

Research Article

Response of pipeline Nepalese maize hybrids to different doses of chemical fertilizers under varying plant densities

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ABSTRACT

Low plant population and inadequate fertilizer application are the major constraints for maize production among farmers in Nepal. In order to identify the integrated effects of plant density and fertilizer dose for production of hybrid maize, series of on station experiments were carried out at Rampur, Chitwan, Nepal using strip plot design with three replications during winter seasons in two consecutive years 2016/17 and 2017/18. Two promising Nepalese hybrids namely RML-95/RML-96 and RML-86/RML-96 were taken as vertical factor whereas five densities viz. 55,555 ha⁻¹ (D₁), 66,666 ha⁻¹ (D₂), 77,519 ha⁻¹ (D₃), 87,719 ha⁻¹ (D₄) and 98,039 ha⁻¹ (D₅) in combination with two doses of NPK fertilizers i.e. recommended and rational as horizontal factor. Recommended dose of NPK for maize was 120:60:40 kg ha⁻¹ and the rational doses for above mentioned densities were calculated based on bench mark of fertilizer recommendation for 53,333 plants ha⁻¹. Derived rational doses of NPK for D₁, D₂, D₃, D₄ and D₅ were 125:63:42, 150:75:50, 174:87:58, 197:99:66, 221:110:74 kg ha⁻¹ respectively. Genotypic variation of two tested hybrids for growth, yield attributes and grain yield were found statistically similar. However, planting the hybrids in various densities and fertilizer doses significantly influenced grain yield ranging from 5.63 to 7.91 t ha⁻¹. Significantly higher grain yield (7.91 t ha⁻¹) and benefit cost ratio (2.21) were observed when plant population was maintained at 77,519 ha⁻¹ with fertilizer dose 174:87:58 NPK kg ha⁻¹. Applying fertilizer as rational dose enhanced the yield up to the density of 77519 plants ha⁻¹ then the yield gradually declined as the density increased. Whereas recommended dose of fertilizer with increasing plant density from 55,555 to 87,719 ha⁻¹ had statistically similar yield and declined more at 98039 ha⁻¹. The present recommended dose of fertilizer application is inadequate for higher plant density to increase the grain yield of hybrid maize.

Keywords: Density, fertilizer, hybrid maize, yield

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INTRODUCTION

Maize (*Zea mays* L.) is the second most important cereal crop in terms of area and production after rice in Nepal in Nepal. Its contribution in National Gross Domestic Products (GDP) and Agriculture GDP is about 3.15% and 9.5% respectively. It occupies 27.39% area of the total food crops and contributes 24.97% of the total cereal production in Nepal. The total maize production in the country is 26, 53,243 mt from 9,40,886 ha with the average productivity of

2.82 t/ha (MoALD, 2020). National feed and food demand has been increased due to emerging poultry and dairy farming industries along with increasing population. Our domestic production of maize does not meet the national requirement since feed demand is increasing at the rate of 11% per annum (KC et al., 2015) and maize growth rate in last three years is 4.52 % (MoALD, 2020). So, the deficit is met through import. Poultry and animal feed have consumed 80% of the current maize demand and our domestic production can fulfill only 30%. Guragain (2019) in his article stated the report of Statistics of trade and export promotion center i.e. 2.92 billion metric tons of maize that worth NRs 71.2 billion, have been imported from India from July 2009 to June 2019. These circumstances have created the utmost necessity for producing higher maize yield per unit area to fulfill the national requirement. Our local varieties and OPVs cannot meet the demand so introducing of hybrid maize, due to their higher yield potentials, could be the best alternative to boost up the production in the given ecologies.

Plant density per unit area is one of the important yield determinants of crops. Hybrid maize with shorter plant height and erect leaves can be grown with higher plant density. Plant density is an efficient agronomic strategy for attaining maximum grain yield by increasing the capture of solar radiation within the canopy (Monnveux *et al.*, 2005). Modern hybrids, respond more favorably to plant densities because of a higher Leaf Area Index (LAI) at silking, which results in more interception of photosynthetically active radiation and have higher radiation use efficiency during grain filling (Azam *et al.*, 2007).

The production can be improved or increased through adequate nutrient management practices. Manures and fertilizers both play an important role in maize cultivation. Maize being the heavy feeder crop, a balanced dose of organic and inorganic application of fertilizer is needed for increased productivity. Fertilizer management is crucial for maize cultivation (Baral *et al.*, 2015; Adhikary *et al.*, 2020). As hybrid varieties respond well to higher plant density, it may require higher doses of fertilizer to exploit the hybrid vigor. Devkota *et al.* (2016) reported that maize productivity can be raised by a factor of four to > 8 t/ha when hybrids are combined with judicious fertilizer use and better-bet agronomy. Rakshit *et al.* (2017) reported that maize plant population of 80-90 thousands/ha along with NPK 250:105:105 kg ha⁻¹ gave the best returns. Adhikary and Adhikary (2013) also reported that highest grain yield (11.10 t ha⁻¹) of Rampur hybrid -2 was recorded when the crop was supplied with 180 kg nitrogen and with 83,383 plants ha⁻¹. Standardization of plant density and fertilizer levels assumes greater importance to achieve more economic returns of hybrid maize (Singh & Singhi, 2006). So, the study was made to determine the optimum planting density and NPK fertilizer level for hybrid maize.

MATERIALS AND METHODS

Experimental site

On station experiments were carried out at research field of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during winter season in two consecutive years 2016 and 2017. Geographically, the experimental site is located at 27° 40' N latitude, 84 ° 19' E longitudes at an altitude of 228 meter above sea level. It has subtropical climate. The texture of the soil was sandy loam. Soil pH was acidic (pH (5.43±0.05) and organic matter was high (3.95±0.17%). Similarly, total nitrogen (0.15±0.005%), extractable potassium

(145.29±8.6 ppm), were medium and available phosphorus (33.76±7.33 ppm) was high (Khadka *et al.*, 2016).

Climatic data

The weather parameters like maximum and minimum temperature ($^{\circ}\text{C}$), rainfall (mm) and relative humidity (%) were recorded during the crop season of 2016/17 and 2017/18 (Fig 1). The total rainfall of 687.9 mm and 181.7 mm was received during the entire cropping period of 2016/17 and 2017/18 respectively. Maximum mean temperature was ranged from 32.27 to 23.97 $^{\circ}\text{C}$ with the mean of 28.05 $^{\circ}\text{C}$ at 2016/17 and 33.36 to 21.11 $^{\circ}\text{C}$ having mean value 28.34 $^{\circ}\text{C}$ at 2017/18. Similarly, Minimum mean temperature ranged from 23.46 to 6.14 $^{\circ}\text{C}$ (mean 13.83 $^{\circ}\text{C}$) and 26.41 to 8.24 $^{\circ}\text{C}$ (mean 17.85 $^{\circ}\text{C}$) at 2016/17 and 2017/18 respectively. The relative humidity was gradually increased from September to January i.e 92.15 to 95.59% at 2016/17 and 95.04 to 95.76 % at 2017/18.

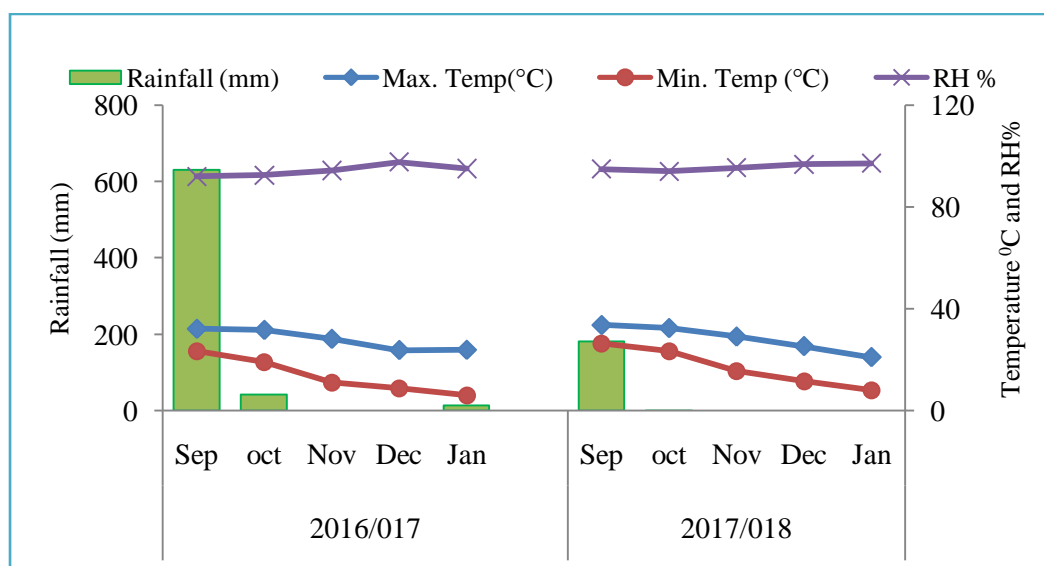


Figure 1: Meteorological data for the cropping period 2016/17 and 2017/18.

Experimental design

The field was laid out in strip plot design with three replications. Two promising Nepalese hybrids namely RML-95/RML-96 and RML-86/RML-96 were taken as vertical factor whereas five densities viz. 55,555 ha^{-1} (D₁), 66,666 ha^{-1} (D₂), 77,519 ha^{-1} (D₃), 87,719 ha^{-1} (D₄) and 98,039 ha^{-1} (D₅) as horizontal factors where each density got two doses of NPK fertilizers i.e recommended and rational. Recommended dose of NPK for maize was 120:60:40 kg ha^{-1} and the rational doses for above mentioned densities were calculated based on bench mark of fertilizer recommendation for 53,333 plants ha^{-1} . Derived rational doses of NPK for D₁, D₂, D₃, D₄ and D₅ were 125:63:42, 150:75:50, 174:87:58, 197:99:66, 221:110:74 Kg ha^{-1} respectively. The respective five densities were maintained by adjusting plant to plant distance of 30, 25, 21.5, 19 and 17 cm with row to row distance of 60 cm. The individual plot size was 18 m^2 (6 rows of 5 m long). Half of the nitrogen along with full phosphorus and potash were applied during field preparation. The remaining nitrogen was applied in two equal splits during the first weeding and at the earthing up. Rest of the crop management operations were done as per the treatment.

Data observation

Yield and yield attributing characters such as; number of cobs per plant, cob length, cob diameter, test weight along with plant and ear height were recorded. The grain yield was adjusted in a 15% moisture level assuming 80% shelling recovery. Grain yield (kg ha^{-1}) at 15% moisture content was calculated using fresh ear weight with the help of the below formula given by Carangal *et al.* (1971) and Shrestha *et al.* (2019).

Statistical analysis

All collected data were processed in MS Excel and analyzed by using ANOVA method of strip plot design in GENSTAT Discovery version. The significant differences between treatments were determined using the least significant difference (LSD) test at 1% or 5% level of significance (Gomez & Gomez 1984; Shrestha, 2019).

RESULTS AND DISCUSSION

Plant and ear height

Average plant height (171.97 cm) of RML 86/RML96 was found significant over RML 95/RML-96 in 2017/18 but their different was not observed when combined over the years. At the same time, their Ear height was found non-significant. From the two years analysis, it can be concluded that these two Nepali hybrids are not comparable for grain yield and yield related attributes and they are agronomically similar to plant and ear height. Planting density and fertilizer dose significantly affected the plant and ear height of maize. There was an increasing trend in plant height with increase in plant densities and fertilizer. In 2016/17, significantly higher plant height (222.17 cm) was recorded having the plant population of $98,039 \text{ ha}^{-1}$ with the fertilizer applied @ 221:110:74 kg NPK ha^{-1} . Similarly, the plant height of 180.3 cm and ear height of 102.5 cm were recorded significantly higher in dense population i.e 98,039 and 87,719 plants ha^{-1} when the NPK were applied rationally of 221:110:74 and 197:99:66 kg ha^{-1} , respectively.

Analysis of two years data revealed that average plant and ear height reached up to 201.3 and 112.4 cm in the treatments having plant densities 98, 039 and 87,719 combining with 221:110:74 and 197:99:66 kg NPK per hectare, respectively. Higher vertical growth in dense plant population could be due to the interplant competition for light. Rafiq *et al.*, 2010 also reported that maximum plant height (224.09cm) was measured where the crop was sown at plant density of $99,900 \text{ plants ha}^{-1}$. The tallest plant height of 177.6 cm was recorded when the crop was supplied with 180 kg N ha^{-1} and with the plant density of $83,383 \text{ plants ha}^{-1}$ (Adhikary & Adhikary, 2013). On the other hand, higher doses of fertilizer especially nitrogen increases the cell division, cell elongation, nucleus formation as well as increase the green foliage which increases the rate of photosynthesis and extension of stem resulting plant height (Diallo *et al.*, 1996). Sapkota *et al.* (2017) reported the higher plant height of hybrid maize with the application of 240:60 kg nitrogen and phosphorus per hectare. Similar results were also reported by Masood *et al.* (2011) with higher dose of nitrogen. Dawadi and Sah (2012) concluded that increasing nitrogen level from 120 to 200 kg ha^{-1} increased the plant height of hybrid maize varieties.

Yield and yield attributes

Average no. of cob per plant (1.12) was significantly higher in RML 86/ RML 96 but cob length (15.69 cm) and test weight (323.37 g) were statistically lower in that hybrid which

resulted insignificant grain yield in between those hybrids in 2016/17. Similarly, RML 86/RML 96 possessed higher cob diameter (4.32 cm) but lower cobs per plant (1.12) in 2017/18 and again the yields were insignificant between the hybrids tested. Two years pooled data revealed that both hybrids were at par in terms of yield and yield attributes (table 3). Sharma *et al.* (2019) and Neupane *et al.* (2019) also reported the insignificant result of RML 95/ RML 96 and RML 86/ RML96. From the data it was also concluded that no. of cobs per plant is the most yield determinant trait since the hybrids having higher no. of cobs per plant gave comparatively higher yield in both the years. The number of cobs per plant is genetically controlled factor but environmental and fertilizer level may also influence it. Tahir *et al.* 2008 reported that the more number of cobs per plant (1.20) in HG-370 hybrid gave significantly in more grain yield (8831 kg ha⁻¹).

Increased population and applying the rational doses of chemical fertilizer had shown negative response to no. of cobs per plant in 2016/17. Lowest cobs per plant (0.93) was observed with 98039 plant population in a hectare either applied with rational fertilizer dose of 221:110:74 or with recommended dose of 120:60:40 kg NPK ha⁻¹ in 2016/17. The number of cobs per plant exhibited a quadratic response to increased plant density and fertilizer in 2017/18. Statistically more numbers of cobs per plant (1.27) was obtained from the plant population of 77519 with 174:87:58 kg NPK ha⁻¹. It gradually decreased as the density and fertilizer increased. Low plant density of 55,555 per hectare combining with recommended fertilizer also possessed more (1.27) cobs per plant (table 2). On the basis of two years pooled data, a maize plant beard significantly more no. of cobs (1.18) with the plant population of 55,555 added with NPK fertilizer with recommended dose (table 3).

There was significant response on cob length with the increased population densities and applying rational doses of chemical fertilizers (Table 3). Cob length reached significantly maximum (15.1 cm) at 77,519 plants ha⁻¹ then the value was gradually lowered down as the density increased. Irrespective of the fertilizer application, maximum cob length (14.9 cm) was measured in lower population (55,555 plants ha⁻¹). The value of cob diameter was more (4.26 cm) in wider spaced plantings than closer spaced planting (table 3). Correspondingly, thousand grain weight also significantly affected by planting densities. In wider planting (55,555 ha⁻¹), significantly higher thousand grain weight (346 gm) was recorded as compared to maximum planting densities of > 77,519 plants ha⁻¹.

Maize yield was significantly affected by planting density and fertilizer dose. The result of data variance analysis showed the significant effect on grain yield of hybrid maize with the varied population and fertilizer dose. The most value of grain yields of 7.55 and 8.27 t ha⁻¹ was recorded in 2016/17 and 2017/18 respectively with the density of 77519 plants ha⁻¹ when fertilizer was applied @ 174:87:58 kg NPK ha⁻¹. Combined two years data also reflected the same result having the average yield of 7.91 t ha⁻¹ in such treatment combination (table 3). Shrestha *et al.* (2018) reported that maize density of 66666 per ha + application of 200 kg N produced the higher maize yield. The data analysis revealed the quadratic response of yield with elevated plant densities and varied fertilizer dose. Applying fertilizer as rational dose enhanced the yield up to the density of 77519 plants ha⁻¹ then the yield gradually declined as the density increased (Fig 2). The application of recommended dose of fertilizer from plant density of 55,555 ha⁻¹ to 87,719 ha⁻¹ had statistically similar crop yield and also Plant density from 77519 plants ha⁻¹ to 98,039 plants ha⁻¹ also had similar grain yield at recommended dose of fertilizer (Table 3). Muranyi (2015), concluded that maize yield showed increasing

tendency up to a plant density of 90,000 plants ha⁻¹ (10.9 t ha⁻¹), but above this density figure, the yield was decreased. Cardwell (1982) also observed that the relationship between grain yield plant densities is parabolic.

Table 1: Morphological traits, yield attributes and grain yield of hybrid maize influenced by varying densities and chemical fertilizer during winter season at NMRP 2016/17

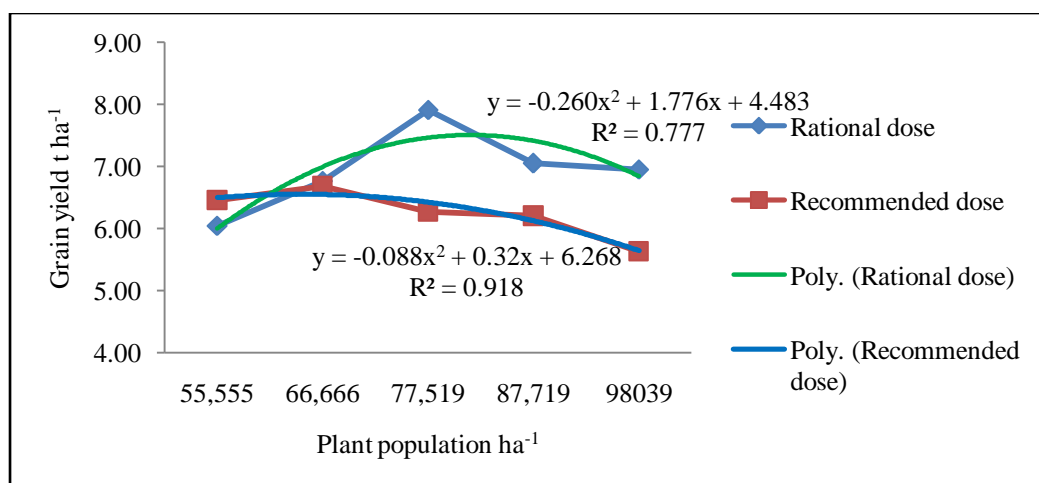
Treatments	Plant height (cm)	Ear height (cm)	No. of cobs plant ⁻¹	Cob length (cm)	Cob diameter (cm)	Test weight (g)	Yield (t ha ⁻¹)
Factor A (Varieties)							
RML 95/ RML 96	209.47	118.20	0.99	15.94	3.98	338.47	5.72
RML 86/ RML 96	208.73	118.67	1.12	15.69	3.92	323.37	6.04
F- test	ns	ns	*	*	ns	*	ns
Factor B (Fertilizer & densities)							
NPK 125:63:42 kg + 55555 pp ha ⁻¹	196.50	114.33	1.26	16.62	4.03	331.00	5.75
NPK 150:75:50 kg + 66,666 pp ha ⁻¹	211.00	118.33	1.16	16.21	3.96	333.17	6.27
NPK 174:87:58 kg + 77,519 pp ha ⁻¹	212.17	117.67	1.01	16.10	3.99	325.67	7.55
NPK 197:99:66 kg + 87719 pp ha ⁻¹	214.17	122.33	0.96	15.51	4.02	338.33	6.25
NPK 221:110:74 kg + 98039 pp ha ⁻¹	222.17	120.83	0.93	15.10	4.01	344.33	5.89
NPK 120:60:40 kg + 55555 pp ha ⁻¹	202.83	112.83	1.18	16.21	4.06	349.33	5.97
NPK 120:60:40 kg + 66666 pp ha ⁻¹	204.33	115.33	1.05	15.67	3.94	327.00	5.84
NPK 120:60:40 kg + 77519 pp ha ⁻¹	207.83	119.67	1.04	16.18	3.93	337.67	5.69
NPK 120:60:40 kg + 87719 pp ha ⁻¹	209.67	120.17	1.01	15.18	3.70	304.83	4.90
NPK 120:60:40 kg + 98039 pp ha ⁻¹	210.33	122.83	0.94	15.40	3.83	317.83	4.66
Grand mean	209.10	118.43	1.05	15.82	3.95	330.92	5.88
F test	*	ns	*	ns	ns	ns	*
LSD (0.05)	3.0	-	0.22	-	-	-	1.23
CV%	10.6	5.8	12.4	5.0	3.6	8.5	12.2

Table 2. Morphological traits, yield attributes and grain yield of hybrid maize influenced by varying densities and chemical fertilizer during winter season at NMRP 2017/18.

Treatments	Plant height (cm)	Ear height (cm)	No. of cobs plant ⁻¹	Cob length (cm)	Cob diameter (cm)	Test weight (g)	Yield (t ha ⁻¹)
Factor A (Varieties)							
RML 95/ RML 96	168.97	96.50	1.16	13.30	4.10	310.97	7.54
RML 86/ RML 96	171.87	97.67	1.12	12.85	4.32	317.33	7.09
F test	*	ns	*	ns	*	ns	ns
Factor B (Fertilizer + densities)							
NPK 125:63:42 kg + 55555 pp ha ⁻¹	164.83	96.67	1.06	13.48	4.42	346.33	6.33
NPK 150:75:50 kg + 66,666 pp ha ⁻¹	167.50	93.33	1.13	13.17	4.31	324.00	7.25
NPK 174:87:58 kg + 77,519 pp ha ⁻¹	172.17	97.50	1.27	14.36	4.24	317.67	8.27
NPK 197:99:66 kg + 87719 pp ha ⁻¹	175.00	102.50	1.11	13.55	4.28	310.83	7.85
NPK 221:110:74 kg + 98039 pp ha ⁻¹	180.33	101.67	1.08	12.44	4.15	299.33	8.02
NPK 120:60:40 kg + 55555 pp ha ⁻¹	169.83	92.50	1.27	13.74	4.42	337.67	6.95
NPK 120:60:40 kg + 66666 pp ha ⁻¹	169.83	94.17	1.14	13.42	4.36	332.33	7.53
NPK 120:60:40 kg + 77519 pp ha ⁻¹	167.67	98.33	1.20	13.29	4.23	304.33	6.85
NPK 120:60:40 kg + 87719 pp ha ⁻¹	171.83	97.50	1.10	11.85	3.90	292.67	7.50
NPK 120:60:40 kg + 98039 pp ha ⁻¹	165.17	96.67	1.05	11.48	3.78	276.33	6.60
Grand Mean	170.42	97.08	1.14	13.08	4.21	314.15	7.32
F test	*	*	*	*	ns	*	**
LSD (0.05)	12.32	8.02	0.15	0.78	0.21	38.29	0.75
CV%	6.2	7.1	11.4	5.0	4.0	9.3	8.8

Table 3. Morphological traits, yield attributes and grain yield of hybrid maize influenced by varying densities and chemical fertilizer during winter season at NMRP 2016/17 -2017/18.

Treatments	Plant height (cm)	Ear height (cm)	No. of cobs plant ⁻¹	Cob length (cm)	Cob diameter (cm)	Test weight (g)	Yield (t ha ⁻¹)
Factor A (Varieties)							
RML 95/ RML 96	189.2	107.4	1.09	13.97	3.98	313.5	6.63
RML 86/ RML 96	190.3	108.2	1.09	13.61	4.06	309.0	6.57
F test	ns	ns	ns	ns	ns	ns	ns
Factor B (Fertilizer + densities)							
NPK 125:63:42 kg + 55555 pp ha ⁻¹	180.7 ^d	105.5 ^{bcd}	1.12 ^{abc}	14.32 ^a	4.26 ^a	341.2 ^a	6.04 ^{de}
NPK 150:75:50 kg + 66,666 pp ha ⁻¹	189.2 ^{bc}	105.8 ^{bcd}	1.09 ^{abcd}	14.43 ^a	4.12 ^{ab}	323.0 ^{ab}	6.76 ^{bcd}
NPK 174:87:58 kg + 77,519 pp ha ⁻¹	192.2 ^{bc}	107.6 ^{abcd}	1.15 ^{ab}	15.10 ^a	4.08 ^{ab}	322.8 ^{ab}	7.91 ^a
NPK 197:99:66 kg + 87719 pp ha ⁻¹	194.6 ^{ab}	112.4 ^a	1.06 ^{bcd}	13.96 ^a	3.99 ^b	307.8 ^{bc}	7.05 ^b
NPK 221:110:74 kg + 98039 pp ha ⁻¹	201.2 ^a	111.3 ^{ab}	1.01 ^{cd}	12.76 ^b	3.99 ^b	293.8 ^c	6.95 ^{bc}
NPK 120:60:40 kg + 55555 pp ha ⁻¹	186.3 ^{cd}	102.7 ^d	1.18 ^a	14.95 ^a	4.22 ^{ab}	328.7 ^a	6.46 ^{bcd}
NPK 120:60:40 kg + 66666 pp ha ⁻¹	187.1 ^{bcd}	104.8 ^{cd}	1.15 ^{ab}	14.65 ^a	4.16 ^{ab}	325.9 ^{ab}	6.69 ^{bcd}
NPK 120:60:40 kg + 77519 pp ha ⁻¹	187.8 ^{bcd}	109.0 ^{abc}	1.10 ^{abcd}	14.49 ^a	4.11 ^{ab}	308.0 ^{bc}	6.27 ^{cde}
NPK 120:60:40 kg + 87719 pp ha ⁻¹	190.8 ^{bc}	108.8 ^{abc}	1.03 ^{cd}	11.93 ^{bc}	3.69 ^c	288.9 ^{cd}	6.20 ^{cde}
NPK 120:60:40 kg + 98039 pp ha ⁻¹	187.8 ^{bcd}	109.8 ^{abc}	0.99 ^d	11.35 ^c	3.63 ^c	272.3 ^d	5.63 ^e
Grand Mean	189.8	107.8	1.09	13.79	4.03	311.2	6.60
F test	**	**	**	**	**	**	**
LSD(0.05)	6.77	5.17	0.10	1.65	0.22	23.77	0.67
CV %	3.0	4.1	8.0	7.1	4.7	5.0	8.8

**Figure 2: Yield response with rational and recommended dose of fertilizer in different population densities**

Economic analysis

Irrespective of the hybrids, significantly higher gross returns (NRS. 130170 ha⁻¹) with the benefit cost ratio of 2.21 were observed when plant population maintained at 77,519 ha⁻¹ with the NPK fertilizer dose @174:87:58 NPK kg ha⁻¹.

Table 4. Economic analysis of maize grain yield under varying densities and chemical fertilizer use during winter season at NMRP 2016/17 -2017/18

Treatments	Total expenditure (NRs. '000) ha ⁻¹	Gross returns (NRs. '000) ha ⁻¹	Profit (NRs. '000) ha ⁻¹	B:C Ratio
Factor A (Varieties)				
RML 95/ RML 96	103.85	198.83	94.98	1.92
RML 86/ RML 96	103.85	196.97	93.12	1.90
F test	ns	ns	ns	ns
Factor B (Fertilizer & densities)				
NPK 125:63:42 kg + 55555 pp ha ⁻¹	98.83	181.19 ^{de}	82.36 ^{bc}	1.83 ^{bc}
NPK 150:75:50 kg + 66,666 pp ha ⁻¹	103.04	202.86 ^{cd}	99.82 ^b	1.97 ^b
NPK 174:87:58 kg + 77,519 pp ha ⁻¹	107.20	237.37 ^a	130.17 ^a	2.21 ^a
NPK 197:99:66 kg + 87719 pp ha ⁻¹	111.35	211.49 ^b	100.14 ^b	1.90 ^b
NPK 221:110:74 kg + 98039 pp ha ⁻¹	115.43	208.59 ^{bc}	93.16 ^b	1.81 ^{bc}
NPK 120:60:40 kg + 55555 pp ha ⁻¹	98.13	193.77 ^{cd}	95.63 ^b	1.97 ^b
NPK 120:60:40 kg + 66666 pp ha ⁻¹	99.33	200.59 ^{cde}	101.26 ^b	2.02 ^b
NPK 120:60:40 kg + 77519 pp ha ⁻¹	100.53	188.12 ^{cde}	87.59 ^{bc}	1.87 ^b
NPK 120:60:40 kg + 87719 pp ha ⁻¹	101.73	186.06 ^e	84.33 ^{bc}	1.83 ^{bc}
NPK 120:60:40 kg + 98039 pp ha ⁻¹	102.93	169.01	66.08 ^c	1.64 ^c
Grand Mean	103.85	197.90	94.05	1.91
F test	-	**	**	**
LSD(0.05)	-	20.31	20.31	0.19
CV %	-	8.8	18.4	8.7

The values of gross returns and benefit cost ratio were increased upto the 77,519 plant densities ha⁻¹ in the treatment of rationally applied chemical fertilizers and on the contrary, at higher densities, their values appeared in declining trend in the treatments of recommended chemical fertilizers (NPK@120:60:40 kg ha⁻¹). Malavirarachchi *et al.* (2016) reported the economical result of maize grown in the density of 88888 plants with 200:100:50 kg NPK ha⁻¹.

CONCLUSIONS

Applying fertilizer as rational dose enhanced the yield up to the 77,519 plants ha⁻¹ then the yield gradually declined as the density increased. The recommended dose of fertilizers with increasing plant density from 55,555 to 87,719 ha⁻¹ had statistically similar yield and declined at 98,039 ha⁻¹. The present recommended dose of fertilizer application is inadequate for higher plant density to increase the yield of hybrid maize. The gross return, profit and benefit cost ratio was the highest at NPK 174:87:58 kg ha⁻¹ with 77,519 plants ha⁻¹. Therefore, the plant density of 77,519 plants ha⁻¹ with rational dose of fertilizer is recommended for higher benefits of hybrid maize cultivation during winter season in Chitwan like climate.

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Authors' Contributions

J. B. Adhikari planned, designed and conducted this experiment. G. KC and D. Regmi helped during this experiment. All authors approved the final version of this manuscript.

Conflict of interest

The author declares no conflicts of interest regarding publication of this manuscript.

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