archives of Agriculture and Environmental Science, 4(3):295–299.

Shrestha, J., Chaudhary, A., Pokhrel, D. 2018a. Application of nitrogen fertilizer in maize: a review. – Peruvian Journal of Agronomy, 2(2):22–26. DOI: 10.21704/pja.v2i2.1201

Shrestha, J., Subedi, S., Acharya, R., Sharma, S., Subedi, M. 2021. Variability for growth and yield traits in single cross hybrids of maize (*Zea mays* L.). – Agraarteadus, 32(2):In Press. DOI: 10.15159/jas.21.31

Shrestha, J., Yadav, D.N., Amgain, L.P., Sharma, J.P. 2018b. Effects of nitrogen and plant density on maize (*Zea mays* L.) phenology and grain yield. – Current Agriculture Research Journal, 6(2):175–182.

Uribelarrea, M., Below, F.E., Moose, S.P. 2004. Grain composition and productivity of maize hybrids derived from the Illinois protein strains in response to variable nitrogen supply. – Crop Science, 44(5): 1593–1600. DOI: 10.2135/cropsci2004.1593