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# Effects of row distance and nitrogen rate on canopy efficiency and yield of maize

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**Key words:** Radiation absorption, Planting density, Canopy development, Maize yield

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## Abstract

Appropriate amount of nitrogen fertilizer and plant spacing are important agronomic practices to increase canopy efficiency and yield of maize. A field experiment was conducted at the Agronomy Experimental Field, Department of Agronomy and Agricultural Extension, University of Rajshahi, using a commonly cultivated hybrid maize variety (cv. ACI - 3110) during the period November 2015 to March 2016. The experiment consisted with three different row distances ($S_1$, 85cm; $S_2$, 75cm and $S_3$, 65cm) and three nitrogen fertilizer (urea) rates (550 kg urea or 100% of conventional rate, 413 kg urea or 75% of conventional rate and 275 kg urea or 50% of conventional rate).The experiment was laid out in a split plot experimental design with three replications placing plant spacing in the main plots and nitrogen fertilizer in the sub plots. Except experimental treatments, standard agronomic practices were maintained for all plots. The results indicated that dense row distance (65 cm) can effectively increase canopy cover. At 60 days after sowing (DAS), maximum canopy cover (57.07%) was derived from 65cm row distance which was 7.06% and 8.65% higher than 75cm and 85cm row distance respectively. At 120 days after sowing, maximum canopy cover (82.04%) was also obtained from 65cm row distance and it was 14.63% and 36.12% higher than75cm and 85cm row distance respectively. Different yield components and yield (5.47 t/ha) was found highest with conventional fertilizer rate (550kg/ha). From our observation it can be suggested that 65 cm row spacing with 550 kg urea would be the best practice for maximizing canopy efficiency and maize productivity in the experimental area.

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## Introduction

Maize (*Zea mays* L.) is the third major cereal which yields much higher than rice and wheat (Akongwubel *et al.,* 2012). Its uses are popularized as food, feed and forage purpose. Hence, it is known as king of crops suitable for storage (Muhammad *et al.,* 1990). Management of row spacing is a crucial factor for increasing the productivity of maize. Yield increases up to 10% while reducing row spacing from 70cm to 60cm. (Widdicombe and Thelen, 2002). Anjum *et al.* (1992) mentioned that, grain yield and compact row distance has linear relationship between them until yield factors are not limiting. Turgut *et al.* (2005) proposed that, the yield can respond dramatically even to a slight change in row distance. Plant density in maize has distinct effect on canopy architecture, transforming growth and developmental patterns with having impact on carbohydrate production and partition (Casal *et al.* 1985). Maize grain yield rises with decreasing row distance (Toler *et al.* 1999; Mariga *et al.* 2000). Production of maize in narrow rows proves efficient in utilizing soil amendments which contributes to yield increase (Turgut *et al.,* 2005). Sangakkara *et al.* (2004) mentioned that, row density affect most of the parameters associated with growth even under ideal growth conditions and therefore it plays a vital role dictating the degree of competition among plants. There was a close relationship observed between narrow rows and increase in light interception during the critical period of grain set (Andrade *et al.*, 2003). Narrow row spacing of maize allows the leaf tips to merge upon each other where the leaf petioles mainly take part in active radiation absorption. Narrow rows provides crowding of leaves resulting less amount of radiation absorption per plant but high rates of intercepted radiation over the whole area (Edwards *et al.* 2005) At close row spacing maize grain yield increases due to improvement in light interception during the critical period for grain set (Andrade *et al.* 1999). On the other hands wide rows of maize facilitate single plant to intercept more sunlight by acclimatizing the architecture with sufficient space and yield more per plant but it reduce total yield.

Grain yield may also be reduced in narrow rows in case of excessive plants per unit area (Maddonni and Otegui, 2006). For the purpose of yielding both forage and biomass yield the corn planting in narrow rows is widely accepted.

Efficient use of nitrogen in plant production proves as a crucial goal in crop management. Hageman and Below (1984) suggested that, nitrogen increases leaf area which is closely related to canopy efficiency for radiation absorption. Modhej *et al.* (2008) mentioned that, nitrogen plays critical function attributable to increase in grain yield and it affects production more than any other element. Even if the grain yield is not limited, nitrogen often affects the nutritional composition of the grain (Thanki *et al.*, 1988; Sabir *et al.*, 2000). Availability of nitrogen is closely related with planting density (Srikanth *et al.,* 2009). Efficiency of nitrogen improves with reduced row distances in maize (Charles and Charles, 2006). Crop growth, leaf area, canopy coverage and radiation use efficiency (REU) of maize can be reduced with reduction of nitrogen (Lawrence *et al.,* 2008). Therefore, the present study was aimed to investigate the effects of row distance and nitrogen rate on canopy efficiency and yield of maize.

## Materials and methods

*Study area*

The present research was conducted at the Agronomy Experimental Field, Department of Agronomy and Agricultural Extension, Rajshahi University of Rajshahi during the period from 10 November 2015 to 31 March 2016 to study on the effects of row distance and nitrogen fertilizer (urea) levels on canopy efficiency and yield of maize (cv. ACI-3110).Geographically the experimental field is located at 24°22'36" N latitude and 88°38'27"Elongitude at an average altitude of 71 ft. above sea level. The land of the experimental field was flat, well drained and above flood level (Medium high land). The soil was sandy loam textured having pH value of 8.1.

*Experimental treatments*

The experiment consists of three row distances ($S_1$ = 85cm, $S_2$ = 75cm and $S_3$ = 65cm) and three nitrogen fertilizer rates ($N_1$ = 550 kg urea/ha, $N_2$ = 413 kg urea/ha and $N_3$ = 275 kg urea/ha). Three row distances and three nitrogen fertilizer rates are combined into nine treatments and those were replicated three times in a split plot experimental design placing row distance in the main plot and fertilizer rates in the sub plot. Each plot occupied area of 16 $m^2$ (4 m× 4 m) and 1.5 m gap within the sub plot and 2 m gap within the main plots were maintained.

*Fertilizer management*

Except urea, other nutrient elements were used as general dose with triple super phosphate - 200 kg $ha^{-1}$, muriate of potash - 140 kg $ha^{-1}$, zinc sulphate- 13 kg $ha^{-1}$, boric acid - 7 kg $ha^{-1}$, gypsum - 160 kg $ha^{-1}$. All the fertilizers along with one third of urea were applied at the time of final land preparation. The remaining urea was divided in two equal splits and applied at 30 and 60 days after sowing (DAS).

*Crop growth and yield components determination*

Crop growth parameters were measured from randomly selected tagged plants. Five plants were randomly selected and uprooted from each unit plot for recording data on growth parameters i.e. plant height, leaf area index (LAI), total dry matter (TDM) and crop growth rate (CGR).Yield contributing characters such as, cob length (cm), number of grains $cob^{-1}$, 1000-grain weight (g), grain yield (t $ha^{-1}$), stover yield ($tha^{-1}$), biological yield (t $ha^{-1}$) and harvest index (%) were also recorded during harvest. At maturity, the experimental crops were harvested plot-wise at 10 April, 2017.

The harvested crops from each plot were bundled separately, tagged and brought to clean threshing floor. The same procedure was followed for sample plant (10 plants from each plot).

*Measurement of canopy efficiency*

Canopy efficiency was measured at mid-day at 30, 60 and 90 days after sowing according to Mullen and Reynolds (2010). Images of canopy shades were captured plot wise using a digital camera and then Adobe Photoshop CS3software was used to calculate canopy efficiency using following formula:

Canopy Efficiency (%) = (pixels of shaded area/pixels of whole captured area) × 100.

*Data management and statistical analysis*

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C.

## Results and discussion

*Plant height*

Plant height was not influenced by row distance (Table 1).

**Table 1.** Effect of row distances and nitrogen fertilizer rates on plant height (cm) of maize plant at different days after sowing.

| Row distances | Plant height (cm) | | |
|---|---|---|---|
| | 30 (DAS) | 60 (DAS) | 90 (DAS) |
| $S_1$ | 58.77 | 100.85 | 220.24 |
| $S_2$ | 58.19 | 99.86 | 219.70 |
| $S_3$ | 57.63 | 93.97 | 218.61 |
| Level of Significance | NS | NS | NS |
| CV% | 4.58 | 7.43 | 2.19 |
| Nitrogen fertilizer rates | | | |
| $N_1$ | 58.70 | 105.14 a | 222.60 |
| $N_2$ | 58.30 | 96.53 ab | 219.28 |
| $N_3$ | 57.58 | 93.12 b | 216.67 |
| Level of Significance | NS | ** | NS |
| CV% | 4.58 | 7.43 | 2.19 |
| Interaction effect (Row distance × Nitrogen rate) | | | |
| $S_1N_1$ | 59.44 | 109.33 | 223.23 |
| $S_1N_2$ | 58.86 | 100.06 | 220.17 |

| | | | |
|---|---|---|---|
| $S_1N_3$ | 58.33 | 93.47 | 217.33 |
| $S_2N_1$ | 58.83 | 107.16 | 222.90 |
| $S_2N_2$ | 58.19 | 97.23 | 219.17 |
| $S_2N_3$ | 57.53 | 95.20 | 217.00 |
| $S_3N_1$ | 58.17 | 98.92 | 221.67 |
| $S_3N_2$ | 57.86 | 92.31 | 218.50 |
| $S_3N_3$ | 56.87 | 90.68 | 215.67 |
| Level of Significance | NS | NS | NS |
| CV% | 4.58 | 7.43 | 2.19 |

$S_1$= 85 cm, $S_2$= 75 cm and $S_3$= 65 cm row distance; $N_1$=100% of conventional nitrogen fertilizer rate, $N_2$= 75%, and $N_3$= 50% of conventional nitrogen fertilizer rate; NS= Non significant; DAS= Days after sowing; CV= Co-efficient of variation.

Maximum plant height was observed in 85cm row distance at all growth stages. Plant height was also not varied significantly for nitrogen fertilizer application at 30 and 90 days after sowing although in both cases the values were found maximum (58.70 and 222.60cm respectively) for conventional fertilizer application ($N_1$). However, at 60 days after sowing, a remarkable higher value was observed for $N_1$, which reduced slightly (8.19%) for $N_2$ and significantly by 11.43% for $N_3$ (Table 1). The interaction effect of row distance and nitrogen fertilizer was not significant at all growth stages and, most of the cases highest value was obtained from 85cm row distance and 550kg ($N_1$) nitrogen fertilizer rate.

**Table 2.** Effect of row distances and nitrogen fertilizer rates on LAI, CGR and TDM of maize plant at different days after sowing.

| | LAI | | | TDM ( g m$^{-2}$) | | | CGR (g m$^{-2}$ day$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| Row distances | 30 DAS | 60 DAS | 90 DAS | 30 DAS | 60 DAS | 90 DAS | 30-60 DAS | 60-90 DAS |
| $S_1$ | 2.68 | 5.69 b | 3.23 | 36.07 | 160.74 c | 390.98 b | 3.94 b | 7.67 b |
| $S_2$ | 2.82 | 6.30 a | 3.29 | 42.47 | 176.67 b | 466.44 a | 4.48 b | 9.11 a |
| $S_3$ | 3.01 | 6.69 a | 3.48 | 42.69 | 212.41 a | 485.78 a | 5.88 a | 9.66 a |
| Level of Significance | NS | ** | NS | NS | ** | ** | ** | * |
| CV% | 11.65 | 6.37 | 7.93 | 16.01 | 6.22 | 9.03 | 9.19 | 16.47 |
| Nitrogen fertilizer rates | | | | | | | | |
| $N_1$ | 3.18 a | 6.80 a | 3.73 a | 45.86 a | 203.89 a | 536.20 a | 5.27 a | 11.08 a |
| $N_2$ | 2.83ab | 6.04 b | 3.24 b | 40.90ab | 189.56 a | 450.59 b | 4.95 a | 8.71 b |
| $N_3$ | 2.51 b | 5.84 b | 2.94 c | 34.47 b | 156.67 b | 356.40 c | 4.07 b | 6.66 c |
| Level of Significance | ** | ** | ** | ** | ** | ** | ** | ** |
| CV% | 11.65 | 6.37 | 7.93 | 16.01 | 6.22 | 9.03 | 9.19 | 16.47 |
| Interaction effect (Row distance × Nitrogen rate) | | | | | | | | |
| $S_1N_1$ | 3.17 | 6.21 | 3.59 | 48.85 | 181.11 | 492.75 | 4.41 | 10.39 |
| $S_1N_2$ | 2.67 | 5.64 | 3.14 | 42.51 | 160.00 | 387.20 | 3.92 | 7.57 |
| $S_1N_3$ | 2.18 | 5.23 | 2.96 | 36.73 | 141.11 | 292.99 | 3.48 | 5.06 |
| $S_2N_1$ | 3.17 | 6.80 | 3.67 | 48.08 | 196.67 | 541.30 | 4.95 | 11.49 |
| $S_2N_2$ | 2.89 | 6.19 | 3.35 | 42.21 | 184.44 | 473.72 | 4.74 | 9.64 |
| $S_2N_3$ | 2.41 | 5.92 | 2.85 | 37.10 | 148.89 | 384.51 | 3.73 | 7.85 |
| $S_3N_1$ | 3.20 | 7.40 | 3.95 | 40.64 | 233.89 | 574.55 | 6.44 | 11.36 |
| $S_3N_2$ | 2.95 | 6.31 | 3.48 | 37.99 | 223.33 | 490.81 | 6.18 | 8.92 |
| $S_3N_3$ | 2.88 | 6.36 | 3.00 | 29.59 | 180.00 | 391.92 | 5.01 | 7.06 |
| Level of Significance | NS | NS | NS | NS | NS | NS | NS | NS |
| CV% | 11.65 | 6.37 | 7.93 | 16.01 | 6.22 | 9.03 | 9.19 | 16.47 |

$S_1$= 85 cm, $S_2$= 75 cm and $S_3$= 65 cm row distance; $N_1$=100% of conventional nitrogen fertilizer rate, $N_2$= 75%, and $N_3$= 50% of conventional nitrogen fertilizer rate; NS= Non significant; DAS= Days after sowing; CV= Co-efficient of variation.

Plant height of maize is greatly affected by row distance and nitrogenous fertilizer (Toler *et al.*, 1999; Mariga *et al.* 2000; Widdicombe and Thelen, 2002). Although our observation did not find remarkable differences except for fertilizer application at 60 DAS, most of the cases highest values for plant height were observed in wide raw spacing ($S_1$) with maximum fertilizer rate ($N_1$).

*Leaf area index (LAI)*

Leaf area index of maize plant was highest at 65cm row distance and maximum nitrogen fertilizer ($N_1$ or conventional urea treatment) (Table 2). Leaf area index influenced marginally for row spacing at 30 and 90 days after sowing but significantly at 60 days after sowing, where a remarkable higher value (6.69) was observed for dense row distance ($S_1$).

**Table 3.** Effects of row distances and nitrogen fertilizer rates on yield components and yield of maize.

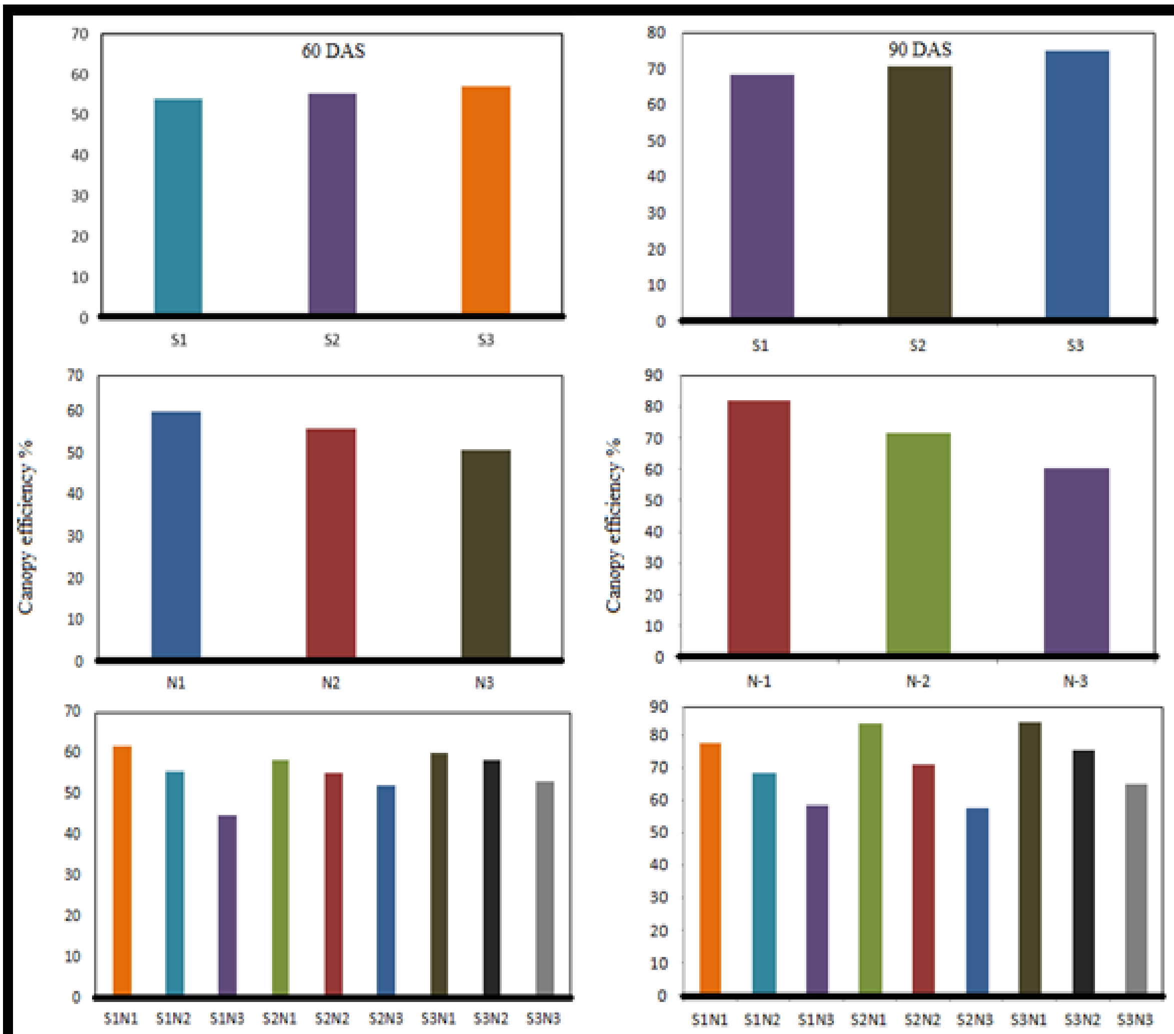
| Row distances | Cob length (cm) | No. of rows cob$^{-1}$ | No. of grains cob$^{-1}$ | 1000 grain weight (g) | Grain yield (t ha$^{-1}$) | Stover yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|
| $S_1$ | 20.04 a | 12.15 | 473.87 a | 315.56 | 4.81 b | 6.11 c | 10.91 b | 43.94 |
| $S_2$ | 18.93 a | 11.74 | 455.56ab | 320.59 | 4.62 b | 6.24 b | 10.87 b | 42.56 |
| $S_3$ | 17.48 b | 11.49 | 407.19 b | 311.67 | 5.35 a | 7.04 a | 12.39 a | 43.24 |
| Level of Significance | ** | NS | ** | NS | ** | ** | ** | NS |
| CV% | 4.71 | 2.77 | 14.31 | 8.04 | 4.00 | 1.20 | 1.86 | 2.24 |
| Nitrogen fertilizer rates | | | | | | | | |
| $N_1$ | 20.45 a | 12.14 | 439.32 a | 329.44 | 5.47 a | 7.29 a | 12.76 a | 42.88 |
| $N_2$ | 18.59 b | 11.96 | 395.91ab | 320.00 | 4.92 b | 6.49 b | 11.41 b | 43.08 |
| $N_3$ | 17.41 c | 11.85 | 386.39 b | 298.33 | 4.38 c | 5.61 c | 9.99 c | 43.83 |
| Level of Significance | ** | NS | ** | NS | ** | ** | ** | NS |
| CV% | 4.71 | 2.77 | 14.31 | 8.04 | 4.00 | 1.20 | 1.86 | 2.24 |
| Interaction effect (Row distance × Nitrogen rate) | | | | | | | | |
| $S_1N_1$ | 22.22 | 12.33 | 505.33 | 325.00 | 5.36 | 6.59 d | 11.94 c | 44.85 |
| $S_1N_2$ | 19.67 | 12.22 | 340.61 | 338.33 | 4.94 | 6.40 e | 11.35 d | 43.50 |
| $S_1N_3$ | 18.22 | 11.89 | 395.67 | 283.33 | 4.11 | 5.34 g | 9.45 f | 43.48 |
| $S_2N_1$ | 20.78 | 11.89 | 441.58 | 333.33 | 5.21 | 7.30 b | 12.51 b | 41.68 |
| $S_2N_2$ | 18.67 | 11.44 | 436.59 | 326.67 | 4.45 | 6.02 f | 10.47e | 42.51 |
| $S_2N_3$ | 17.33 | 11.89 | 353.51 | 301.67 | 4.19 | 5.42 g | 9.62 f | 43.56 |
| $S_3N_1$ | 18.33 | 12.22 | 371.05 | 330.00 | 5.82 | 8.00 a | 13.83 a | 42.08 |
| $S_3N_2$ | 17.45 | 12.22 | 410.56 | 295.00 | 5.37 | 7.06 c | 12.47 b | 43.21 |
| $S_3N_3$ | 16.67 | 12.11 | 409.98 | 310.33 | 4.85 | 6.06 f | 10.91 de | 44.44 |
| Level of Significance | NS | NS | NS | NS | NS | ** | ** | NS |
| CV% | 4.71 | 2.77 | 14.31 | 8.04 | 4.00 | 1.20 | 1.86 | 2.24 |

$S_1$= 85 cm, $S_2$= 75 cm and $S_3$= 65 cm row distance; $N_1$=100% of conventional nitrogen fertilizer rate, $N_2$= 75%, and $N_3$= 50% of conventional nitrogen fertilizer rate; NS= Non significant; DAS= Days after sowing; CV= Co-efficient of variation.

The interaction effect of row distance and nitrogen rate was not significant (Table-2), although most of the cases highest result was obtained from 65cm row distance with maximum or conventional urea application ($N_1$). Orkaido (2004) described that, wide rows allow space for canopy architecture which allows less interception of radiation than dense area. For this reason, the LAI gets lower at narrow rows. Leaf area index (LAI) in maize increases with an increase in plant density and nitrogen rate was also supported by Amanullah *et al* .(2007).

*Total dry matter (TDM)*

Total dry matter (TDM) of maize varied marginally due to row distance at 30 days after sowing but significantly at 60 and 90 days after sowing. At 60 days after sowing (Table 2), the highest TDM (212.41 $g^{-2}$) was found in 65cm row distance which was 20.22% and 32.15% higher than 75cm and85cm row distances respectively. At 90 days after sowing, highest TDM (485.78 $g^{-2}$) was also found in 65cm row distance which was statistically similar to 75 cm row distance but significantly 24.25% higher than 85cm row distance treatment. Different nitrogen fertilizer rate also differed significantly in total dry matter production of maize at all observations (Table 2). Results revealed that total dry matter production increased progressively with the increase of nitrogen fertilizer rate. Highest TDM of45.86, 203.89 and 536.20 $g/m^2$ was noted for maximum urea application at 30, 60 and 90 days after sowing (Table 2). The interaction between row distance and nitrogen fertilizer rate was not differed significantly at all observations although most of the cases highest values were observed with narrow row distance with maximum nitrogen fertilizer.




$S_1$= 85 cm, $S_2$= 75 cm and $S_3$= 65 cm row distance, $N_1$=100% of conventional nitrogen fertilizer rate, $N_2$= 75%, and $N_3$= 50% of conventional nitrogen fertilizer rate, NS= Non significant; DAS= Days after sowing.

**Fig. 1.** Effects of row distances and nitrogen fertilizer rates on canopy efficiency of maize.

Nitrogen fertilizer is widely accepted to increase total dry matted (TDM) production in different crops (Amanullah *et al.*, 2007; Modhej *et al.;* 2008). During our observation it was also found that maize TDM increased with increasing nitrogen fertilizer application. Narrow row spacing gave highest TDM might be due to presence of more crop per unit of area (Turgut *et al.*, 2005).

*Crop Growth Rate (CGR)*

Crop growth rate (CGR) was significantly influenced by row distance (Table 2). During 30-60 days after sowing, highest CGR (5.88 $gm^2 day^{-1}$) was found in 65 cm row distance which was significantly 31.25 and 49.23% higher than 75cm and 65cm row distance respectively. Crop growth rate during 60-90 days after sowing was higher both in 65 and 75 cm row distance (9.11 and 9.66 5.88 $gm^2$ $day^{-1}$respectively) and lower (7.67 $gm^2 day^{-1}$) in 85 cm row distance. Crop growth rate (CGR) also varied significantly with different levels of nitrogen (Table 2). During 30-60 days after sowing the highest CGR (5.27$gm^2$ $day^{-1}$) was found in high rate of nitrogen ($N_1$) which was statistically similar to $N_2$ but significantly 29.48% higher than low rate of nitrogen ($N_3$). The CGR also varied vastly during 60-90 days after sowing where the highest CGR (11.08 gm-2 day-1) was found from high rate of nitrogen ($N_1$) which reduced by 27.21 and 66.36% for medium ($N_2$) and low ($N_3$) rate of nitrogen application respectively. The interaction effect was non-significant in respect of CGR at all observations

*Yield parameters*

*Cob length*

Both nitrogen fertilizer rate and row distance showed significant effect on maize cob length (Table 3). Considering row distance, highest cob length (20.04cm) was produced with 85 cm row distance lowest cob length (17.48) produced from 65cm row distance. In case nitrogen rates, the highest cob length (20.45cm) was produced with high rate of nitrogen fertilizer ($N_1$) which was 10% and 17.46% higher than $N_2$ and $N_3$respectively. Number of rows per cob was minutely varied due to interaction between row distance and nitrogen rate although 85cm row distance and 550kg urea/ha gives maximum result.

*Number of grains per cob*

Number of grains per cob was remarkably influenced by row distance and nitrogen rate (Table 3). The highest result was obtained from 85cm row distance and 550kg urea/ha. Maximum number of grains per cob (473.87) was counted from 85cm row distance and minimum (407.19) was for 65 cm row distance. In terms of nitrogen rate, maximum number of grains per cob (439.32) was counted from high rate of nitrogen fertilizer ($N_1$) and minimum (386) number was found for low rate of nitrogen ($N_3$) fertilizer.

*1000 grain weight*

1000 grain weight showed insignificant difference in respect of row distance and nitrogen rate. 75cm row distance and 550kg urea/ha provided maximum weight of 1000 grain. However interaction effect of row distance and nitrogen fertilizer was not differed statistically (Table 3).

*Grain yield*

Grain yield of maize varied significantly due to row distance and nitrogen rate and the combination of 65cm row distance and 550kg urea/ha was found to provide highest yield (Table 3).Considering row distance, highest grain yield (5.35 t ha-1) was obtained from 65 cm row distance which was 11.23% and 15.80% higher than 75c and 85cm row distance respectively.

In case of nitrogen fertilizer, The highest grain yield (5.47 t ha-1) was found in 550kg urea/ha(N1) which was significantly 11.18% and 29.94% higher than N2 (413kg/ha) and N3 (275kg/ha) urea application respectively.

The combined effect of row distance and nitrogen rate had no significant influence on grain yield (Table 3). The highest grain yield (5.82 t ha-1) was obtained from 65 cm row distance with maximum nitrogen rate treatment and the lowest grain (4.11 t ha-1) was found from 85cm row distance with low rate of nitrogen. Both the factors (row distance and nitrogen fertilizer) are important for better crop growth and yield. Wider row space provide available nutrient elements but use less solar radiation (Orkaido, 2004) on the other hands dense row space create more competition for nutrient and light. Higher grain yield production with narrow row spacing might be due to presence of more plant per unite of area and use of maximum solar radiation (Edwards *et al.* 2005; Maddonni and Otegui, 2006).

*Stover yield*

Row distance and nitrogen rate showed significant difference in stover yield and combination of 65 cm row distance and 550 kg urea/ha was marked for maximum stover yield. During our observation, it was found that the highest stover yield (7.04 t $ha^{-1}$) was produced in 65 cm row distance which was 12.82% and 15.22% higher than 75cm and 85 cm row distance respectively. For Nitrogen fertilizer, 550kg urea/ha ($N_1$) gave highest result (7.29 t $ha^{-1}$) which was significantly 12.32% and29.94% higher than 413kg/ha and 275kg/ha urea application respectively (Table 3).

*Biological yield*

Biological yield was significantly influenced by row distance and nitrogen rate. It was seen that the highest Biological yield (12.39t $ha^{-1}$) was produced in 65 cm row distance which was 13.56% and 13.98% higher than 75cm and 85 cm row distance respectively. 550kg urea/ha produced highest biological yield (12.76 t $ha^{-1}$) which was 11.83% and 27.73% higher than 413kg/ha and 275kg/ha urea application respectively. Interaction effect of 65 cm row distance and 550kg urea application provided maximum biological yield (Table 3).

*Harvest index*

Harvest index was not departed vastly in respect of row distance and nitrogen rate. Highest harvest index was found from 85 cm row distance and 275kg urea application treatment. Quality characteristics in maize such as ear size, tip fill and individual grain weight improve with an increase in N levels in both low and high density plots; ear size, tip fill and individual grain weight declines at high density regardless of N supply (Stone *et al.,* 1998). Wider spacing encourages growth of weed and thus, more labor and increase cost of production.

*Canopy efficiency*

Canopy efficiency was influenced significantly by row distance at 60 days after sowing (Figure 1). The maximum canopy cover (57.07%) was derived from 65cm row distance which was 7.06% and 8.65% higher than 75cm and 85cm row distance respectively. Narrow rows of maize suits the plant to intercept sunlight acclimatizing the architecture with remaining space and yield more forage per plant.

Yield may be reduced compared to narrow rows per unit area regardless of merit. Canopy efficiency showed extent effect in respect of nitrogen fertilizer rate at 60 days after sowing (Figure 1). The highest PAR absorption 60.17% was attained from 550kg urea/ha which was 7.44% and 17.77% higher than 413kg urea/ha and 275kg urea/ha treatment respectively.

Canopy efficiency at 90 days after sowing also showed significant effect in respect of row distance (Figure - 1). The maximum canopy cover (75.02%) was recorded from 65cm row distance and minimum (68.19%) was from 85cm row distance. Narrow rows provides crowding of leaves resulting less amount of radiation absorption per plant but high rates of intercepted radiation over the whole area. Due to nitrogen fertilizer treatment, canopy efficiency departed widely at 90 days after sowing (Figure 1). The highest canopy cover(82.04%) was attained from 550kg urea/ha which was 14.63% and 36.12% higher than 413kg urea/ha and 275kg urea/ha treatment respectively.

## Conclusion

It is concluded from the found result that, 65cm row distance showed 5.35 t/ha yield and maximum radiation use efficiency. It utilizes the maximum of space and nutrient. Application of 550 urea/ha resulted in maximum yield of biomass and radiation use efficiency. Sowing of maize in 65cm row distance and 550kg urea/ha produced highest grain yield and most efficient radiation use efficiency.

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