Performance of maize hybrids under different tillage methods and nitrogen levels

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A field experiment was conducted at the National Maize Research Program (NMRP), Chitwan, Nepal during summer of 2014 to evaluate the response of tillage methods (conventional and zero tillage) and nitrogen levels (0, 60, 120 and 180 kg ha⁻¹) on grain yield of two maize (Zea mays L.) hybrids (Rampur hybrid-2 and RML32/RML17). The experiment was laid out in strip-split plot design consisting of sixteen treatments with three replications. Growth and yield parameters of maize were measured and economic analysis was conducted during plant growth and after harvest. The maize hybrids, Rampur hybrid-2 and RML32/RML17, and tillage methods, zero tillage and conventional tillage, had similar grain yield (2.9 t ha⁻¹). The grain yield obtained from control without nitrogen application (1.64 t ha⁻¹) was significantly lower than that of all levels (60, 120 and 180 kg ha⁻¹) of nitrogen. The grain yield (3.57 t ha⁻¹) obtained with 180 kg N ha⁻¹ was significantly higher than 60 kg N ha⁻¹ (3.05 t ha⁻¹) but was at par with 120 kg N ha⁻¹ (3.44 t ha⁻¹). The difference between 120 and 60 kg N ha⁻¹ application with respect to grain yield was non-significant. Grain yield increased non-linearly with increasing levels of N application, while the physical and economical maximum doses of nitrogen equaled to 172.38 and 153.77 for zero tillage, and 140.00 and 127.86 kg ha⁻¹ for conventional tillage methods, respectively. Results highlight the potential use of zero tillage with 120 kg ha⁻¹ nitrogen level in hybrid varieties to harness agronomic and economic benefits in the inner Terai region of Nepal during summer season.

Key words: Maize hybrids, tillage, nitrogen, yield.

INTRODUCTION

Maize (Zea mays L.) is one of the most important cereal crops next to wheat and rice in the world (Rawal and Kuligod, 2014). Globally, maize is cultivated in nearly 177 million ha, producing 960 million metric tons (FAOSTAT, 2013). In Nepal, maize shares about 24% of the total cereal production, and is the most important staple food crop of hilly region and placed second after rice (MOAD, 2013). It shares about 6.54% to Agricultural Gross Domestic Product (AGDP). Maize is grown in approximately 0.85 million ha with annual total production of 1.9 million metric tons and productivity of 2.35 t ha⁻¹ (MOAD, 2013). While grain yield of hybrid maize may
range between 5 and 9 during winter (Bishwokarma et al., 2015), information on yield of such improved varieties during summer season is incomplete. The average yield per hectare in Nepal (2.35 t ha\(^{-1}\)) is still very low despite suitable production environment and high yielding varieties. Different factors such as genotypes, tillage, nitrogen levels, and climate (temperature and precipitation) influence remarkably on the growth and grain yield of maize among others crops (Paudel et al., 2014). The need of the grain maize is increasing in the hills of Nepal for human consumption as staple food and for livestock feed in Terai and inner Terai (Pandey et al., 2007). Thus, hybrid maize can be a good option to increase the total production of maize grains with high input in Terai and mid-hills. It is because of the fact that the hybrid maize gives significantly higher grain yield than the open pollinated varieties (Shah et al., 2014).

Maize cultivation is subjected to tillage operation at different growth stages to facilitate germination of seed and promote plant growth and development. In conventional tillage, the soil is opened with mouldboard plough for primary tillage. The soil mass is broken into a loose system of colds of mixes sizes. Subsequently, a fine seedbed is prepared by secondary tillage (Ghimire et al., 2016). Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seed bed preparation in the row zone only. Zero tillage is advantageous where soils are subjected to wind and water erosion, tillage operation is too difficult and labor for tillage are too high (Ghimire et al., 2016). Khurshid et al. (2006) reported that tillage contributes up to 20% of the crop production factors. Recently, conservation tillage practices such as zero and minimum tillage are emphasized for soil water conservation, fuel energy saving, and erosion control (Sharafi et al., 2013). Thus, with scientific basis, zero-tillage as an alternative to conventional tillage is gaining popularity worldwide (Monneveux et al., 2006).

Soil is important for plant survival, balancing environment, ecology and climate. Maize is heavy feeder of nutrients. Nitrogen (N) has been considered as a primary nutrient in the fertilizer management programme to obtain the yield potential of maize crop (Sampath et al., 2013). A study conducted in Hyderabad, India, reported that N fertilization at 100 kg ha\(^{-1}\) increased grain yield from 43 to 68% and above ground biomass production from 25 to 42% as compared to 0 kg N ha\(^{-1}\) (Ogola et al., 2002). Further, it is assumed that for every 100 kg of grain yield, 1.8 kg N in the grain and 1.0 kg in the above ground parts of the plant are required and must be supplied by soil and/or fertilizer (Sampath et al., 2013). It has been reported that agronomic managements like proper tillage (Duiker et al., 2006) and fertilizer application (Rasheed et al., 2004) increased yield attributes and ultimately the grain yield. However, there is limited understanding on the response of hybrid maize to different level of nitrogenous fertilizers under different tillage practices in Terai region of Nepal. Moreover, the economic level of fertilizer application maize production is rarely evaluated. The objective of this research was to evaluate the response of different maize hybrids to nitrogen levels under different tillage systems for maximizing grain yields during summer season in 2014 at NMRP, Rampur.

**MATERIALS AND METHODS**

**Experimental site**

The experiment was conducted during summer season (May to September) of 2014 at the research farm of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal. The experimental site is located 10 km south-west direction from district headquarter of Chitwan district, Nepal. It is located at 27°37’ North latitude and 84°25’ East longitude with an elevation of 256 m above mean sea level. Geographically, the experimental location falls in the inner Terai region of central development region of Nepal. Total rainfall received during the experiment was 1936.35 mm and the mean maximum and minimum temperature was 36.87 and 19.5°C, respectively.

Soil samples were collected from 0 to 15 cm soil depths of experimental plots and total nitrogen was determined by the Macro-Kjeldahl method, available phosphorus by the Olsen’s bicarbonate method, available potassium by the ammonium acetate method and organic matter was determined by the Walkley and Black method in Central Soil Science Laboratory of Nepal Agriculture Research Council (NARC), Khumaltar (Khanal et al., 2014).

From soil analysis, sand (71.5%) was found dominant soil particle followed by silt (18.5%) and clay (11%), which signify sandy loam texture of the experimental soil. Furthermore, the total nitrogen, available phosphorus and available potassium were 0.165%, 34.38 kg ha\(^{-1}\) and 73.89 kg ha\(^{-1}\) in the top soil layer, respectively. Similarly, soil organic matter content was 3.12%. Soil pH was found to be acidic (5.39).

**Experimental design, tillage and fertilization**

The experiment was laid out in strip split plot design with sixteen treatments and three replications by assigning two maize hybrids (Rampur hybrid-2 and RML 32/RML 17) as horizontal factor, two tillage systems (Zero and conventional tillage) as vertical factor and four levels of nitrogen (0, 60, 120 and 180 kg N ha\(^{-1}\)) as sub plot factor.

Thus, altogether there were 8 rows in each plot of which 1st and 8th rows were treated as boarder rows. The central three rows (5, 6 and 7th) were used as net plot rows for harvesting and remaining rows (2, 3 and 4) were treated for biometrical and phenological observations.

The individual gross plot size was 30 m\(^2\) consisting of 5 m length and 6 m breadth. Row to row spacing was maintained at 75 cm and plant to plant at 25 cm for each plot. The net experimental area was 1516 m\(^2\) consisting of 48 plots (Figure 1). The experimental plots for conventional tillage were prepared by ploughing the plots with tractor 15 days prior to sowing seeds. For zero tillage, the field was sprayed with glyphosate 47/VL using recommended dose (5 ml/L of water) to make field free from weeds.

In the experimental field, farm yard manure (FYM) at the rate of 10 t ha\(^{-1}\) was applied as a main source of organic fertilizer. Maize was fertilized with 120:60:40 NPK kg ha\(^{-1}\). The required amount of nitrogen fertilizer was calculated separately for each treatment. The total nitrogen at 0, 150, 260.85 and 391.2 g per plot were applied in
All maize plants in the net plots were harvested from the base near the soil surface and weighed.

**Harvest index**

Harvest index is the ratio of grain yield and total upper ground biomass which indicates the efficiency of plant to assimilate partition to the parts of economic yield (that is, maize grain) (Bishwokarma and Shrestha, 2014). Harvest index in percentage was calculated following the method described by Beadle (1987).

Harvest index = \[ \frac{[\text{Economical yield (grain yield, kg ha}^{-1})/\text{Biological yield (grain + stover yield, kg ha}^{-1}])] \times 100 \]

**Statistical analysis**

Data were tested for normality and constant variance and the relationship between nitrogen level and grain yield was analyzed using non-linear regression analyses using MSTAT-C package. Data were subjected to Analysis of Variance (ANOVA) to evaluate the effect of hybrid varieties, tillage methods and nitrogen levels, and their interaction on grain yield (t ha\(^{-1}\)), stover yield (t ha\(^{-1}\)) and harvest index of maize. Duncan Multiple Range Test (DMRT) was used to compare means using Least Significance Difference (LSD) at 5% level of significance (Khanal et al., 2014; Shrestha et al., 2013).

**RESULTS AND DISCUSSION**

**Grain yield**

Rampur hybrid-2 and RML32/RML17 hybrids showed similar performance in respect of grain yield formation (2.93 and 2.9 t ha\(^{-1}\), respectively). Results showed no significant effect of the tillage methods on grain yields of hybrid maize in the humid subtropical climate of Chitwan, Nepal. The grain yield from control treatment without nitrogen application (1.64 t ha\(^{-1}\)) was significantly lower than that of all levels (60, 120 and 180 kg N ha\(^{-1}\)) of nitrogen (3.05, 3.44 and 3.57 t ha\(^{-1}\), respectively, \(P < 0.05\)). Application of nitrogen at 60, 120 and 180 kg ha\(^{-1}\) increased grain yield significantly as compared to control indicating the need of nitrogen fertilizer for boosting maize productivity in sandy loam soil of Chitwan. This is in agreement with Mosis et al. (2007) and Wonde et al. (2007) who reported that application of nitrogen increases grain yield of hybrid maize varieties under optimum condition of nitrogen level. Similarly, Khaliq et al. (2009) and Ahmad et al. (2009) suggested that the grain yield increases by increasing the nitrogen level. Soil fertility acts as a yield-limiting factor in maize production under excessive leaching of soil nitrogen during rainy season (Bekeko, 2013). The grain yield obtained with 180 kg N ha\(^{-1}\) was at par with that of 120 kg N ha\(^{-1}\) but significantly higher than 60 kg N ha\(^{-1}\). Effect of nitrogen levels on grain yield was significant and grain yield increased non-linearly with increasing N levels. The physical and economical maximum doses of nitrogen were higher for RML32/RML17 in conventional tillage.
compared with zero tillage. Surprisingly, economical maximum doses of nitrogen were higher in zero tillage compared with conventional tillage for Rampur hybrid-2 compared to RML32/RML17. Reason behind difference in physical and economical maximum doses of two hybrids in different tillage system is unknown as these hybrids are launched recently and studies regarding these hybrids in different tillage and nitrogen levels are not available.

In the current study, yield from two hybrid varieties grown during the summer 2014 were similar to each other in respect of grain yield formation. This indicates that the varieties did not differ in their genetic make-up or potential and capacity to transport photosynthates from source to sink. Other studies with hybrid maize in South and South-West Asian countries show similar results (Mukhtar et al., 2011; Muhammad et al., 2004; Wajid et al., 2007). For example, Mukhtar et al. (2011) tested two maize hybrids (YH-1898 and YH-1921) with different nitrogen level and reported grain yield of 6.734 and 7.622 t ha\(^{-1}\). The yield reported in their studies with other hybrid maize were higher compared with the current study. The present experiment was done during the monsoon season of Nepal, which is characterized by greater rainfall and cloudy days during the growing season. Heavy rain likely leached applied nitrogen, and cloudy weather potentially affected photosynthesis process resulting poor grain yield. Depletion of organic matter and fertility in tilled plots could be the reason for getting similar grain yield in conventional tillage compared to zero tillage (Shah et al., 2014; Ghimire et al., 2016). In the present research the values of weed dry matter recorded in zero and conventional tillage methods were similar to each other at all growth stages (22, 55 and 75 DAS). Similar results were obtained by Chopra et al. (2007) during 30 and 90 DAS and at harvest. This might be causal factor for obtaining similar effects of tillage practices on grain yield of hybrid maize varieties.

**Stover yield**

The stover yield produced by Rampur hybrid-2 (4.97 t ha\(^{-1}\)) was significantly higher than that of RML32/RML17 (4.49 t ha\(^{-1}\)). No difference in stover yield between different hybrids (Gaurav and Rajkumar) was also reported by Dawadi and Sah (2012) on a study conducted in the same research station. In the current study, stover yield was not significantly influenced by tillage methods (zero tillage 4.62 t ha\(^{-1}\); conventional tillage 4.84 t ha\(^{-1}\)). These results are inconsistent with the results obtained by Chopra and Angiras (2007) in which they reported significantly higher stover yield in conventional tillage compared with zero tillage using maize variety PSCL-3438 during Kharif season at Himanchal Pradesh in India. Differences in hybrids, season of the year and eco-region for maize cultivation are likely to result in different stover yield. Significantly higher stover yield was obtained in the treatment with 180 kg nitrogen (6.44 t ha\(^{-1}\)) per hectare in comparison to control (2.71 t ha\(^{-1}\), 60 (4.21 t ha\(^{-1}\)), and remained at par with 120 (5.65 t ha\(^{-1}\)) kg N ha\(^{-1}\). Other studies also indicate increase in stover yield with increased level of nitrogen (Dawadi and Sah, 2012; Sampath et al., 2014). In the current study, there was no interaction between hybrid, tillage methods and nitrogen levels with respect to stover yield.

**Physical maximum vs. economic maximum**

The effect of nitrogen levels on grain yield of maize hybrid was significant (\(P < 0.05\)) and polynomial regression equation was obtained. The values of coefficient of determination (R\(^2\)) shows contribution of nitrogen in the formation of grain yield was remarkably higher in case of RML32/RML17 (73 and 85\%) as compared to Rampur hybrid-2 (61 and 54\%) under zero and conventional tillage practices, respectively. Further, the relationships between nitrogen levels and grain yield were found strong as indicated by the values of correlation coefficient (r) which were remarkably higher for RML32/RML17 (0.857 and 0.921) than Rampur hybrid-2 (0.786 and 0.738) under zero and conventional tillage practices, respectively. Moreover, the physical and economical maximum doses indicate that they were higher for RML32/RML17 in conventional tillage but lower in zero tillage as compared to Rampur hybrid-2 and vice-versa for Rampur hybrid-2. The average value of these parameters showed that they were remarkably higher in zero tillage (172.38 and 153.77 kg N ha\(^{-1}\)) as compared to conventional tillage (140.00 and 127.86 kg N ha\(^{-1}\)), respectively. The results from the finding are consistent with Randall and Bandle (1991) who reported that in the fertilizer N rates are increased up to 25\% to counter the adverse effect on yield from sort term immobilization in zero tillage. It is because of the fact that the estimates of the lower N in zero tillage vary from 10 to 40 kg ha\(^{-1}\) in comparison to tilled soils (Bandel et al., 1984).

Thus, on the basis of the aforementioned analysis it can be mentioned that N is a vital plant nutrient and major yield determining factor in maize production (Shanti et al., 1997).

**Harvest index (HI)**

The maize hybrids did not significantly influence harvest index (RML32/RML17, 0.37; Rampur hybrid-2, 0.34). To our understanding, this is the first study to report the effect of RML 32/RML17 and Rampur hybrid-2 maize on harvest index. Studies from other maize hybrids indicate differences in harvest index (Wajid et al., 2007). In this study, tillage methods had no significant effect on harvest
index (zero tillage, 0.35; conventional tillage, 0.36) which is consistent with results from Chopra and Angiras (2007) and Pandey and Chaudhary (2014). The largest harvest index was obtained from 60 kg ha⁻¹N (0.404) but the index did not differ significantly between 180 (0.43), 0 (0.32) and 120 (0.362) kg N ha⁻¹ application. The effect of nitrogen level in harvest index is consistent with Dawadi and Sah (2012) but inconsistent with Pandey and Chaudhary (2014). Such difference in the result could be due to difference in maize hybrids and season of growth.

Conclusion

This study clearly demonstrates the dependency of grain yield in Terai, Nepal on N application. Grain yield was not significantly influenced by hybrids and tillage methods. However, grain yield increased continuously with the increasing nitrogen level. The grain yield from 180 kg ha⁻¹ was at par with 120 kg ha⁻¹ which indicates that higher rate of nitrogen application is not sound strategy to obtain maximum grain yield. This study outlines 120 kg N ha⁻¹ as an appropriate dose N fertilization for hybrids maize cultivation in inner Terai region of Nepal. However, more research is warranted for better understanding of the influence of tillage practices and nitrogen levels on yield sustainability in maize cultivation across different climate and agro-ecological regions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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