*Agronomy Journal of Nepal. **7**(1):82-87*
ISSN: 2091-0649 (Print)
DOI: https://doi.org/10.3126/ajn.v7i1.62152

Identification of Optimum Plant Population and Nitrogen Dose in Maize for Mid Hills Conditions of Nepal

Bhimsen Chaulagain[1], Rajendra Kumar Bhattarai[1], Tika Bahadur Karki[1], Reshama Neupane[1], Sangita Kaduwal[1], Pankaj Gyawaly[1], Chetan Gyawali[2], Ramesh Acharya[3], Prakash Paneru[4] and Soni Kumari Das[1]

[1]National Agronomy Research Centre, Khumaltar, Lalitpur, Nepal
[2]National Rice Research Program, Hardinath, Dhanusha, Nepal
[3]Directorate of Agricultural Research, Lumle, Kaski, Nepal
[4]National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal

Corresponding author: bhimsen.chaulagain@gmail.com
ORCID: https://orcid.org/0000-0002-9856-8301

Received: May 18, 2023
Revised: June 10, 2023
Published: July 10, 2023

OPEN ACCESS

The authors declare that there is no conflict of interest.

ABSTRACT

An experiment was conducted in the summer seasons of 2021 and 2022 at the National Agronomy Research Centre's Farm Khumaltar to find out the appropriate row spacing and optimum nitrogen dose for maize. The experiment was laid out in a split plot design where nitrogen levels were allocated in the main plot and row spacing was assigned in subplots. The four different nitrogen levels were 120:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}, 150:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}, 180:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} and 210:60:40 N: $P_2O_5:K_2O$ kg ha^{-1}. Four different rows spacing were 75 cm, 60 cm, 50 cm and 43 cm. Seeds were sown at 25 cm apart. The individual plot size was 4m x 3m. Maize variety BGBY POP was used in the experiment. The sowing dates were 6 May and 19 May in 2021 and 2022 respectively. In the combined analysis of two-year data, days to 50% tasseling was found significant in 150:60:40 N: $P_2O_5:K_2O$ kg ha^{-1} while other traits were found non-significant. The mean grain yield was 4.29 t ha^{-1}. Few traits were found significant in subplot factor i.e., cob diameter (4.38 cm), cob length (16.72 cm), ear height (107.1 cm) and seed per row (28.84) were found superior to other treatments within traits while all other traits in subplot factor were non-significant in pool analysis. Late maize sowing in the second year and rainfall during earthing up affected maize performance and gave lower maize yield. From the experiment, we could say that sowing of maize should be done within the second week of May and more experiments need to be done to conclude nitrogen optimization.

Keywords: nitrogen, row spacing, earthing up, optimization, traits

How to cite this article:
Chaulagain B, RK Bhattarai, TB Karki, R Neupane, S Kaduwal, P Gyawaly, C Gyawali, R Acharya, P Paneru and SK Das. 2023. Identification of Optimum Plant Population and Nitrogen Dose in Maize for Mid Hills Conditions of Nepal. Agronomy Journal of Nepal. **7**(1):82-87. DOI: https://doi.org/10.3126/ajn.v7i1.62152

INTRODUCTION

Around three-fourths of the food humans consume globally comes from just 12 plant and five animal sources, with just three crops — wheat, rice and maize — accounting for 51 percent of the calories included in the diet, according to the United Nations Food and Agriculture Organization (FAO 2022). Maize is second important food crop of Nepal in terms of both area coverage and production. The total production and area coverage of maize in 2020/21 was 2999733 Mt and 979776 ha with average productivity of 3.06 Mt ha^{-1} (MoALD 2022).

The crop is grown under rain-fed conditions during the summer (April- September) as a sole crop or relayed with finger millet later in the season in hills. In the winter and spring seasons, it is grown in the terai, inner terai and low-lying river basin areas, with partial irrigation (Paudyal et al 2001). Large population still consume maize as their staple food and its demand is increasing rapidly due to the expansion of poultry and feed industries in Nepal (Ghimire et al 2018). Poor soil fertility, quantity and pattern of rainfall, time of crop establishment, quality of seed, level of input use, availability of irrigation and disease and pest infestations are the commonly identified problems for lower productivity of maize in the mid hills of Nepal. Moreover, the productivity of maize in Nepal is very low as compared to global yield, the wide yield gap can be attributed to various biotic and abiotic factors (Subedi, 2015). Dominance of OPV's and lower seed replacement rate are also among the major reasons behind lower productivity (Gaire et al 2018). The production and productivity of maize is highly influenced by nitrogen rate and plant density (Gözübenli and Konuskan 2010, Shrestha 2013). Yield potential of maize is highly dependent on the amount of intercepted solar radiation, water, and nitrogen supply (Birch 2003).

Less plant population and poor nutrient management practices are the major yield reducing factors in maize. Higher densities (92000 plants/ha) at vegetative stage and about 30,000 plants per hectare at harvesting period prevail in maize (KC et al 2015). Increasing plant density would require more fertilizer especially nitrogen and water (Dawadi and Sah 2012). Amount of nitrogen to be applied for maize plant depends upon variety, soil type, crop fertility status, location and yield (Singh and Singh 2002). The amount of nitrogen applied mainly depends to a large extent on the plant density of the plants/unit of cultivated land area. The higher grain yield can be achieved at an optimal high plant population with enough nutrient specially nitrogen application (Shrestha et al 2018).

Maize planting should ensure efficient uptake of nutrients and minimum mutual over shading and interplant competition. In confined row spacings most plants remain barren, plant, ear and ear size remain smaller, crop become susceptible to lodging, disease and pest and result lower yield per unit area. Nitrogen fertilization is a key component to high maize grain yield and optimum economic return (Ali and Ali 2018).

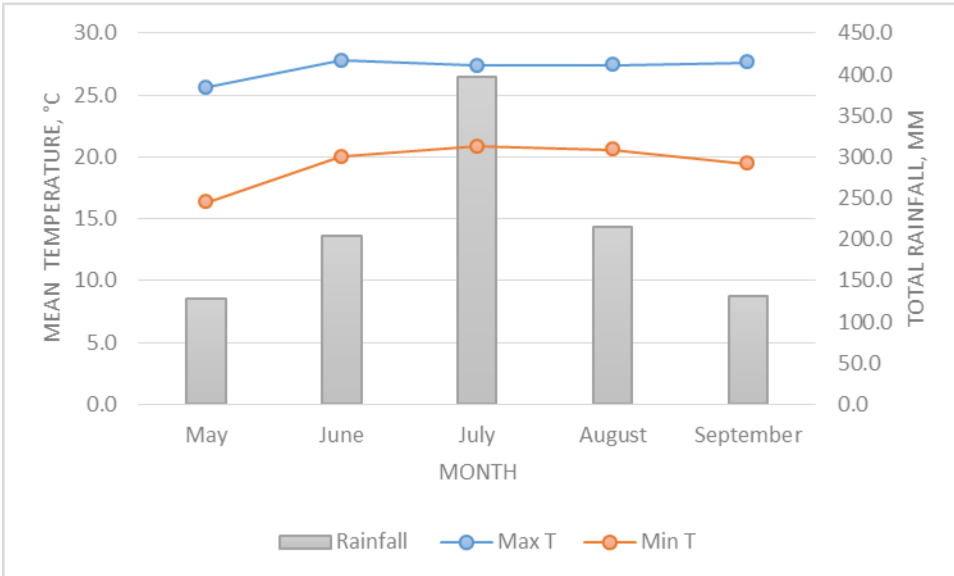
Therefore, an experiment was designed and executed at Agronomy Farm Khumaltar to identify the optimum amount of nitrogen and plant density for maximum return.

MATERIALS AND METHODS

Field experiments were conducted at National Agronomy Research Centre Farm during summer season of 2021 and 2022. The location falls in the mid hill valley condition of Nepal (27°39' N, 85°19' E, 1285 masl). The climate is warm temperature with hot and dry summers, cold winters and monsoon rains generally starts in July and continue till September. Meteorological data on rainfall, and temperature received from the meteorological station at the Centre for crop seasons (May to September 2021 and 2022) is presented in figure 1 and figure 2. The initial soil fertility status, particularly a pH of 5.98 (acidic), low organic matter (2.01%), medium total nitrogen (0.14%), high available P_2O_5 (478.6 kg ha^{-1}), medium available K_2O (160.5 kg ha^{-1}), with a silty clay loam soil texture was found in the experimental plot.

The experiment was laid out in split plot design where level of nitrogen was main plot factor and row spacing (plant density) was sub plot factor. The scientific name of maize is *Zea mays* L. (2n=20) and used variety in experiment was BGBYPOP. The recommended dose of $N:P_2O_5:K_2O$ for OPV maize is 120:60:40 kg ha^{-1} and spacing is 75cm x 25cm in summer season. Researchers generally increase plant density but forgot to increase nutrient doses. To correct such types of redundancies, an experiment was designed and executed to optimize nutrient level (nitrogen) with increasing plant densities in maize. To optimize nutrient level and plant density, 4 different nutrient levels and 4 different plant densities were tested in the experiment. Maize plant density was very low in major maize growing areas of mid hills from east to west. We can expect suitable plant density and optimum nutrient level for OPV maize after conducting this experiment. The data obtained were analyzed using GenStat 18 Edition and MS Excel were used for making graphs. The moisture content was adjusted at 14% for grain yield calculation.

The meteorological data of crop duration in 2021 showed higher total rainfall than 2022. Total rainfall days were also more in 2021 than 2022. Highest rainfall was received in July in both years however mean temperatures and total rainfall were insignificant.



\

Figure 1. Meteorological data of National Agronomy Research Centre, Khumaltar, Lalitpur, Nepal during May-Sept, 2021.

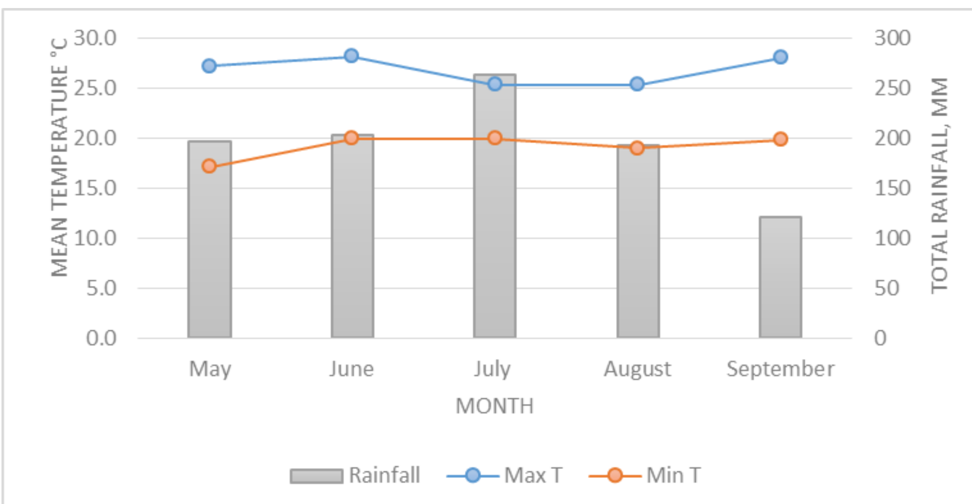


Figure 2. Meteorological data of National Agronomy Research Centre, Khumaltar, Lalitpur, Nepal during May-Sept, 2022.

RESULTS

Combined analysis of data for yield and yield attributing traits were found insignificant for most of the traits except cob length, cob diameter, ear height and seeds per row in sub plot factor (spacing). Cob diameter and cob length was higher in low plant density than higher plant density due to wider spacing between row for better growth and development of crop. Zamir et al (2011) reported that in wider plant spacing there is abundance of available resources and hence the plants were healthier than thick plant stands. Sharifai et al (2012) and Porter and Hicks (1997) stated that an increase in plant density decreases the size of cobs since the needed space for the plant is gradually reduced, the plant absorbs less nutrients and it proportionally transfers less assimilates to the cobs which cause smaller cobs. Ear height was minimum in low plant density due to easy availability of resources. In high plant density, crop would get sufficient nutrients, moisture and sunlight as the plant grows higher and ear height is also high. The root system also goes deeper in search of more nutrients and moisture. Seeds per row was found maximum in low plant density due to longer cob length.

Maximum number of grains row^{-1} (28.9) was obtained from 75 cm row spacing, while the minimum number of grains row^{-1}(25.3) was obtained from 43 cm row spacing. These results are in line with those of Shafi et al (2011) and Ali et al (2003) who reported significant variation in number of grains row-^{1} under different row spacing. Also, Bavec and Bavec (2002) observed that increase of plant population from a certain level decreased number of grains row^{-1}.

Table 1: Combined analysis result of maize trial for different yield and yield attributing traits at Khumaltar, 2021/22

Treatments	Pl ht	Ear ht	50%tas	90%mat	Cob Ø	Cob ln	seeds/row	TGW	Gr Yld
$NP_2O_5K_2O$(A)									
120:60:40	242.7	111.0	67.5	106	4.23	15.32	26.65	253.1	4.0
150:60:40	239.7	109.4	68.5	106	4.22	15.65	26.66	256.3	4.12
180:60:40	244.7	113.1	68.2	106	4.40	16.75	27.2	266.2	4.74
210:60:40	240.4	107.3	68.0	106	4.22	16.20	28.3	257.3	4.28
P-value (<.05)	Ns	Ns	ns	Ns	Ns	ns	Ns	ns	Ns
Spacing(B)									
75*25	241.4	107.1	67.9	105	4.38	16.72	28.9	262.8	4.24
60*25	241.0	109.3	68.0	106	4.27	16.27	27.6	261.7	4.23
50*25	244.4	113.1	68.1	106	4.25	15.92	27.0	257.0	4.46
43*25	240.7	111.2	68.2	106	4.17	15.01	25.3	251.0	4.21
P-value(<.05)	Ns	0.015	ns	Ns	0.00	0.002	<.001	ns	Ns
A×B	Ns	Ns	ns	Ns	Ns	ns	Ns	ns	Ns
CV%	2.7	3.9	1.4	0.6	3.1	6.2	5.9	5.2	13.8

Note: pl ht: plant height(cm), ear ht: ear height(cm), 50% tas: 50% tasseling, 90% mat: 90% maturity, Cob Ø: cob diameter(cm), Cob ln: cob length(cm), seeds/row: no. of seeds/row, TGW: thousand grain weight (gm), Gr Yld: grain yield (Mt ha^{-1})

DISCUSSION

Plant height was not significantly influenced by nutrient and spacing because single variety was used and height is mainly genetic character. Ear height was also not significantly influenced by nutrient and plant density. Days to 50 % tasseling and 90 % maturity were not significant as well. Cob diameter and cob length were found significant in plant density because low plant population allows availability of nutrients, solar radiation and moisture. Similarly, seeds per row was significantly high in low plant density. Longer cob had more number of grains per row than shorter cob. Increasing density is associated with a decrease in maize grain yield as the radiation use efficiency decreases and the competition among plants for water and nutrient increases (Griesh and Yakout 2001).

Plant reduction per unit area prevents maximum usage of production parameters while excessive density can increase the competition and decrease the yield. Maize sown in closer spacing imposes higher competition for various growth factors that resulted delayed in tasseling, silking, physiological maturity (Imran et al 2015, Sharifi et al 2016, Hayat et al 2017). However, the result is non-significant for days to 50% tasseling, days to 90% maturity, the value was highest in closer spacing (43 cm x 25 cm) than other spacing. Grain yield of maize increased significantly with increasing in N rate. N-fertilization provided sufficient nutritional requirements for the maize plants to rapidly grow and hence promoted its grain production. The grain yield has increased upto optimum level and then decreased. Although grain yield was also found non-significant. The maximum days to 50% tasseling (68.2) was recorded under the lowest row spacing (43cm), while the lowest day to 50% tasseling (67.9) were noted under the highest row spacing (75 cm). This might be due to that higher plant densities under narrow row spacing, induce competition among crop plants for different growth resources such as light, nutrient, water and air. The result is similar to Golla B et al 2019. Increasing nitrogen level has increased days to 50% tasseling due to prolonged vegetative growth period. The result is similar to result of Imran et al (15). Increasing in plant density has increased in days to 90% maturity which is similar to Shrestha J 2013. In general, the grain yield ha^{-1} was increased with the increase in N rate and with decreasing in plant/row spacing. The grain yield was 4.74 t ha^{-1} for 180 kg Nitrogen and yield decreased (4.28 t ha^{-1}) for further increase in Nitrogen (210 kg). Similarly, grain yield increased up to row spacing of 50 x 25 cm (4.46 t ha^{-1}) and decreased for 43cm x 25cm (4.21 t ha^{-1}). Higher grains yield at higher nitrogen levels might be due to the lower competition for nutrient and positive effect of N on plant growth and coincide synchrony of male and female flowering. Cob length increased with increased row spacing. The maximum cob length was 16.72cm in 75cmx25cm and decreased with decreased row spacing. The data were in line with Zamir et al 2011 that the cob length decreased as the plant population increased. Cob length generally decreases with increasing plant population (Gobeze et al 2012, Fanadzo et al 2010, Manan et al 2016). Cob diameter increased with increased row spacing. The maximum cob diameter was 4.38 cm in 75cm x 25cm and decreased with decrease in row spacing which was 4.17 cm in 43cm x 25cm. Zamir et al (2011) reported that in wider plant spacing there is abundance of available resources and hence the plants were healthier than thick plant stands. In narrow plant spacing there was more competition for available resources and hence plants were tall but weaker than wider plant spacing (Jatinder et al 2016). Although there was no significant difference in number of seeds/row in different level of nitrogen however the number of seeds/row increased with increased row spacing. The result is similar to Sharifi et al (2009) and Abuzar et al (2011) where wider row spacing significantly increased number of seeds/row. Statistical analysis of thousand grain weight showed non-significant difference for both nitrogen dose and row spacing however thousand grain weight was found maximum (266.2 g) for 180 kg nitrogen when compared with lower nitrogen doses.

CONCLUSION

The optimum dose of NPK for OPV Maize in Khumaltar and similar agroecological zones is 180:60:40 kg ha^{-1} and appropriate geometry is 50cmx25cm. Maize should be planted within second week of May to obtain maximum yield in mid hills representing Khumaltar condition. Maize roots are shallow and need earthing up before onset of monsoon. Therefore, early planting is advised to avoid rainy period during earthing up time. Similarly, increasing plant density improves efficient utilization of resources. The objective of above trial was to identify to intersection point for plant density and nitrogen level. Therefore, the experiment should be repeated to precise level of nitrogen along with plant density in OPV maize in Khumaltar condition.

ACKNOWLEDGEMENT

Authors would like to thank NARC management for allowing budget to conduct the research activity. All the staffs of National Agronomy Research Centre are highly appreciated for their dedication for timely execution for work.

AUTHORS' CONTRIBUTION

Mr. B. Chaulagain was responsible for project development, field layout, research execution and manuscript writing. Mr. Bhattarai gave valuable inputs beginning from project proposal to data analysis. Mr. Gyawaly helped with data analysis and paper write-up. Mr. Karki reviewed the article before sending it to an external reviewer and gave valuable suggestions and input.

CONFLICT OF INTEREST

The authors declare no conflict of interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Ali M, H Akbar, Inamullah and S Ali. 2018. Impact of row spacing and nitrogen placement on the performance of maize. Int. J. Agri and Env. Res., **2**(4): 282-288.

Ali R, SK Khalil, SM Raza and H Khan. 2003. Effect of herbicides and row spacing on maize (*Zea mays* L.) Pak. J. Weed Sci. Res., **9**(3and4): 171-178.

Azam S, Ali M, Amin M, Bibi S, Arif M. 2007. Effect of plant population on maize hybrids. J Agricul Biologic Sci. **2**: 104-111. Link: http://bit.ly/2v3Qmpb

Bavec F and M Bavec. 2002. Effect of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars. Eur. J. Agron., **16**: 151- 159

Birch CJ, MJ Robertson, E Humphreys, N Hutchins. 2003. Agronomy of maize in Australia: in review and prospect. In Versatile Maize-Golden opportunities: 5th Australian Maize Conference 45-57. Link: https://tinyurl.com/y8bbnjjx

Dahmardeh M. 2011. Effect of plant density and nitrogen rate on PAR absorption and maize yield. Am J Plant Physiol. **6**: 44-49. Link: http://bit.ly/2ueJHbr

Dawadi DR and SK Sah. 2012. Growth and Yield of Hybrid Maize (*Zea mays* L.) in Relation to Planting Density and Nitrogen Levels during Winter Season in Nepal. Tropical Agricultural Research, 23(3): 218 – 227

Fanadzo M, C Chiduza and PNS Mnkeni. 2010. Effect of inter-row spacing and plant population on weed dynamics and maize (*Zea mays* L.) yield at Zanyokwe irrigation scheme. African Journal of Agricultural Research, 5(7):518-523

FAO 2022. World Food and Agriculture – Statistical Yearbook 2022. Rome. https://doi.org/10.4060/cc2211en

Farnia A, M Mansouri, A Farnia, B Branch. 2015. Study on Morphological Characteristics of Maize (*Zea mays* L.) Cultivars under Different Plant Densities. Indian J Nat Sci 5. Link: http://bit.ly/2TII8NN

Gaire S, HK Shrestha and K Timsina. 2018. Dynamics of major cereals productivity in Nepal. Journal of Nepal Agricultural Research Council, 4(1), 60-71

Gehl RJ, JP Schnidt, LD Maddux and WB Gordon. 2005. Corn yield response to nitrogen rate and timing in sandy irrigated soil. Agron. J. **97**:1230-1238

Ghimire KH, KB Koirala, BK Joshi, H.K Prasai and RP Poudel. 2007. Full season maize varietal research in western hills of Nepal (2004-2006). pp. 147-156.In: Gurung, D.B., Paudel, D.C., KC, G., Upadhaya, S.R. and Pokhrel, B.B. (eds.) Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal held in June 21-23, 2007 at NARC, Khumaltar, Lalitpur, Nepal.

Ghimire YN, KP Timsina, D Devkota, S Gautam, D Choudhary, H Poudel and J Pant. 2018. Dynamics of Maize consumption and its implication in maize technology demand in Nepal. In B.M. Prasanna, Aparna Das and Kelah K. Kaimenyi (eds.) 2018. Book of Extended summaries, 13th Asian Maize Conference, and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Ludhaina, India. October 8-10, 2018. CIMMYT, Mexico D.F. p. 184-190

Gobeze YL, GM Cennio and LD van Rensberg. 2012. Effect of row spacing and plant density on yield and yield component of maize (*Zea mays* L.) under irrigation. J. Agricultural Science and Technology,B2:263-271

Golla B and D Chalchisa. 2019. Response of maize phenology and grain yield to various nitrogen rates and plant spacing at Bako, West Ethiopia. Open J Plant Sci 4(1): 009-014. DOI: 10.17352/ojps.000016

Gözübenli H and Ö Konuskan. 2010. Nitrogen dose and plant density effects on popcorn grain yield. African Journal of Biotechnology **9**: 3828-3832.

Hayat Z, SK Khalil, A Iqbal, I Ullah, M Ali et al. 2017. Nitrogen Doses and Plant Density Affect Phenology and Yield of Sweet Corn. Fresenius Environmental Bulletin 26: 3809-3815. Link: http://bit.ly/2NKBhQ1

Imran S, M Arif, A Khan, MA Khan, W Shah et al. 2015. Effect of nitrogen levels and plant population on yield and yield components of maize. Adv Crop Sci Tec 1-7. Link: http://bit.ly/2ummi8c

KC G, TB Karki, J Shrestha and BB Achhami. 2015. Status and prospects of maize research in Nepal. Journal of Maize Research and Development, 1(1), 1-9.

Khan N, NW Khan and IA Khan. 2012. Integration of nitrogen fertilizer and herbicides for efficient weed management in maize (Zea mays) crop. Sarhad J Agric 28: 457-463. Link: http://bit.ly/2Ga0kYy

Manan J, G Singh, M Sharma and G Singh. 2016. Effect of plant spacing on yield and yield attributes of maize hybrids. J. Krishi Vigyan, 5(1):41-45

MoALD. 2022. Statistical information of Nepalese Agriculture 2020/2021. Agribusiness Promotion and Statistics Division, Kathmandu, Nepal.

Paudyal KR, JK N Ransom, P Rajbhandari, KR Adhikari, V Gerpacio and P L Pingali (eds.). 2001. Maize in Nepal: Production Systems, constraints and priorities for research. NARC and CIMMYT. Kathmandu. Nepal, 48p.

Shafi M, J Bakht, MJ Khan, MA Khan and M Raziuddin. 2011. Role of abscisic acid and proline in salinity tolerance of wheat genotypes. Pak. J. Bot., **43**(2): 1111-1118

Sharifai AI, M Mahmud, B Tanimu and IU Abubakar. 2012. Yield and Yield componemts of extra early maize (zea mays L.) as influenced by intra-row spacing, nitrogen and poultry manure rates. Bayero J Pure Appl Sci 5: 113-122. Link: http://bit.ly/38pGynV

Sharifi RS and A Namvar. 2016. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). Biologija 62. Link: http://bit.ly/30E27yx

Shrestha J, DN Yadav, LP Amgain, JP Sharma. 2018. Effects of Nitrogen and Plant Density on Maize (*Zea Mays* L.) Phenology and Grain Yield. Curr Agri Res; **6**(2).

Singh NP and RA Singh. 2002. Scientific Crop Production. 1st ed. Kalyani Publisher New Delhi, India. Pp. 111-117.

Subedi, S. 2015. A review on important maize diseases and their management in Nepal. Journal of Maize Research and Development, 1(1), 28-52.

Zamir MSI, AH Ahmad, HMR Javeed and T Latif. 2011. Growth and yield behaviour of two maize hybrids (*Zea mays* L.) towards different plant spacing. Cercetări Agronomice în Moldova 2 (146): 33-40.