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Effects of tillage and planting geometry on the performance of maize hybrids

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ABSTRACT

An experiment was conducted during the spring season of 2013 at Rampur, Chitwan, Nepal. The experiment was laid out in a strip plot design with three replications having 12 treatments, and consisted of two tillage treatments: no tillage (NT) and conventional (CT), two genotypes: Rampur Hybrid-2 and RML-32/RML-17, and three planting geometries: D1=75cm× 25cm, D2=70cm× 25cm and D3= 60cm×25cm between rows and between plants, respectively. Higher Normalized Difference Vegetation Index (NDVI) values of 0.747 were recorded in NT over the CT with 0.657. Rampur Hybrid-2 had the lowest value of NDVI with 0.747 and the highest value was found in RML-32/RML-17 with 0.757. Plant height in CT (167.88 cm) was higher than one (167.17 cm) in NT. Similarly, the highest plant height of 169.91cm was recorded in RML-32/RML-17 over 165.14 cm in Rampur Hybrid-2. The highest number of cobs (73,177 /ha) was recorded at G3. A higher number of 27.3 kernels per row in NT was recorded over the 25.8 in CT. RML-32/RML-17 produced the highest test weight of 363.94g over the Rampur Hybrid-2 with 362.17g. Significantly higher grain yield of 9.24t /ha was recorded in planting geometry of D3. The experiments need to be further tested with higher plant population densities in Nepalese hybrids.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops grown during the summer season in Nepal. It is the second most important staple crops after rice both in terms of area and production. Its area, production, and productivity in Nepal are 849635 ha, 1999010 t, and 2353 kg (MOAD 2013) respectively. It contributes 3.15% to national gross domestic production GDP and 9.5% to agricultural GDP (MOAD 2013). Maize occupies about 40.6% area of the total food crops in the hills and 26.05% in the country. It shares about 25.69% of total edible food production in Nepal (NMRP 2011).

Despite the many efforts made, the productivity of maize is almost stagnant or slightly decreasing (MOAD 2012 and MOAD 2013). The overall demand for maize driven by increased demand for human consumption and livestock feed is expected to grow by 4% to 6 % per year over the next 20 years (Paudyal et al. 2001). Thus, Nepal will have to resort to maize imports in the future if productivity is not increased substantially.

Harvesting extremely low cobs due to lower plant stand per unit area is the major causes of poor yield of maize in Nepal. Very recently one maize hybrid Rampur Hybrid-2 has been released for general cultivation and another RML-32/RML-17 is under consideration for release in Nepal. Maize hybrids differ in their response to plant density (Xue et al. 2002). As maize does not have tillering capacity to adjust to variation in plant stand, optimum plant population for grain production is important (Xue et al. 2002). Agronomic practices that affect the plant population are known to affect also the crop environment, which influences yield and yield components. Optimum population levels should be maintained to exploit maximum natural resources such as nutrient, sunlight, soil moisture and to ensure satisfactory yield (Lhote and Khuspe 1987).

Many studies have been conducted with the aim of determining the optimum plant density for maize within and outside the country. Unfortunately, there is no single robust

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recommendation, because the optimum plant density varies depending on environmental factors such as crop establishment methods i.e. tillage, soil fertility, moisture supply, genotype (Gonzalo et al. 2006) planting date, planting pattern, plant population (Xu et al. 2002) and harvest time. Nepal has developed some promising hybrids for the tropical flat lands (Terai) and foot hills and it is necessary to test, verify and promote them under no till condition, since no tillage planting along with residue retention in the field has been emerging as the inevitable technology to save labor cost, conserve moisture and increase yields thereby 'sustaining productivity. The aim of this study is to determine the effects of crop establishment methods in combination with differential plant densities on yield and yield components of maize hybrids in Nepal.

MATERIAL AND METHODS

Experimental site

The experimental was planted during winter season of 2013 and the field was laid out in strip plot design with three replications and 12 treatments. Maize crop was planted on 12th of February, 2013 and harvested on 27th of June, 2013. The vertical factor was tillage with no tillage (NT) and conventional tillage (CT) and the horizontal factor were genotypes (Rampur Hybrid- 2 and RML-32/RML-17) and in split planting geometries (75cm × 25cm =53,333 plants /ha, 70 cm × 25cm=57,142 plants /ha and 60cm × 25cm= 66,666 plants /ha). The individual plot size was having 7 rows of 5 meter long as prescribed by the treatments. The three central rows were used as net plot rows for biometric and agronomical data recording and the remaining 2 rows leaving the two border rows at either side were used for biometrical and phenological observations.

The crop was fertilized with 120:60:40 kg $NP_2O_5K_2O$ /ha. Fifty % of the N along with full P_2O_5 and K_2O was applied during seeding and remaining N was split into 2 and first half was applied at V7 i.e 7th leaf stage and the remaining N was used at pre-tasseling stage of maize. Rest of the crop management operations were carried out as and when needed. Weather parameters were recorded from the NMRP's meteorological station. Total nitrogen was determined by Kjeldahl distillation unit (Jackson 1967) available phosphorus by Olsen's method (Olsen et al. 1954) and available potassium by Ammonium Acetate method (Black, 1965). Organic matter was determined by Walkey and Black method (1934) pH (1:2 soil water suspensions) by Beckman Glass Electrode pH meter (Wright 1939) and soil texture by Hydrometer method.

Plant height and normalized difference vegetation index (NDVI) was measured at pre-tasseling stage of the crop for each treatment. An active hand-held sensor NTech's GreenSeeker™ was used for this study to determine NDVI using the equation 1 below:

(1) NDVI = (Near Infrared Band Reflectance– Red)/ (Near Infrared Band Reflectance + Red)

GreenSeeker® calculates NDVI using red and NIR light. Red light is absorbed by plant chlorophyll as an energy source during photosynthesis. Therefore, healthy plants absorb more red lights and reflect larger amounts of NIR than those that are unhealthy. NDVI is an excellent indicator of biomass (amount of living plant tissue), and is used in conjunction with growing degree days greater than zero (GDD>0) or days from planting to accurately project yield potential.

No of cobs /ha, no of kernel rows/cob, no of kernels/ row, thousand grain weight (g) and grain yield (t/ha) were measured. The collected data was processed by MS Excel and analyzed by using GenStat Discovery version.

RESULT AND DISCUSSION

Normalized Difference Vegetation Index (NDVI) of maize

NDVI shows the vigor and healthiness of the plant. It varied significantly due to tillage and genotypes however did not due to planting geometry. Significantly higher value of NDVI (0.747) was recorded in NT as against the 0.657 in CT. It might be due to the availability of plant nutrients especially N fertilizers applied near to planting rows during spring season, since the N leaching during this season is less likely to occur due to low rainfall as compared to summer. Rampur hybrid-2 had the lowest value of NDVI with 0.747 and the highest was found in RML-32/RML-17 with 0.757. Similarly, interaction effect of tillage and genotype was also found and RML-32/RML-17 outperformed over Rampur Hybrid-2 in either of the tillage methods (Figure 1). Regression analysis (Figure 3) revealed that the contribution of NDVI for grain yield was 98.6 %, indicating one of the best in-season yield predicting parameters in maize (Karki 2013).

Plant height of maize

Significant effects of tillage, genotype, tillage ×spacing and tillage × genotype × spacing on plant height of maize was observed. Conventional tillage had the highest plant height of 167.88 cm as against 167.17 cm in NT. Similarly, the highest plant height of 169.91cm was recorded in RML-32/RML-17 over 165.14 cm in Rampur Hybrid-2. Plant population densities did not affect the plant height of maize; however the height was increased with increasing densities. It was also affected by tillage × plant spacing and tillage × genotype × spacing and was higher in CT with higher plant densities and CT with RML-32/RML-17 having higher plant densities (Fig 2). NDVI and plant height of maize at pre-tasseling stage was positively correlated (R^2=0.21). Similarly, the plant height also affected the grain yield of maize (R^2=0.23).The trend line shows the increment of NDVI with increase in plant height (Figure 3a and 3b). Plant density significantly increased the plant height in maize hybrids. Data regarding the effect of maize hybrids and plant density on plant height ANOVA revealed the significant effect of tillage, genotype, tillage × spacing and tillage x genotype × spacing on plant height of maize.

Crop maturity

Crop duration was affected significantly by tillage, genotypes and planting geometry. Irrespective of genotypes and planting geometry, crop from NT matured earlier at 130.72 days than CT at 133.83 days. Araus et al. (2008) also reported that maize under NT field matured earlier than CT field. As far as genotypes are concerned, Rampur Hybrid-2 took 131.78 days, whereas RML-32/RML-17 took 132.78 days to maturity. Wider spaced crop matured earlier than the closed spaced and the crop planted at planting geometry of 75cm between rows (RR) and 25cm between plants (PP) matured earlier at 130.83 days followed by RR of 70cm and PP of 25cm with 132.42 days. The longest duration of 133.58 days was recorded in the planting geometry of 60 X 25cm (Table 1). Similar results were found by Amanullah et al. (2009) and reported that physiological maturity was delayed in those plots maintained at higher plant density. This suggests that dense planting might have slightly slowed down the rate of plant development because of more competition in dense population (Hamid and Nasab, 2001).

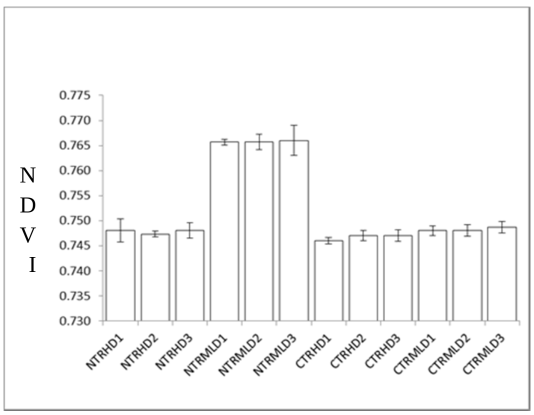

Fig 1. Normalized difference vegetation index (NDVI) of maize as affected by tillage, genotypes and cropping geometry at pre-tasseling stage, 2013, Rampur

Note: NT; No tillage, CT: Conventional tillage, RH: Rampur Hybrid -2, RML: RML-32/RML-17, D1: 60× 25cm, D2: 70× 25cm and D3:75× 25cm. ANOVA revealed the significant effect of tillage, genotype and tillage* genotype on NDVI of maize.

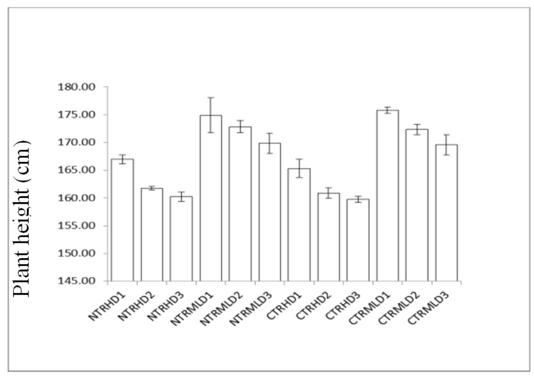

Fig 2. Plant height (cm) of maize as affected by tillage, genotypes and planting geometries at pre-tasseling stage, Rampur, 2013

Note: NT: No tillage, CT: Conventional tillage, RH: Rampur Hybrid -2, RML: RML-32/RML-17, D1: 60cm × 25cm, D2: 70cm ×25cm and D3:75cm ×25cm. ANOVA revealed the significant effect of tillage, genotype, tillage × spacing and tillage x genotype × spacing on plant height of maize.

Table 1. Grain yield and related parameters of two hybrids Rampur Hybrid-2 and RML-32/RML-17 under various tillage methods and planting geometries in Rampur, during winter, 2013

Treatments	No of cobs /ha	No of kernel rows /cob	No of kernels /rows	Test weight (g)	Grain yield (t/ ha)	Maturity days
Tillage						
Conventional tillage	62120	14	25.8	362.5	8.35	133.83
No tillage	64962	13.7	27.3	363.61	8.36	130.72
F-test	*	NS	*	NS	NS	**
$LSD_{0.05}$	1831.1	-	1.06	-	-	0.48
Genotype						
Rampur Hybrid-2	64205	13.8	26.4	362.17	8.32	131.78
RML-32/RML-17	62876	13.8	26.7	363.94	8.39	132.78
F-test	NS	NS	NS	*	NS	**
$LSD_{0.05}$	-	-	-	1.61	-	0.48
Planting geometry						
60×25 cm^2	64942	13.8	26.1	362.5	9.24	133.58
70×25 cm^2	63603	13.8	26.5	363.08	7.95	132.42
75×25 cm^2	62077	14.6	27.1	363.58	7.88	130.83
F-test	*	NS	NS	NS	**	**
$LSD_{0.05}$	2242.7	-	-	-	0.72	0.59
CV,%	4.2	3.2	5.8	3.6	8.3	2.5
Grand mean	63541	13.9	26.6	363.06	10.36	132.28

Number of cobs /ha

Number of cobs per hectare was influenced by tillage, and a significantly higher number of cobs (64962 /ha) were recorded in NT compared to 62120 /ha in CT. Similarly, cobs per hectare was also influenced by planting geometry and a higher number cobs were (64942 /ha) recorded at the planting geometry of 60cm between rows and 25cm between plants and the lowest of 62077 /ha in planting geometry of 75 cm between rows and 25cm between plants and was statistically at par with (63603 /ha) in the planting geometry of 70cm between rows and 25cm between plants (Table 1). There was a positive correlation of number of cobs and grain yields with R^2 value of 56.3% (Figure 4).

Number of kernel rows per cob

Number of kernel rows /cob did not vary due to tillage, genotypes and planting geometry. Both the methods of tillage (NT and CT) produced the similar number of kernel rows in a cob. It might be due to the similar availability of soil moisture, nutrients and solar radiation for photosynthesis. However, the rows were more in conventionally tilled plot and planting geometry of 75cm between rows and 25cm between plants. The two hybrids Rampur Hybrid-2 and RML-32/RML-17 were having the same number of kernel rows in a cob (Table 1).

Number of kernels per row

Difference due to genotypic and planting geometry was not evident for the number of kernels /row. However, significantly the highest number of kernels per row was recorded at the planting geometry of 60 cm between rows and 25cm between plants. Tillage methods affected it and were higher of 27.3 rows in NT as against the 25.8 in CT (Table 1). Similar findings were also reported by Sornpoon and Jayasuriya (2013) where they found no difference in number of kernels per row of maize.

Test weight (g)

Except genotypic difference, no difference was observed due to tillage and planting geometry on the 1000 grains weight of maize. RML-32/RML-17 produced the highest 1000 grain weight of 363.94 g over the Rampur hybrid-2 with 362.17 g. However, NT had higher 1000 grain weight to CT. Similarly, slightly a higher of it was observed in wider spaced planting than closely spaced.

Grain yield (t/ha)

Like the other parameters, grain yield of maize was not significantly affected by tillage. Similarly, genotypic differences among both the released hybrid (Rampur Hybrid-2) and pre-released hybrid (RML- 32/RML-17) were not observed during the spring season at Rampur. Since, similar grain yields were harvested from NT and CT, NT saved significant costs in production. Small holder farmers in Indonesia are realizing 25 percent savings in labor, 65 percent savings in land preparation costs, 28 percent savings in irrigation water per cropping cycle and 2-3 weeks' time saving for land preparation due adoption of conservation tillage (FAO 2012).Change in microenvironment of soil is generally adjusted in NT by its overall strength and Iqbal et al. (2013) reported that on average, the NT had 63% higher soil strength than CT.

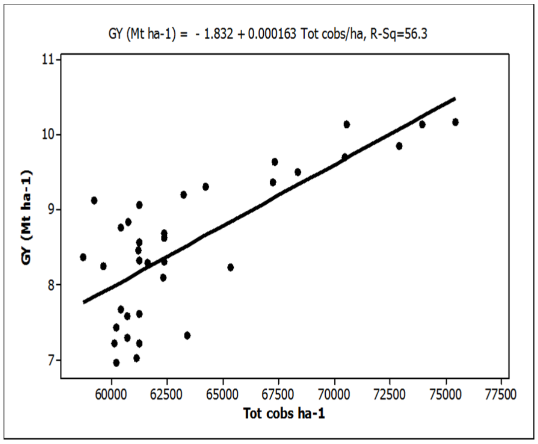

Figure3: Correlation between total number of cobs and grain yields of maize, Rampur, 2013.

Note: Tot: Total, GY: grain yield

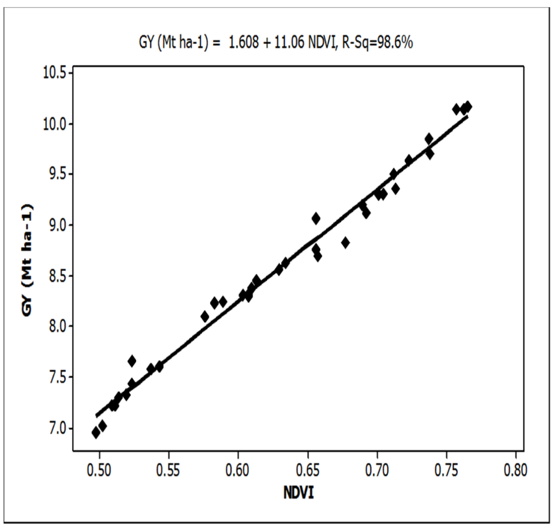

Figure 4: Correlation between Normalized Difference Vegetation Index (NDVI) value and grain yields of maize, Rampur, 2013

The variation in grain yield was evident due to cropping geometry and was significantly higher (9.24 T/ha) in planting geometry of 60cm between rows and 25cm between plants (Table 1). It is mainly due to the higher number of cobs per hectare in planting geometry of 60cm between rows and 25cm between plants.

Many researchers have depicted that the dwarf maize hybrids perform better up to 90,000 plants in a hectare. Population of maize for maximum economic grain yield varies from 30,000 to over 90,000 plants /ha, depending on water availability, soil fertility, maturity rating, planting date and row spacing. Xue et al. (2002) reported that grain yield increased with increasing plant density from 54000-94000 plants /ha, but decreased after 97000 plants/ha. Our findings are also in agreement with observations made by many researchers Mobasser et al. (2007).

CONCLUSION

There was a strong positive correlation of NDVI and grain yield of maize (R^2=98.6%). Rampur hybrid-2 had the lowest value of NDVI with 0.747 and the highest was found in RML-32/RML-17 with 0.757.Conventional tillage had the highest plant height of 167.88 cm as against the 167.17 cm in NT. Similarly, the highest plant height of 169.91cm was recorded in RML-32/RML-17 over 165.14 cm in Rampur hybrid-2. Number of cobs per hectare was influenced by tillage, and significantly higher number of cobs (64962 /ha) was recorded in NT compared to 62120 /ha in CT. A higher number of cobs were (64942 /ha) recorded at the planting geometry of 60cm between rows and 25cm between plants. Number of kernel rows cob^{-1} did not vary due to tillage, genotypes and planting geometry. A higher number of 27.3 kernels per row in NT were recorded as against the 25.8 in CT. The genotype RML-32/RML-17 produced the highest thousand grain weight of 363.94 g over the Rampur hybrid-2 with 362.17 g. Grain yield was not affected by tillage and genotypes. Significantly higher grain yield of 9.24 t/ha in planting geometry of 60cm between rows and 25cm between plants. The experiments need to be further tested with further higher plant population densities of Nepalese hybrids.

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