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Response of Different Levels of Nitrogen and Plant Population to Grain Yield of Winter Hybrid Maize in Chitwan Valley

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ABSTRACT

A field experiment on "Performance of hybrid maize under different levels of nitrogen and plant population" was conducted in Randomized complete block design (RCBD) at the research farm of the National Maize Research Program (NMRP), Rampur, Chitwan during the winter season of 2015/16 to determine the optimum level of nitrogen and plant population for winter season hybrid maize. The results revealed that the grain yield (2.38 Mt ha^{-1}) obtained in control without nitrogen was significantly lower in comparison to the other levels (70, 140 and 210 kg N ha^{-1}). Moreover, grain yield (5.45 Mt ha^{-1}) produced by the application of 210 kg N ha^{-1} was significantly superior over 70 kg N ha^{-1} (3.83 Mt ha^{-1}) but remained at par with 140 kg N ha^{-1} (5.02 Mt ha^{-1}). The grain yield (4.98 Mt ha^{-1}) recorded with the population of 101010 plants ha^{-1} was significantly superior over 55,555 with 3.34 Mt ha^{-1} and 69,444 with 3.90 Mt ha^{-1} plants ha^{-1} but similar to that of 85,470 plants ha^{-1} with 4.46 Mt ha^{-1} which was also significantly higher as compared to 69,444 and 55,555 plants ha^{-1} and were at par with each other. Regression analysis revealed that the ineraction between level of N and plant population were significant and positive correlation was found between higher level of N and plant population. Thus, hybrid maize (RML95/RML96) can be successfully grown by applying 145 kg N ha^{-1} and maintaining a population of 87 thousand plants ha^{-1} to achieve a higher grain yield during the winter season.

Keywords: Grain yield, hybrid maize, nitrogen, plant population

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INTRODUCTION

In Nepal maize is basically grown for food, feed, and fodder and is believed as traditional crop in the world. Moreover, maize is one of the most important cereals grown over all environments and geographical ranges for human food, feed, and fodder for livestock, and raw materials for industries (Jeet et al 2012).

In Nepal, by analyzing data maize can be considered as the second most important staple crop after rice both in terms of area and production (ABPSD 2015). The rapidly increasing demand of maize grain is related to its greater demand for direct human consumption in the hills as a staple food crop (Ghimire et al 2007) and for livestock feeds in terai and inner terai areas (Pandey et al 2007). It contributes 3.15% to national gross domestic production (GDP) and 9.5 % to agricultural GDP (MoAD 2013). About 2.9 million mt of maize is required per year for food (Timilsina et al 2016). It has been grown over an area of 9,40,886 hectares in 2019/20 with a production of 26,53,243 Mt, and a productivity of 2.82 Mt ha^{-1} in Nepal (MoALD 2020). Its share on AGDP is 9.5% and on GDP is 3.15% (MoALD 2020). In Nepal, the demand for maize has been growing constantly by 5% in the last decade (Sapkota and Pokhrel 2010). A study on utilization of maize in hilly districts revealed that 60%, 25%, and 3% of the grain were used for animal feed, food, and seed respectively. Whereas the remaining amount of the maize (12%) was sold to different buyers (Timilsina et al 2016). The demand for poultry feed and animal feed has been increased by 13% and 8.5% over the last five years in Nepal (Timilsina et al 2016). To fulfill the growing feed demand, Nepal is importing about 45% of maize from India (NMRP 2017).

Agriculture statistical data of Nepal for cultivated area and productivity during 2011/12 to 2015/16 indicate that in last five years, the grain yield of maize remained constant (2.3 to 2.5 Mt ha^{-1}) and an increment in yield by only one Mt/ha can provide one million tone more production in the country which is obvious due to improvement in maize technology. Grain yield of maize is the products of three yield components i.e. the number of ears per unit area, the number of grains per ear and the unit grain weight. Increase or decrease in any one of these components, keeping the size of other components constant, contributes to increase or decrease in grain yield, respectively, and thus any practice whether agronomic (management) or breeding type (genotype), which increase any of these components, keeping the other components constant, will increase the final grain yield (Inamullah et al 2011).

It has been reported that agronomic measurements like proper plant spacing (Maddonni et al 2001) and application of fertilizer Rasheed et al 2004 helps to increase the yield attributing characters and ultimately the grain yield (Inamullah et al 2011).The nitrogen (vital plant nutrient) is important factor for any crop production. For maize production and productivity Jeet et al 2012 and its availability in sufficient quantity throughout the growing season is essential (Habtegebrial et al 2007). Nitrogen is an essential and macro nutrient for maize and a key determinant of grain yield, particularly through its role in photosynthesis, absorption of water and minerals, vacuole storage and xylem transport and other biochemical reaction. The higher nitrogen fertilizer increases vegetative growth through enhancing leaf initiation, increment chlorophyll concentration in leaves that improves the photosynthesis (Mekded 2015).

Further, stand density affects the plant architecture, pattern of growth and development, and carbohydrate production in maize (Abuzar et al 2011). Maize is generally grown in wide spaced rows. Most of the growth parameters of maize can be affected by plant population even in optimal growing conditions (Abuzar et al 2011). As other cereals, maize does not have tillering capacity. So, to adjust to variation in plant stand, optimum plant population for grain production in maize is important (Ashrafi and Seiedi 2010; Luque et al 2006). Plant population changes canopy of crop, growing behavior and developmental phases and grain production of maize. At low densities, many modern and high yielding maize varieties do not produce more than one effective cob/ear per plant. Whereas, with the use of high population densities increased interplant competition for light, water and nutrients, which might be detrimental producing lower grain yield per plant (Abuzar et al 2011).

Thus, the research was conducted by applying different levels of nitrogen and plant population with the objectives of to determine the optimum level of nitrogen and plant population for winter season hybrid variety of maize.

MATERIALS AND METHODS

The research was conducted at National Maize Research Program, Rampur, Chitwan during September 2015 to March 2016 using the maize hybrid (RML95/RML96). The experiment was laid out in split plot design with three replications consisting of four levels of plant population as main plot factor (55,555,69,444, 85,470 and 101010 plants ha^{-1}) and four levels of nitrogen (0, 70, 140 and 210 kg ha^{-1}) as sub plot factor. Out of total half dose of nitrogen and full dose of phosphorous and potash were applied at sowing time and remaining divided dose of nitrogen was applied in two splits at knee high and tasseling stages. The final plant stand was maintained at knee high stage. Thus, the plant to plant distance of 30, 24, 19.5 and 16.5 cm was maintained for the population of 55, 69, 85 and 101 thousand plants ha^{-1}, respectively keeping the row to row distance of 60 cm constant. Urea, MoP and SSP were used as a fertilize source in the experiment. The soil of the experimental field was slightly acidic with pH 6.1 and very low organic matter 1.83 Jaishy 2000 and very low, high and medium total nitrogen, available phosphorous and available potassium, respectively (Khatri and Chettri 1991). The phenological data were recorded at 15 days interval at the field since germination. Furthermore, reproductive data were recorded at one day interval starting from 60 DAS. Moreover, yield attributing characters (number of cobs harvested per hectare, number of rows per cob, number of grains per row, number of grains per cob, weight of grains per cob, shelling percentage, harvest index and yield were calculated. The data analysis was carried by using excel, Gen-Stat and M-Stat C.

RESULTS AND DISSCUSSION

It is found that (table 1) the application of 210 kg N ha^{-1} (96,737) produced significantly greater number of cobs per hectare as compared to control (67,199) but remained at par with 140 (78,505) and 70 (83,431) kg N ha^{-1} which were also similar to each other. Similarly, the number of ears harvested per hectare was influenced significantly due to variation in plant population. It was significantly higher with 101 (1,01,530 cobs ha^{-1}) thousand plants ha^{-1}. The increase in yield attributes like number of cobs per hectare and grains per cob in maize at higher level of N was related to increase in availability of nutrients Tetwarlal et al 2011 which empowered the plants to manufacture more quantity of photosynthates for the formation of yield components (Singh et al 2002). Thus, the higher availability of nitrogen assisted in better growth and metabolism in maize plants leading to better seed filling and higher number of cobs per hectare (Kumar et al 2008).

The number of grains per cob increased with the increase in nitrogen level from 0 to 70 and then remained at par with 140 and 210 kg N ha^{-1}. On the hand, the number of grains per cob was not influenced significantly by the levels of plant population, however, it was decreasing insignificantly with the levels of plant population ranging from 55 to 101 thousand plants ha^{-1}. Increase in grains per ear at higher nitrogen levels might be due to lower competition for nutrient which allowed the plants to accumulate more biomass with higher capacity to transport more photosynthates towards sink resulting in more grains per ear (Daliri et al 2013). These results are in unison with Zeidan et al 2006 who concluded that grain number per ear was maximum at the highest nitrogen level. Moreover, probable reason for lesser number of kernels was N deficiency which reduced biomass production traits of the plant which could be primarily relate to number of kernel per cob (Hammad et al 2011). Decline in resources availability at low fertilization might have adversely affected the efficiency of plants to convert intercepted radiation into sink capacity as competition for photosynthates cause kernel abortion in maize (Asif et al 2013).

When the number of individuals per area is boost up beyond the optimum plant density, there is a series of issues that are harmful to ear ontogeny that result in barrenness (Sangoi 2001). The lesser number of grains per ears in plots of high density might be due to greater inter-plant competition for solar radiation, water and available nutrients which increased barrenness and decreased number of grain per ears (Amanullah et al 2009). The weight of grains per cob was found to increase with the level of nitrogen from 0 to 140 and then remained at par with 210 kg N ha^{-1}. On the other sense, the values of weight of grains per cob were decreasing non-significantly with the levels of plant population ranging from 55 to 101 thousand plants ha^{-1}. This was due to lower number of grains per cob and thousand grain weight which were decreasing with the increase in plant population ha^{-1}. Wassya et al (2011) explained that nitrogen rate affected the grains weight per cob significantly.

Shelling percent was influenced significantly with the increase of nitrogen level from 0 to 70 kg ha^{-1} which remained at par with 140 and 210 kg ha^{-1}. The higher shelling percentage (76.2%) obtained with 210 kg N ha^{-1} was similar to that of 140 (74.8%) and 70 (72.3%) kg N ha^{-1} but all of these were significantly superior over 70 (64.1%). On the other hand, shelling percentage of hybrid maize was statistically similar in respect of plant population. It was decreasing insignificantly as the level of plant population was increased from 55 to 101 thousand plants ha^{-1}. The positive response of nitrogen application on yield attributes of maize could be ascribed to overall improvement in crop growth enabling the plants to absorb more nutrients which empower the plants to manufacture more quality of photosynthates accumulating them in reproductive part (Singh et al 2002). Thus, on the testimony of above discussion it can be stated that almost all yield attributing characters were affected by levels of nitrogen except thousand grain weight. On the other hand, significant effects of different levels of plant population were recorded only in number of cobs harvested ha^{-1} and thousand grain weight.

Table 1. Yield attributes of hybrid maize as influenced by different levels of nitrogen and plant population at Rampur, 2016

Treatments	CH ha^{-1} (000)	$NGRC^{-1}$	NGR^{-1}	NGC^{-1}	WCG (g)	WGC (g)	TGW (g)	S %
Nitrogen kg ha^{-1}								
0	67^{b}	11^{b}	15^{b}	171^{b}	53.3^{c}	37.7^{c}	220.5^{b}	64.1^{b}
70	79^{ab}	13^{a}	17^{ab}	225^{a}	70.3^{b}	54.8^{b}	245.5^{a}	72.3^{a}
140	83^{ab}	13^{a}	19^{a}	251^{a}	78.4^{ab}	62.9^{ab}	251.8^{a}	74.8^{a}
210	97^{a}	14^{a}	19^{a}	263^{a}	84.7^{a}	69.0^{a}	256.2^{a}	76.2^{a}
SEM	6.3	0.5	0.9	16.0	4.2	4.2	6.0	1.6
LSD	18.5	1.5	2.5	46.8	12.3	12.1	17.6	4.7
Plant population (ha^{-1})								
55555	63^{b}	13	19	250	80.6	64.9	256.7^{a}	75.0

Treatments	CH ha^{-1} (000)	$NGRC^{-1}$	NGR^{-1}	NGC^{-1}	WCG (g)	WGC (g)	TGW (g)	S %
69444	73^{ab}	13	18	232	72.1	56.8	246.1^{ab}	73.5
85470	88^{ab}	13	17	226	71.2	55.5	238.0^{b}	70.6
101010	102^{a}	12	16	202	62.8	47.2	233.1^{b}	68.3
SEM	9.0	0.9	1.2	24.2	7.07	6.9	4.7	2.6
LSD	31.2	ns	ns	ns	ns	ns	16.1	ns
CV (%)	27.0	14.3	17.1	24.4	20.3	25.7	8.6	7.9
Grand Mean	**81.5**	**12.8**	**17.5**	**227.4**	**71.7**	**56.1**	**243.5**	**71.8**

Note: Means followed by the common letter(s) within each column are not significantly different at 5 % level of significance by DMRT. ns= non-significant, CH=Cobs harvested ha^{-1}, $NGRC^{-1}$= No of grains rows per cob, NGR^{-1}=No of grains per row, NGC^{-1}=No grains per cob, WCG=Weight of cob with grain, WGC=Weight of grain per cob, TGW=Thousand grain weight, S%=Shelling%

The result of the experiment given in table 2, shows that the grain yield achieved with 140 (5.02 Mt ha^{-1}) and 210 (5.45 Mt ha^{-1}) kg N ha^{-1} were similar to each other but both of them were significantly superior over 70 kg N ha^{-1} (3.83 Mt ha^{-1}) and control (2.38 Mt ha^{-1}) which also differed significantly.

The increase in yield as a result of increasing nitrogen fertilizer levels may be due to the importance of nitrogen as one of the macronutrient elements for plant nutrition and its role in increasing vegetative growth through enhancing leaf initiation, increment chlorophyll concentration in leaves which may be reflected in improving process of photosynthesis (Mekdad 2015). Adeniyan et al 2014 mentioned that the increase in fertilizer levels assisted to increase the growth and yield attributes of maize crops by better uptake of nutrients as a result of which the grain yield increased. In general, the application of nitrogen at higher rate leads to the development of leaf area more rapidly, improves leaf area duration and increases crop net assimilation rate. All these factors contribute to improve grain yield of maize (Shahid et al 2016). Moreover, the increase in yield with the application of nitrogen might be due to the increase in availability of N which accelerated photosynthetic rate and production of carbohydrate (Arif et al 2010). Dawadi and Sah 2012 during winter season, the grain yields obtained with 160 (10.59 Mt ha^{-1}) and 200 (10.9 Mt ha^{-1}) kg N ha^{-1} were similar to each other but significantly greater than that of 120 kg N ha^{-1} (9.76 Mt ha^{-1}).

On the other hand, the result shows that significant differences in grain yield were recorded when a difference of 30 thousand plants ha^{-1} and more was maintained between the treatments. Thus, significantly higher grain yield (4.98 Mt ha^{-1}) was obtained from the population of 101010 plants ha^{-1} as compared to 55,555 (3.34 Mt ha^{-1}) and 69,444 (3.90 Mt ha^{-1}), but remained at par with 85,470 plants ha^{-1} (4.46 Mt ha^{-1}) which was similar to 69,444 plants ha^{-1} but significantly superior over 55,555 plants ha^{-1} in respect of grain yield formation. Moreover, the difference in grain yields obtained from 55 and 69 thousand plants ha^{-1} was not significant. At high density, vegetative growth of maize is extended, a greater number of leaves per plant are produced that assists to increase light interception at high density Amanullah et al 2009 as a result of which more assimilates are produced by maize crop that help to increase plant heights as well as light interception which ultimately lead to higher grain yields at high than at low plant density (Amanullah et al 2008). Higher plant density than optimum level causes severe competition among plants for light above ground or for nutrients below the ground, consequently the plant growth is slowed down and the grain yield is decreased (Mahdi et al 2015). In other words, at very high plant density the grain yield per plant decreases due to decrease in light, moisture, nutrient and other environmental resources available to each plant (Shrestha et al 2013).

The grain yield obtained with 101 thousand plants ha^{-1} was significantly higher in comparison to 69 and 55 thousand plants ha^{-1} in this experiment. This is because that light interception increases with the increase in plant density due to increase in plant height which leads to the higher grain yield in high density than low (Amanullah et al 2008). Rafiq et al 2010 and Dahmardeh et al 2011 recorded significant increment in grain yield with the level of plant population ranging from 57 to 99.9 and 60 to 100 thousand plants ha^{-1} in the condition of Pakistan and Iran, respectively.

Table 2. Grain yield, stover yield and harvest index of hybrid maize under different levels of nitrogen and plant population during winter season at NMRP, Rampur, Chitwan, Nepal, 2016

Treatments	GY (Mt ha^{-1})	SY (Mt ha^{-1})	HI %
Nitrogen kg ha^{-1}			
0	2.38^{c}	2.99^{c}	40.4
70	3.83^{b}	5.01^{b}	41.6
140	5.02^{a}	5.94^{ab}	43.4
210	5.45^{a}	7.18^{a}	43.6
SEM	0.17	0.55	3.0
LSD	0.48	1.61	ns
Plant population (ha^{-1})			
55555	3.34^{c}	4.22^{b}	40.4
69444	3.90^{bc}	5.30^{ab}	41.6
85470	4.46^{ab}	5.67^{ab}	42.1
101010	4.98^{a}	5.93^{a}	43.2
SEM	0.17	0.46	2.3
LSD	0.61	1.61	ns
CV (%)	13.30	36.20	25.1
Grand Mean	**4.17**	**5.28**	**41.8**

Note: Means followed by the common letter(s) within each column are not significantly different at 5 % level of significance by DMRT. ns= non-significant, GY=Grain yield, SY= Stover yield, HI%=Harvest Index%

Interaction effect of nitrogen and plant population on grain yield of hybrid maize

The data presented in the Table 3 show that interaction between levels of plant population and nitrogen level was found significant with respect to grain yield formation of hybrid maize. In general, significant effect of plant population was recorded at higher levels of nitrogen i.e. 140 and 210 kg N ha^{-1}. Thus, in the treatment with 140 kg N ha^{-1} the grain yields obtained with 55 and 69 thousand plants ha^{-1} were similar to each other but significantly lower than that of 85 and 101 thousand plants ha^{-1} which were also at par with each other.

On other hand, significantly higher grain yield was obtained with 101 thousand plants ha^{-1} as compared to 55, 69 and 85 thousand plants ha^{-1} in the treatment with 210 kg N ha^{-1}. Moreover, the grain yield obtained with 55 thousand plants ha^{-1} was significantly lower in comparison to 69 and 85 thousand plants ha^{-1} which were at par with each other.

Thus, from above analysis, it is obvious that the requirement of hybrid maize for N was found higher in dense population. Similarly, at higher levels of nitrogen significantly higher grain yields were produced in dense plant population i.e 85 and 101 thousand plants ha^{-1}.

Table 3. Interaction effect of nitrogen and plant population on grain yield of hybrid maize

Plant population ha^{-1}	Nitrogen levels kg ha^{-1}				Mean
	0	**70**	**140**	**210**	
55555	1.8^{g}	3.6^{de}	3.7^{de}	4.2^{d}	**3.3^{c}**
69444	2.0^{fg}	3.8^{de}	4.4^{cd}	5.4^{c}	**3.9^{bc}**
85475	2.8^{ef}	3.9^{de}	5.5^{b}	5.6^{bc}	**4.4^{ab}**
101010	2.9^{ef}	4.0^{d}	6.4^{ab}	6.7^{a}	**5.0^{a}**
Mean	**2.4^{c}**	**3.8^{b}**	**5.0^{a}**	**5.5^{a}**	

Note: Means followed by the common letter(s) within each column are not significantly different at 5 % level of significance by DMRT. ns= non-significant

The influence of nitrogen levels on grain yield of hybrid maize was spotted to be significant and polynomial regression equation was achieved. The values of coefficient of determination (R^2) shows that contribution in the formation of grain yield and prominently greater in case of nitrogen (65%) as compared to plant population (17%).

Further, the association between nitrogen levels and grain yield was detected powerful as suggested by the values of correlation coefficient (r) which was higher (0.8) than plant population (0.4). Thus, on the testimony of above analysis it can be refer that N is a vital plant macro nutrient and major yield governing factor in maize production (Shanti et al 1997). Grain yield increases significantly with various levels of nitrogen Mukhatar et al 2011 and physical and economical maximum doses acquire in the experiment was (164.7 and 144.7 kg N ha^{-1}), respectively (Table 4 and 5) and further, physical maximum level of plant population was 87445 plants ha^{-1} (table 5) was gained in growing of hybrid maize (RML95/RML96) during winter season at NMRP, Chitwan.

Table 4. Nitrogen response equation, physical and economic maximum dose of nitrogen (kg ha^{-1}) during winter season at NMRP, Rampur, Chitwan, Nepal, 2015/16

Quadratic Regression	Physical maximum dose of N (kg ha^{-1})	Economical maximum dose of N (kg ha^{-1})
$y = -0.054x^2 + 17.806x + 2360$	164.7	144.7

Table 5. Plant population response equation, physical maximum level of plant population (plants ha-1) of hybrid maize during winter season at NMRP, Rampur, Chitwan, Nepal, 2015/16

Quadratic Regression	Physical maximum level of plant population (plants ha^{-1})
$-0.7104x^2 +124.242x + 767.3$	87445

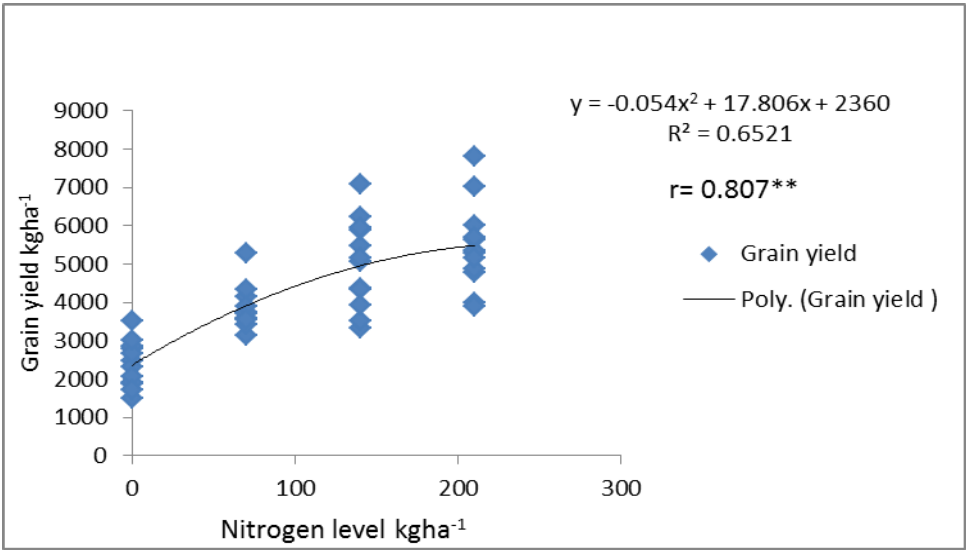

Fig 1. Response of plant population on grain yield of hybrid maize (RML95/RML96)

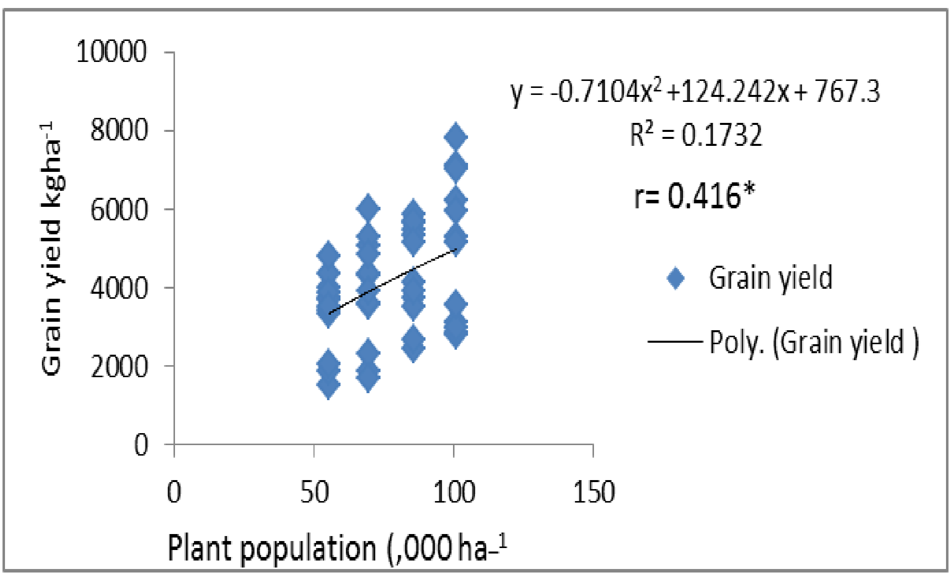

Fig 2. Response of nitrogen on grain yield of hybrid maize (RML95/RML96)

CONCLUSIONS

Hybrid maize (RML95/RML96) can be successfully grown by applying 145 kg N ha^{-1} with the plant population of 87445 ha^{-1} for higher grain yield during winter season at Rampur, Chitwan.

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AUTHOR'S CONTRIBUTION

The main author Goma Dhital prepared the research proposal, carried out the experiment, prepared the ANOVA and manuscript in consultation with co-authors Santosh Marahattha, Tika Bahadur Karki and Komal Bahadhur Basnet.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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