Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2019 16(2): 1565-1576. **OPEN ACCESS**

Maize hybrids yield potential as affected by plant population density in Qalyubia, Egypt

Mohamed E. Sidi, A. A. El-Hosary, G. Y. Hammam, El Saeed M. El-Gedwy and A.A. A. El-Hosary

Agronomy Department, Faculty of Agriculture, Benha University, **Egypt**.

***Correspondence:** Ahmed.alhossary@fagr.bu.edu.eg **Accepted: 04** May 2019 **Published online:** 21May 2019

Two field experiments were carried out during the two successive of 2016 and 2017. To study the effect of three plant population densities on the growth characters, yield components, yield and some kernels chemical properties of three white single cross hybrids of maize. Significantly increased mean values of No. of days to 50 % tasseling, No. of days to 50 % silking, leaf area index (LAI), plant height (cm), ear position % (EP), No. of plants/fed, No. of barren plants/fed (NB), No. of ears/fed (NE), stover yield/fed (kg) (SY) and biological yield/fed (kg) (BY) in both seasons with increasing plant density from 20000 to 28000 plants/fed. On the other hand, mean values of No. of green leaves/plant (NGL), area of topmost ear leaf (cm^2) (ATEL), leaf area/plant (cm^2) (LA), NE, No. of kernels/row (NKR), ear weight (g) (EW), kernels shelling (%) (KS), 100-kernel weight (g) (100KW), ear yield/fed (kg), grain yield (GY)/fed (kg), GY/plant (g), harvest index (%) (HI), kernels nitrogen content (KNC), kernels crude protein content (KCPC), nitrogen uptake/fed (kg) (NU) and protein yield/fed (kg) (PY) were significantly decreased in the two seasons. All growth traits, yield components, yield and kernels chemical properties were significant differences with the studied three S.C. hybrids of maize. Hybrids were significantly differed in all traits studied under study in the both seasons, except NP at harvest. S.C. 30K8 was significantly surpassed S.C. 7071 and S.C. 2031 in mean values of No. of plants carried two ears/fed, NE, NE, NKR, NKR, GY/fed, GY/plant and HI as well as gave the lowest mean values of NB and the shortest period from planting to tasseling and silking dates in the both seasons. Moreover, S.C. 2031 surpassed the other two hybrids in mean values of area of ATEL, LA, LAI, EW, 100KW, ear yield/fed, BY, KNC, KCPC, NU and PY in the two seasons. Meanwhile, S.C. 7071 recorded the highest mean values of NGL, PH, EP, KS and SY in the two seasons. Planning maize hybrid of S.C. 30K8 at 20000 plants/fed recorded the greatest mean values of NE, NKR and HI as well as gave the lowest mean values of NB in the both seasons, while, sowing the same hybrid by 28000 plants/fed significantly recorded the highest mean values of NE during the both seasons. The greatest mean values of ATEL, LA, EW, 100KW, EY/fed, GY/plant, NU and PY in the both seasons were obtained from planting maize hybrid of S.C. 2031 at 20000 plants/fed. Meanwhile, planting the same maize hybrid under 28000 plants/fed significantly recorded the maximum mean values of LAI and BY. Planting S.C. 7071 at 20000 plants/fed recorded significantly the greatest mean values of NGL, NKR and KS during the two seasons. However, planting maize by 28000 plants/fed from the same hybrid significantly gave the maximum mean values of PH, EP and SY.

Keywords: white maize hybrids, S.C. 2031, S.C. 30K8, S.C. 7071, plant population densities.

INTRODUCTION

Maize (*Zea mays,* L.) is one of the most important cereal crops in the world and ranks the third of the most important cereal crops in the world which surpassed by wheat and rice. In Egypt, Maize is essential for livestock's and human consumption as an available source of carbohydrate, oil and slightly for protein (EL-Hosary et al. 2011). The total production of maize in world was 1134.75 million tonnes in 2017 produced from an area of 469.49 million fed one fed = 4200 m^2, (www.fao.org), with an average yield of 2416.97 kg grain/fed. In Egypt, The total production of maize was 7.10 million tonnes in 2017 year produced from an area of 2.192 million fed, with an average yield of 3239.19 kg/fed. The total production supplies 80 % of the require consumption with a reduction gap of 20 % which has to be filled via importation.

Maize crop bears high yield potential and responds to various agro-management practices. Low yield of maize is due to many constraints but among them, imbalanced use of high yielding hybrids and lack of optimal crop stand for these hybrids are the factors of prime importance which intensely and repeatedly impact resource availability. As maize do not have tillering capacity to adjust to variation in plant stand, optimum plant population for grain production is important. Thus to increase grain yield, it must be planted maize at proper plant population density. The optimum plant population determines growth and yield of maize due its less capability of adjustment to a thinner stand than other cereals. Plant population per unit area is an important factor that influences the crop yield. The relationship of yield and spacing is complex. The yield increases with an increase in the total No. of plants/unit area and thereafter, the grain production/plant drops. So, optimization of plant population has an important role in increasing the productivity of maize.

Increasing plant population density of maize significantly increased No. of days from planting to 50 % tasseling, and silking, leaf area index, plant height (cm), ear position (%), No. of plants/fed, No. of barren plants/fed, No. of ears/fed, stover yield/fed (kg), grain yield/fed (kg) and biological yield/fed (kg). On the other hand, No. of green leaves/plant, area of topmost ear leaf (cm^2), leaf area/plant (cm^2), No. of plants carried two ears/fed, No. of ears/plant, No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight (g), kernels shelling (%), 100-kernel weight (g), ear yield/fed (kg), grain yield/plant (g), harvest index (%), kernels nitrogen content, kernels crude protein content, nitrogen uptake/fed (kg) and protein yield/fed (kg) were significantly decreased (El-Koomy 2000; Agasibagil 2006; Hassan et al,. 2008; Sallah et al., 2009; Sharifi et al., 2009; Gozubenli 2010; El-Gedwy 2011; Gomaa et al. 2011; Lashkari et al., 2011; Sharifi and Pirzad 2011; Zamir et al., 2011; Dawadi and Sah 2012; Robles et al. 2012; Shafi et al., 2012; Adeniyan 2014; Ahmadu 2014; Timlin et al., 2014; Imran et al., 2015; Karki et al., 2015 Mahdi and Ismail 2015; Gobeze et al., 2016; Mandić et al., 2016; Rahman et al., 2016; Sharanabasappa et al., 2017; Eyasu et al., 2018 and Zeleke et al., 2018)..

Several investigators showed that maize hybrids differed in growth, yield components, yield and some chemical properties (El-Koomy 2000; Agasibagil 2006; Hassan et al., 2008; Sallah et al., 2009; Sharifi et al., 2009; Gozubenli 2010; Lashkari et al., 2011; Sharifi and Pirzad 2011; Zamir et al., 2011; Dawadi and Sah 2012; Robles et al., 2012; Shafi et al., 2012; Adeniyan 2014; Ahmadu 2014; Delibaltova 2014; Khan et al., 2014; Malekabadi et al., 2014; Mohsin et al., 2014; Rehman et al., 2014; Hafez and Abdelaal 2015; Karki et al., 2015 Kinfe et al., 2016; Majid et al., 2017; Marković et al., 2017; Ahmad et al., 2018 and Eyasu et al., 2018)

MATERIALS AND METHODS

Two field experiments were carried out at the Farm of Agricultural Research and the Experimental Center of Faculty of Agriculture at Moshtohor, (Toukh Directorate, Qalyubia Governorate) Benha Univ. Egypt, during the two summer successive growing seasons of 2016 and 2017. This study was to investigate the performance of three white single cross hybrids of maize, *i.e.* single cross 7071 for Tech Seed Company (S.C. 7071), single cross 30 K 08 for Pioneer hybrids (S.C. 30K8) and single cross hybrid 2031 for Misr Hytech Seed Int. (S.C. 2031) to three plant population densities treatments (20000 plants/fed from grown in ridges 70 cm apart and 30 cm between hills), (24000 plants/fed from grown in ridges 70 cm apart and 25 cm between hills) and (28000 plants/fed from grown in ridges 70 cm apart and 21.43 cm between hills) on the growth traits, yield components, yield and kernels chemical properties. Soil texture of the experimental site was clay of pH nearly of 8.0. The chemical and mechanical properties analysis of the experimental soil were determined according to the standard procedures described by Black and Evans (1965) and represented in Table 1 in each of the two growing seasons.

Table 1: Chemical and mechanical properties of the experimental soil units at planting maize during 2016 and 2017 seasons.

Properties	Seasons	
	2016	2017
Chemical analysis		
E.C.	2.28	2.31
pH (1 :2.5)	8.12	8.09
$CaCo_3$ %	3.21	2.94
O.M %	2.28	2.31
N % (total)	0.19	0.20
N (ppm) (available)	61.93	63.72
P % (total)	0.120	0.125
P (ppm) (available)	23.80	25.12
K % (total)	0.62	0.63
K (ppm) (available)	919.06	969.98
Particle size distribution (mechanical analysis)		
Course sand %	6.93	5.50
Find sand %	27.28	28.64
Silt %	13.23	11.60
Clay %	52.58	54.26
Texture grade	Clay	Clay

The preceding winter crop in the two seasons was wheat (*Triticum aestivum*, L.). The experimental design was laid out using randomized complete block design (RCBD) using split plot design in three replications. Each of the three plant densities were distributed in the main plots and the three white single cross hybrids of maize were assigned at random in sub plots. The sub plot area was 10.5 m^2 and contained five ridges of 3 m long and 70 cm apart. Phosphorous fertilizer was applied in form of Calcium super phosphate (12.5 % P_2O_5) at a rate of 100 kg/fed during soil preparation in each season. Experiments were planted on May 23th and 29th of in the first season (2016) and the second season (2017), respectively. Maize plants were thinned before the first irrigation to one plant/hill. Nitrogen fertilizer was applied at a rate of 120 kg N/fed as urea (46 % N), and divided into two equal parts and applied side dressed before the first and second irrigations in each season. The first irrigation was applied after 21 days from sowing and the following irrigations were applied at 12-15 days intervals during the growing seasons. Maize plants were harvested on 17th and 23th of September in the first and the second seasons, respectively. The other agricultural practices were kept the same as normally practiced in maize fields according to the recommendations of Ministry of Agriculture and Land Reclamation, except for the factors under study.

Studied parameters:

A- Growth characteristics:

1- Time of tasseling was determined as the No. of days from planting to 50 % tasseling.

2- Time of silking was determined as the No. of days from planting to 50 % silking.

3- Number of green leaves/plant at 80 days after planting.

4- Area of topmost ear leaf (cm^2) at 80 days after planting was estimated as described by Stickler, 1964. It was calculated from the following equation:

$$\textbf{Area of topmost ear leaf} = \textbf{Ear leaf length X Greatest leaf width X 0.75}$$

5- Leaf area/plant (cm^2) at 80 days after planting. It was calculated from the following equation:

$$\textbf{Leaf area/plant} = \textbf{Area of topmost ear leaf X No. of green leaves /plant}$$

6- Leaf area index at 80 days after planting was estimated as described by Stickler, 1964. It was estimate from the following formula:

$$\text{Leaf area index} = \frac{\text{Leaf area/plant}}{\text{land area/plant}}$$

7- Plant height (cm) at harvest, from the soil surface to the top of tassel.

8- Ear position %). It was calculated from the following formula:

$$\text{Ear position (\%)} = \frac{\text{Ear height (cm)}}{\text{Plant height (cm)}} X100$$

9- Number of plants/fed at harvest.
10- Number of plants carried two ears/fed at harvest.
11- Number of barren plants/fed at harvest.
12- Number of ears/fed at harvest.
13- Number of ears/plant at harvest. It was estimate from the following formula:

$$\text{No. of ears/plant} = \frac{\text{No. of ears/fed}}{\text{No. of plants/fed}}$$

Ten plants were chosen from the three center ridges at random from each sub plots to determine No. of green leaves/plant, area of topmost ear leaf (cm^2), leaf area/plant (cm^2), leaf area index, plant height (cm), ear height (cm) and ear position (%). Whereas, the tasseling and silking dates, No. of plants/fed, No. of plants carried two ears/fed, No. of barren plants/fed, No. of ears/fed and No. of ears/plant were estimated from the whole plants in the three center ridges.

B- Yield and yield components:

1- Number of rows/ear.
2- Number of kernels/row.
3- Number of kernels/ear.
4- Ear weight (g).
5- Shelling %. It was calculated by using the following formula:

$$\textbf{Shelling (\%)} = \frac{\text{Weight of kernels/ear (g)}}{\text{Ear weight (g)}} X\ 100$$

6- Weight of 100–kernel (g).
7- Ear yield/fed (kg).
8- Stover yield/fed (kg).
9- Grain yield/fed (kg), adjusted to 15.5 % moisture content. It was calculated by using the following formula
10- $\textbf{Grain yield/fed (kg)} = \frac{\textbf{Ear yield/fed (kg) X Shelling \%}}{\textbf{100}}$
11- Grain yield/plant (g). It was calculated by using the following formula:
12- $\textbf{Grain yield/plant (g)} = \frac{\textbf{Grain yield/fed (kg)}}{\textbf{No.of plants/fed}} X\ 1000$
13- Biological yield/fed (kg). It was calculated by using the following formula:

$$= \text{Ear yield/fed (kg)} + \text{Stover yield/fed (kg)}$$

14- Harvest index (%). It was calculated by using the following formula:

$$\textbf{Harvest index (\%)} = \frac{\text{Grain yield/fed (kg)}}{\text{Biological yield/fed (kg)}} X\ 100$$

Ten ears were chosen from the three center ridges at random from each sub plots to determine No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight (g), kernels weight/ear (g), shelling % and 100-kernel weight. Whereas, ear yield/fed (kg), stover yield/fed (kg), grain yield/fed (kg), grain yield/plant (g), biological yield/fed (kg) and harvest index (%) were estimated from the whole plants in the three center ridges.

C- Chemical analysis

Maize kernels samples were taken after harvest at random from all kernels of ten ears to determine:
1-Kernels nitrogen content (%) was determinate according to the modified micro Kjeldahl method (A. O. A. C., 1990).
2-Kernels crude protein content (%) was calculated by multiplying nitrogen content (%) X 6.25 (A. O. A. C., 1990).
3-Nitrogen uptake/fed (kg) = grain yield (kg) x kernels nitrogen content (%).
4-Protein yield/fed (kg) = grain yield (kg) x kernels crude protein content (%).

Statistical analysis:

The analysis of variance was carried out according to the procedure described by Gomez and Gomez (1984). Data were statistically analyzed according to using the MSTAT-C Statistical Software Package (Michigan State University, 1983). Where the F-test showed significant differences among means L. S. D. test at 0.05 level was used to compare between means.

RESULTS AND DISCUSSION

Effect of plant population densities:

Results presented in Tables 2, 3 and 4 revealed that the differences between the studied three plant population densities, *i.e.* 20000, 24000 and 28000 maize plants/fed were significant on flowering, growth, yield components, yield and kernels properties during the two seasons. Meanwhile, mean values of No. of rows/ear was not significantly affected by plant densities under study during the both seasons.

Data revealed that planting 20000 maize plants/fed gave the greatest mean values of No. of green leaves/plant (13.69 and 13.33 leaves), area of topmost ear leaf (681.70 and 667.13 cm^2), leaf area/plant (9338.38 and 8899.59 cm^2), No. of plants carried two ears/fed (2222.22 and 1600.00 plants), No. of ears/plant (1.111 and 1.079 ears), No. of kernels/row (45.09 and 45.61 kernels), No.

of kernels/ear (584.70 and 592.30 kernels), ear weight (215.69 and 217.08 g), shelling (82.01 and 81.64 %), 100-kernel weight (34.53 and 33.58 g), ear yield/fed (3935.19 and 3992.59 kg), grain yield/fed (3214.17 and 3254.50 kg), grain yield/plant (165.73 and 172.45 g) and harvest index (43.14 and 43.41 %), kernels nitrogen content (1.730 and 1.726 %), kernels crude protein content (10.81 and 10.79 %), nitrogen uptake/fed (56.04 and 56.32 kg) and protein yield/fed (350.22 and 352.00 kg) in the first and second seasons, respectively. In the 2016 season, planting maize at plant density of 20000 plants/fed increased grain yield/fed by 3.33 and 21.09 % compared with the growing maize at plant densities of 24000 and 28000 plants/fed respectively, the respective corresponding in the second season, were 3.44 and 30.46 %. It could be noticed that planting 20000 maize plants/fed was superior to the other plant densities treatments in increasing grain yield/fed. Such increase in grain yield/fed at planting density of 20000 plants/fed could be due to the increases No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight, weight of kernels/ear, shelling %, 100-kernel weight and grain yield/plant. This trend could be explained on the fact that in case of low population density produced by increasing hill spacing resulted in low competition between it for nutrient elements, soil moisture and sun light, plants would have better opportunity to produce more metabolite contents and positive effect on plant growth and productivity as well as increased translocation and consequently accumulation of metabolites through kernels and gave the maximum values of plant traits and yield components.

The greatest values of No. of days to 50 % tasseling (66.33 and 65.93 days), No. of days to 50 % silking (69.04 and 68.81 days), leaf area index (5.355 and 5.322), plant height (315.93 and 322.59 cm), ear position (50.47 and 50.26 %), No. of plants/fed (27170.37 and 26859.26 plants), No. of barren plants/fed (681.48 and 977.78 plants), No. of ears/fed (26785.19 and 26488.89 ears), stover yield/fed (4796.30 and 4611.11 kg) and biological yield/fed (8144.44 and 7801.85 kg) in the first and second seasons, respectively were obtained from planting 28000 maize plants/fed. Increasing population density from 20 to 24 and 28 thousand plants/fed significantly increased stover yield/fed by 18.27 and 36.39 % respectively, in the first season. The corresponding increases were 10.65 and 31.33% in the second season for the respective densities. Such increase in stover yield/fed could be due to the increase in plant height, area of topmost ear leaf, plant leaf area, leaf area index and No. of plants/fed. The increases in plant height by increasing plant densities is mainly due to the increased intra-specific competition among cotton plants for light and decrease in light penetration, interception and photosynthetic efficiency at higher densities as well as higher dense of plants excessive shade exist which help to produce more content of gibberellin in tissues and consequently higher plants formed. These results are in harmony with those reported by El-Koomy 2000; Agasibagil 2006; Hassan et al., 2008; Sallah et al., 2009; Sharifi et al., 2009; Gozubenli 2010; El-Gedwy 2011; Gomaa et al., 2011; Lashkari et al., 2011; Sharifi and Pirzad 2011; Zamir et al., 2011; Dawadi and Sah 2012; Robles et al., 2012; Shafi et al., 2012; Adeniyan 2014; Ahmadu 2014; Timlin et al., 2014; Imran et al., 2015; Karki et al., 2015 Mahdi and Ismail 2015; Gobeze et al., 2016; Mandić et al., 2016; Rahman et al., 2016; Sharanabasappa et al., 2017; Eyasu et al., 2018 and Zeleke et al., 2018.

Effect of white single cross hybrids of maize:

Results presented in Tables 2, 3 and 4 revealed that the differences between the studied three white single cross hybrids of maize, *i.e.* S.C. 7071, S.C. 30K8 and S.C. 2031 in all growth traits, yield components, yield and kernels chemical properties in the both seasons were significant except, No. of plants/fed at harvest was not significant.

These results revealed that S.C. 30K8 maize hybrid was significantly recorded the greatest mean values of No. of plants carried two ears/fed (2266.67 and 2029.63 plants), No. of ears/fed (25333.33 and 24503.70 ears), No. of ears/plant (1.098 and 1.080 ears), No. of rows/ear (13.33 and 13.54 rows), No. of kernels/row (40.49 and 41.56 kernels), No. of kernels/ear (541.00 and 564.02 kernels), grain yield/fed (3289.30 and 3158.74 kg), grain yield/plant (144.44 and 142.40 g) and harvest index (43.20 and 42.49 %) as well as gave the lowest mean values of No. of barren plants/fed (207.41 and 355.56 plants) and the shortest period from planting to 50 % tasseling (64.04 and 62.93 days) and No. of days to 50 % silking (66.37 and 65.19 days) in the first and second seasons, respectively.

Planting maize hybrid of S.C. 30K8 increased grain yield kg/fed by 6.57 and 26.77 % in the first season, corresponding to 3.00 and 18.30 % in second season, over grain yield/fed of S.C. 2031 and S.C. 7071 maize hybrids, respectively.

Results may reveal the superiority of S.C. 2031 maize hybrid in mean values of area of topmost ear leaf (702.48 and 693.39 cm^2), leaf area/plant (9568.69 and 9302.48 cm^2), leaf area index (5.413 and 5.282), ear weight (197.42 and 195.23 g), 100-kernel weight (35.30 and 33.77 g), ear yield/fed (4053.70 and 3996.30 kg), biological yield/fed (8403.70 and 8066.67 kg), kernels nitrogen content (1.877 and 1.829 %), kernels crude protein content (11.73 and 11.43 %), nitrogen uptake/fed (58.35 and 56.25 kg) and protein yield/fed (364.66 and 351.56 kg) in the first and second seasons, respectively. Planting maize hybrid of S.C. 2031 increased ears yield kg/fed by 1.44 and 31.47 % in 2016 season, corresponding to 3.55 and 23.74 % in 2017 season, over ears yield/fed of S.C. 30K8 and S.C. 7071 maize hybrids, respectively.

Planting maize hybrid of S.C. 7071 gave the highest mean values of No. of green leaves/plant (13.75 and 13.64 leaves), plant height (311.30 and 317.22 cm), ear position (56.95 and 56.60 %), shelling (84.01 and 82.41 %) and stover yield/fed (4492.59 and 4346.30 kg) in the first and second seasons, respectively. Planting maize hybrid of S.C. 7071 increased stover yield kg/fed by 3.28 and 23.78 % in 2016 season, corresponding to 6.78 and 21.04 % in 2017 season, over stover yield/fed of S.C. 2031 and S.C. 30K8 maize hybrids, respectively.

These differences may be due to the genetic differences between the three white single cross maize hybrids. Also, the differences in 100-kernel weight might be attributed to the variation in translocation rate of photosynthetic from leaves to the storing organs, *i.e.* the kernels. The superiority of S.C. 30K8 maize hybrid in grain yield/fed over the other maize hybrids might be due to the increase in yield components, namely, No. of plants carried two ears/fed, No. of ears/fed, No. of ears/plant, No. of rows/ear, No. of kernels/row, No. of `kernels/ear, grain yield/plant and harvest index. These results are in harmony with those reported by El-Koomy 2000; Agasibagil 2006; Hassan et al., 2008; Sallah et al., 2009; Sharifi et al., 2009; Gozubenli 2010; Lashkari et al., 2011; Sharifi and Pirzad 2011; Zamir et al., 2011; Dawadi and Sah 2012; Robles et al., 2012; Shafi et al., 2012; Adeniyan 2014; Ahmadu 2014; Delibaltova 2014; Khan et al., 2014; Malekabadi et al., 2014; Mohsin et al., 2014; Rehman et al., 2014; Hafez and Abdelaal 2015; Karki et al. 2015 Kinfe et al., 2016; Majid et al., 2017; Marković et al., 2017; Ahmad et al., 2018 and Eyasu et al., 2018 recorded that maize hybrids markedly varied for almost growth, yield, yield components and kernels chemical properties.

Interaction effect:

Significant effect of the interaction between plant population densities and white single cross hybrids obtained for almost growth, yield components, yield and chemical properties of maize in the both seasons were significant except, No. of days to 50 % tasseling, No. of days to 50 % silking, No. of plants/fed at harvest, No. of rows/ear, kernels nitrogen content and kernels crude protein content were not significant (Tables 2, 3 and 4).

Data showed that planning maize hybrid of S.C. 30K8 with 20000 plants/fed recorded the maximum mean values of No. of plants carried two ears/fed (3377.78 and 2622.22 plants), No. of ears/plant (1.174 and 1.137 ears), No. of kernels/ear (626.69 and 621.91 kernels) and harvest index (46.31 and 46.16 %) as well as gave the lowest mean values of No. of barren plants/fed (0.00 and 44.44 plants) in the first and second seasons, respectively. While, sowing the same hybrid in the highest plant density (28000 plants/fed) significantly recorded the greatest mean values of No. of ears/fed (27466.67 and 27555.56 ears) during the both seasons, respectively. The maximum grain yield/fed in the first season (3520.49 kg) was obtained from planting the same hybrid when planting by 24000 plants/fed.

Results indicated that the greatest mean values of area of topmost ear leaf (748.82 and 716.52 cm^2), leaf area/plant (10485.65 and 9793.70 cm^2), ear weight (237.91 and 233.38 g), 100-kernel weight (38.14 and 36.94 g), ear yield/fed (4472.22 and 4288.89 kg), grain yield/plant (178.16 and 176.93 g), nitrogen uptake/fed (67.88 and 62.87 kg) and protein yield/fed (424.24 and 392.94 kg) in the both seasons, respectively, as well as grain yield/fed (3348.52 kg) in the second season were obtained from planting maize hybrid of S.C. 2031 at the lowest plant density (20000 plants/fed). Meanwhile, planting the same maize hybrid with 28000 plants/fed significantly recorded the maximum mean values of leaf area index (5.831 and 5.825) and biological yield/fed (8666.67 and 8188.89 kg) in the first and second seasons, respectively.

Table 2: Mean values of No. of days to 50 % tasseling, No. of days to 50 % silking, No. of green leaves/plant, area of topmost ear leaf (cm^2), plant leaf area (cm^2), leaf area index, plant height (cm), ear position %, No. of plants/fed at harvest and No. of plants carried two ears/fed as affected by plant population densities, white single hybrids of maize and their interaction during 2016 and 2017 seasons.

Treatment	Trait	No. of days to 50 % tasseling		No. of days to 50 % silking		No. of green leaves /plant		Area of topmost ear leaf (cm^2)		Plant leaf area (cm^2)		Leaf area index		Plant Height (cm)		Ear Position (%)		No. of plants /fed at harvest		No. of plants carried two ears/fed	
	Season	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Plant population density (plants/fed)																					
20000		63.33	63.00	65.41	65.15	13.69	13.33	681.70	667.13	9338.38	8899.59	4.447	4.238	283.15	277.96	46.89	47.01	19392.59	18874.07	2222.22	1600.00
24000		64.67	64.11	66.93	66.37	13.33	13.22	644.87	646.96	8600.90	8554.60	4.915	4.888	297.59	300.93	49.05	49.03	23274.07	22903.70	1348.15	1140.74
28000		66.33	65.93	69.04	68.81	12.99	12.74	618.18	626.27	8033.11	7983.61	5.355	5.322	315.93	322.59	50.47	50.26	27170.37	26859.26	296.30	607.41
L.S.D at 5%		0.50	0.30	0.67	0.38	0.15	0.12	3.65	16.81	90.87	176.95	0.054	0.099	4.80	5.05	0.20	1.25	113.87	220.19	287.88	306.84
Maize hybrid																					
S.C. 7071		64.70	65.15	66.85	67.67	13.75	13.64	612.17	615.60	8423.12	8402.81	4.778	4.767	311.30	317.22	56.95	56.60	23333.33	22918.52	192.59	459.26
S.C. 30K8		64.04	62.93	66.37	65.19	12.66	12.24	630.09	631.37	7980.57	7732.50	4.526	4.400	281.67	279.44	45.68	45.77	23274.07	22829.63	2266.67	2029.63
S.C. 2031		65.59	64.96	68.15	67.48	13.60	13.41	702.48	693.39	9568.69	9302.48	5.413	5.282	303.70	304.81	43.79	43.93	23229.63	22888.89	1407.41	859.26
L.S.D at 5%		0.29	0.33	0.37	0.31	0.07	0.04	4.50	3.61	74.51	47.52	0.041	0.027	1.83	2.21	0.45	0.91	N.S.	N.S.	158.19	146.31
Interaction between plant population density and maize hybrid																					
20000	S.C. 7071	63.11	63.67	64.89	65.89	14.18	13.99	635.33	638.09	9009.00	8927.06	4.290	4.251	291.11	296.67	55.92	55.62	19333.33	18933.33	444.44	933.33
	S.C. 30K8	62.78	61.67	65.00	63.67	12.89	12.33	660.95	646.79	8520.48	7978.00	4.057	3.799	270.00	254.44	42.58	42.79	19377.78	18755.56	3377.78	2622.22
	S.C. 2031	64.11	63.67	66.33	65.89	14.00	13.67	748.82	716.52	10485.65	9793.70	4.993	4.664	288.33	282.78	42.18	42.63	19466.67	18933.33	2844.44	1244.44
24000	S.C. 7071	64.78	64.78	67.11	67.11	13.77	13.84	606.47	610.61	8350.16	8453.58	4.772	4.831	308.33	314.44	57.12	57.08	23422.22	22888.89	133.33	266.67
	S.C. 30K8	63.78	62.78	65.89	64.89	12.72	12.29	627.08	637.48	7979.20	7833.53	4.560	4.476	280.00	282.22	46.24	46.27	23244.44	22933.33	2711.11	2088.89
	S.C. 2031	65.44	64.78	67.78	67.11	13.51	13.53	701.04	692.77	9473.34	9376.69	5.413	5.358	304.44	306.11	43.79	43.74	23155.56	22888.89	1200.00	1066.67
28000	S.C. 7071	66.22	67.00	68.56	70.00	13.30	13.09	594.71	598.09	7910.20	7827.79	5.273	5.219	334.44	340.56	57.81	57.11	27244.44	26933.33	0.00	177.78
	S.C. 30K8	65.56	64.33	68.22	67.00	12.36	12.11	602.25	609.82	7442.03	7385.98	4.961	4.924	295.00	301.67	48.21	48.26	27200.00	26800.00	711.11	1377.78
	S.C. 2031	67.22	66.44	70.33	69.44	13.30	13.02	657.59	670.89	8747.09	8737.06	5.831	5.825	318.33	325.56	45.39	45.40	27066.67	26844.44	177.78	266.67
L.S.D at 5%		N.S.	N.S.	N.S.	N.S.	0.13	0.06	7.79	6.26	129.05	82.30	0.071	0.046	3.17	3.83	0.78	1.57	N.S.	N.S.	273.99	253.41

Table 3: Mean values of No. of barren plants/fed, No. of ears/fed, No. of ears/plant, No. of rows/ear, No. of kernels/row, No. of kernels/ear, ear weight (g), shelling % and 100-kernel weight (g) as affected by plant population densities, white single hybrids of maize and their interaction during 2016 and 2017 seasons.

Treat.	Trait	No. of barren plants/fed		No. of ears/fed		No. of ears/plant		No. of rows/ear		No. of kernels/row		No. of kernels/ear		Ear weight (g)		shelling %		100-kernel weight (g)	
	Season	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Plant population density (plants/fed)																			
20000		74.07	118.52	21540.74	20355.56	1.111	1.079	12.96	12.99	45.09	45.61	584.70	592.30	215.69	217.08	82.01	81.64	34.53	33.58
24000		222.22	444.44	24400.00	23600.00	1.049	1.030	12.79	12.78	39.90	41.66	510.69	532.82	181.90	185.65	80.94	80.77	32.57	31.39
28000		681.48	977.78	26785.19	26488.89	0.986	0.986	12.34	12.43	33.78	32.58	417.30	406.52	142.93	135.86	79.56	78.37	30.13	28.16
L.S.D at 5%		272.80	259.02	400.14	581.61	0.016	0.022	N.S.	N.S.	0.55	0.78	5.45	18.20	2.93	9.20	0.26	0.15	0.43	0.43
Maize hybrid																			
S.C. 7071		370.37	755.56	23155.56	22622.22	0.995	0.992	12.31	12.08	40.16	40.36	495.29	488.83	156.58	163.44	84.01	82.41	29.74	28.82
S.C. 30K8		207.41	355.56	25333.33	24503.70	1.098	1.080	13.33	13.54	40.49	41.56	541.00	564.02	186.52	179.92	82.27	81.77	32.18	30.54
S.C. 2031		400.00	429.63	24237.04	23318.52	1.052	1.024	12.46	12.58	38.11	37.93	476.40	478.79	197.42	195.23	76.23	76.60	35.30	33.77
L.S.D at 5%		107.03	142.12	267.30	260.45	0.009	0.008	0.06	0.09	0.63	0.84	7.93	10.83	2.36	2.80	0.15	0.11	0.26	0.34
Interaction between plant population density and maize hybrid																			
20000	S.C. 7071	88.89	222.22	19688.89	19644.44	1.018	1.037	12.47	12.29	46.44	47.62	579.13	585.55	192.94	206.11	85.29	84.04	31.80	31.34
	S.C. 30K8	0.00	44.44	22755.56	21333.33	1.174	1.137	13.62	13.80	45.99	45.03	626.69	621.91	216.21	211.76	83.20	82.83	33.63	32.46
	S.C. 2031	133.33	88.89	22177.78	20088.89	1.139	1.061	12.80	12.89	42.82	44.17	548.29	569.45	237.91	233.38	77.53	78.06	38.14	36.94
24000	S.C. 7071	222.22	711.11	23333.33	22444.44	0.996	0.980	12.36	12.07	40.83	42.92	504.68	517.95	155.07	170.52	84.02	82.82	29.76	28.66
	S.C. 30K8	177.78	400.00	25777.78	24622.22	1.109	1.074	13.38	13.62	40.82	43.59	546.34	594.00	193.10	183.90	82.49	82.39	32.77	31.17
	S.C. 2031	266.67	222.22	24088.89	23733.33	1.040	1.037	12.64	12.64	38.03	38.46	481.05	486.50	197.53	202.52	76.32	77.10	35.18	34.34
28000	S.C. 7071	800.00	1333.33	26444.44	25777.78	0.971	0.957	12.11	11.89	33.19	30.52	402.07	363.00	121.72	113.68	82.73	80.38	27.66	26.46
	S.C. 30K8	444.44	622.22	27466.67	27555.56	1.010	1.028	12.98	13.20	34.67	36.06	449.98	476.15	150.26	144.11	81.11	80.08	30.13	28.00
	S.C. 2031	800.00	977.78	26444.44	26133.33	0.977	0.973	11.93	12.20	33.49	31.17	399.85	380.40	156.81	149.78	74.85	74.65	32.59	30.01
L.S.D at 5%		185.38	246.17	462.98	451.11	0.015	0.014	N.S.	N.S.	1.10	1.45	13.74	18.76	4.09	4.86	0.25	0.19	0.46	0.59

Table 4: Mean values of stover yield/fed (kg), ear yield/fed (kg), grain yield/fed (kg), grain yield/plant (g), biological yield/fed (kg), harvest index (%), kernels nitrogen content (%), kernels crude protein content (%), nitrogen uptake/fed (kg) and protein yield/fed (kg) as affected by plant densities, white single hybrids of maize and their interaction during 2016 and 2017 seasons.

Treat.	Trait	Stover yield/ fed (kg)		Ear yield/ fed (kg)		Grain yield/ fed (kg)		Grain yield /plant (g)		Biological yield/fed (kg)		Harvest index (%)		Kernels nitrogen content (%)		Kernels crude protein content (%)		Nitrogen uptake/ fed (kg)		Protein yield/fed (kg)	
	Season	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Plant density (plants/fed)																					
20000		3516.67	3511.11	3935.19	3992.59	3214.17	3254.50	165.73	172.45	7451.85	7503.70	43.14	43.41	1.730	1.726	10.81	10.79	56.04	56.32	350.22	352.00
24000		4159.26	3885.19	3850.00	3901.85	3110.69	3146.39	133.72	137.40	8009.26	7787.04	38.82	40.44	1.669	1.691	10.43	10.57	52.24	53.44	326.48	334.00
28000		4796.30	4611.11	3348.15	3190.74	2654.26	2494.69	97.70	92.92	8144.44	7801.85	32.52	31.85	1.603	1.628	10.02	10.17	43.03	41.04	268.96	256.48
L.S.D at 5%		183.63	125.57	92.25	144.64	68.58	118.03	3.60	7.98	166.98	194.31	1.15	0.99	0.018	0.015	0.11	0.10	1.38	2.06	8.63	12.89
Maize hybrid																					
S.C. 7071		4492.59	4346.30	3083.33	3229.63	2594.72	2670.16	115.28	121.81	7575.93	7575.93	34.38	35.16	1.461	1.519	9.13	9.49	38.14	40.84	238.35	255.24
S.C. 30K8		3629.63	3590.74	3996.30	3859.26	3289.30	3158.74	144.44	142.40	7625.93	7450.00	43.20	42.49	1.664	1.697	10.40	10.61	54.83	53.71	342.66	335.67
S.C. 2031		4350.00	4070.37	4053.70	3996.30	3095.10	3066.68	137.43	138.55	8403.70	8066.67	36.90	38.05	1.877	1.829	11.73	11.43	58.35	56.25	364.66	351.56
L.S.D at 5%		57.67	44.43	68.57	42.81	55.74	33.46	3.65	3.20	98.53	69.04	0.39	0.27	0.010	0.007	0.07	0.04	0.99	0.66	6.16	4.15
Interaction between plant density and maize hybrid																					
20000	S.C. 7071	3772.22	3833.33	3411.11	3727.78	2910.10	3133.21	150.53	165.47	7183.33	7561.11	40.49	41.42	1.541	1.581	9.63	9.88	44.91	49.58	280.67	309.86
	S.C. 30K8	3116.67	3144.44	3922.22	3961.11	3263.86	3281.75	168.49	174.94	7038.89	7105.56	46.31	46.16	1.693	1.721	10.58	10.76	55.32	56.51	345.76	353.22
	S.C. 2031	3661.11	3555.56	4472.22	4288.89	3468.55	3348.52	178.16	176.93	8133.33	7844.44	42.61	42.66	1.956	1.876	12.22	11.72	67.88	62.87	424.24	392.94
24000	S.C. 7071	4500.00	4227.78	3250.00	3477.78	2731.87	2880.59	116.68	125.84	7750.00	7705.56	35.20	37.36	1.450	1.522	9.06	9.51	39.67	43.89	247.94	274.30
	S.C. 30K8	3600.00	3438.89	4266.67	4050.00	3520.49	3337.17	151.45	145.60	7866.67	7488.89	44.68	44.54	1.681	1.714	10.51	10.72	59.25	57.23	370.29	357.71
	S.C. 2031	4377.78	3988.89	4033.33	4177.78	3079.71	3221.41	133.03	140.74	8411.11	8166.67	36.57	39.43	1.876	1.837	11.72	11.48	57.79	59.20	361.22	369.99
28000	S.C. 7071	5205.56	4977.78	2588.89	2483.33	2142.20	1996.67	78.63	74.13	7794.44	7461.11	27.44	26.71	1.391	1.453	8.69	9.08	29.83	29.05	186.43	181.57
	S.C. 30K8	4172.22	4188.89	3800.00	3566.67	3083.55	2857.29	113.37	106.64	7972.22	7755.56	38.61	36.78	1.617	1.657	10.10	10.35	49.91	47.38	311.93	296.10
	S.C. 2031	5011.11	4666.67	3655.56	3522.22	2737.05	2630.12	101.09	97.99	8666.67	8188.89	31.51	32.07	1.801	1.773	11.26	11.08	49.36	46.68	308.52	291.76
L.S.D at 5%		99.89	76.96	118.76	74.14	96.54	57.96	6.32	5.54	170.66	119.59	0.68	0.46	N.S.	N.S.	N.S.	N.S.	1.71	1.15	10.67	7.19

Also results, indicated that the greatest mean values of area of topmost ear leaf (748.82 and 716.52 cm^2), leaf area/plant (10485.65 and 9793.70 cm^2), ear weight (237.91 and 233.38 g), 100-kernel weight (38.14 and 36.94 g), ear yield/fed (4472.22 and 4288.89 kg), grain yield/plant (178.16 and 176.93 g), nitrogen uptake/fed (67.88 and 62.87 kg) and protein yield/fed (424.24 and 392.94 kg) in the both seasons, respectively, as well as grain yield/fed (3348.52 kg) in the second season were obtained from planting maize hybrid of S.C. 2031 at the lowest plant density (20000 plants/fed). Meanwhile, planting the same maize hybrid with 28000 plants/fed significantly recorded the maximum mean values of leaf area index (5.831 and 5.825) and biological yield/fed (8666.67 and 8188.89 kg) in the first and second seasons, respectively.

Data showed that planting maize hybrid of S.C. 7071 at 20000 plants/fed recorded significantly the greatest mean values of No. of green leaves/plant (14.18 and 13.99 leaves), No. of kernels/row (46.44 and 47.62 kernels) and shelling (85.29 and 84.04 %) during the two seasons, respectively. However, planting maize with the highest plant density (28000 plants/fed) from the same hybrid significantly gave the maximum mean values of plant height (334.44 and 340.56 cm), ear position (57.81 and 57.11 %) and stover yield/fed (5205.56 and 4977.78 kg) in the first and second seasons, respectively.

These results agree with those reported by El-Koomy 2000; Agasibagil 2006; Hassan et al., 2008; Sallah et al., 2009; Sharifi et al., 2009; Gozubenli 2010; Lashkari et al., 2011; Sharifi and Pirzad 2011; Zamir et al., 2011; Dawadi and Sah 2012; Robles et al., 2012; Shafi et al., 2012; Adeniyan 2014; Ahmadu 2014; Karki et al., 2015 and Eyasu et al., 2018 which showed that there was significantly difference among the interaction between plant densities and hybrids in growth, yield components, yield and chemical properties of maize.

CONCLUSION

It could be summarized that, the best plant population density when planting maize hybrid of 30K8 was 24000 plants/fed, meanwhile, the best plant density at planting maize hybrids of S.C. 2031 and S.C. 7071 was 20000 plants/fed to maximized grain yield/fed.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

It give me immense pleasure to express our deep sense of gratitude and appreciation to facilities offered from all staff members of Experiment and Research Station of Moshtohor, Benha University, Qalyubiya Governorate, EGYPT.

AUTHOR CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author A.A. El-Hosary designed the study, wrote the protocol and wrote the first draft of the manuscript. The other Authors supervised the study and managed the literature searches. Also, all Authors managed the experimental process and performed data analyses. All authors read and approved the final manuscript. Also, they have read and are fully aware of the journal policy

REFERENCES

AOAC, 1990. Official Methods of Analysis Association of Official Analysis Chemists, 13th Ed., Washington, D. C., U. S. A.

Adeniyan ON, 2014. Effect of different population densities and fertilizer rates on the performance of different maize varieties in two rain forest agro ecosystems of South West Nigeria. Afr, J. Plant Sci., 8 (8): 410-415.

Agasibagil AB, 2006. Response of maize (Zea mays, L.) genotypes to planting densities in drill sown paddy tract of Karnatka. M. Sci. Thesis. Agron., Fac. Agric. Univ. Agric. Sci., Dharwad, India.

Ahmad S, Khan AA, Kamran M., Ahmad I., Ali S., Fahad S., 2018. Response of maize cultivars to various nitrogen levels. Eur. Exp. Biol., 8

(1-2): 1-4.

Ahmadu IA, 2014. Performance of extra-early maize (*Zea mays*, L.) varieties as influenced by rate of nitrogen and intra-row spacing. M. Sc. Thesis, Fac. Agric.,Ahmadu Bello Univ. Zaria, Nigeria.

Black CA, Evans DD, 1965. Methods of Soil Analysis. Amer. Soc. of Agron., Inc. Pub. Madison, Wisconsin, USA.

Dawadi DR, Sah SK, 2012. Growth and yield of hybrid maize (*Zea mays*, L.) in relation to planting density and nitrogen levels during winter season in Nepal. Tropical Agric. Res., 23 (3): 218-227.

Delibaltova V, 2014. Response of maize hybrids to different nitrogen applications under climatic conditions of Plovdiv region. Intl. J. Farm. & Alli. Sci., 3 (4): 408-412.

El-Gedwy EMM, 2011. Determination of the critical period of weed control in maize grown under different plant densities. Ph.D. Thesis, Fac. Agric., Benha Univ., Egypt.

EL-Hosary AAA, Sedhom, AS , EL-Badawy, M EL M, 2011. Genetic and Biotechnological Studies for Important Traits in Maize. LAP Lambert Academic Publishing, ISBN 978-3-8454-4108-5, paperback, 280 PP.

El-Koomy MBA, 2000. Canopy characteristics and yield of certain yellow maize hybrids as influenced by plant density. M. Sci. Thesis, Fac. Agric., Ain Shams Univ., Egypt.

Eyasu E, Shanka D, Dalga D, Elias E, 2018. Yield response of maize (*Zea mays*, L.) varieties to row spacing under irrigation at Geleko, Ofa Woreda, Wolaita Zone, Southern Ethiopia. J. Exp. Agric. Inter., 20 (1): 1-10.

Gobeze YL, Ceronio GM, Rensburg LDV, 2016. Effect of spatial arrangements of row spacing and plant density on water use and water use efficiency of maize under irrigation. J. Nat. Sci. Res., 6 (1): 13-22.

Gomaa MR, Allam SAH, El-Gedwy EMM 2011. Determination of the critical period of weed control in maize grown under different plant densities. J. Plant Production, Mansoura Univ., 2 (12): 1861-1878.

Gomez KA, Gomez AA, 1984. Statistical Procedures for Agricultural Research. 2nd, (ed). John Wiley and Sons, NY, U.S.A.

Gozubenli H, 2010. Influence of planting patterns and plant density on performance of maize hybrids in the Eastern Mediterranean conditions. Int. J. Agric. Biol., 12 (4): 556-560.

Hafez EM, Abdelaal Kh AA, 2015. Impact of nitrogen fertilization levels on morphophysiological characters and yield quality of some maize hybrids (Zea mays, L.). Egypt. J. Agron., 37 (1): 35-48.

Hassan MMM, El-Ghonemy MAM, Aly RSH 2008. Response of some maize single cross hybrids to plant density under different Egyptian environmental conditions. J. Agric. Sci. Mansoura Univ., 33 (2): 427-443.

Imran S, Arif M, Khan A, Khan MA, Shah W, Abdul Latif M, 2015. Effect of nitrogen levels and plant population on yield and yield components of maize. Adv. Crop Sci. Tech., 3 (2): 1-7.

Karki TB, Govind KC, Shrestha J, Yadav JP 2015. Tillage and planting density affect the performance of maize hybrids in Chitwan, Nepal. J. Maize Res. Dev., 1 (1):10-20.

Khan F, Khan S, Fahad S, Faisal S, Hussain S, Ali S, Ali A 2014. Effect of different levels of nitrogen and phosphorus on the phenology and yield of maize varieties. Amer. J. Plant Sci., 5: 2582-2590.

Kinfe H, Yiergalem T, Alem R, Redae W, Desalegn Y, Welegerima G, Kifle G, Husien S 2016. Evaluating hybrid maize genotypes for grain yield and yield related traits in north western Tigray, Ethiopia. Inter. J. Res. Agric. For., 3 (12): 17-21.

Lashkari M, Madani H, Ardakani MR, 2011. Effect of plant density on yield and yield components of different corn (Zea mays, L.) hybrids. Am-Euras. J. Agric. & Environ. Sci., 10 (3): 450-457.

Mahdi A H A, Ismail SKA, 2015. Maize productivity as affected by plant density and nitrogen fertilizer. Int. J. Curr. Microbiol. App. Sci., 4 (6): 870-877.

Majid MA, Islam MS, EL Sabagh A, Hasan M K, Saddam M O, Barutcular C, Ratnasekera D, Abdelaal KhAA, Islam MS, 2017. Influence of varying nitrogen levels on growth, yield and nitrogen use efficiency of hybrid maize (*Zea mays*, L.). J. Exp. Biol. Agric. Sci., 5 (2): 134-142.

Malekabadi SR, Pazoki A, Mehrvar M R, 2014. Evaluating the effects planting date on some quantitative and qualitative characteristics of new maize varieties in the region Rey. Bull. Env. Pharmacol. Life Sci., 3 (3): 189-192.

Mandić V, Bijelić Z, Krnjaja V, Tomić Z, Stanojković-Sebić A, Stanojković A, Caro-Petrović V, 2016. The effect of crop density on maize grain yield. Biotech. Animal Husb., 32 (1): 83-90.

Marković M, Josipović M, Šoštarić J, Jambrović A , Brkić A, 2017. Response of maize (Zea mays, L.) grain yield and yield components to irrigation and nitrogen fertilization. J. Cen. Eur. Agric., 18 (1): 55-72.

Michigan State University, 1983. MSTAT-C: Micro-computer Statistical Program, Version 2. Michigan State University, East Lansing.

Mohsin AU, Ahmad AUH, Farooq M, Ullah S 2014. Influence of zinc application through seed treatment and foliar spray on growth, productivity and grain quality of hybrids maize. J. Anim. Plant Sci., 24 (5): 1494:1503.

Rahman, MM, Paul SK, Rahman MM 2016. Effects of spacing and nitrogen levels on yield and yield contributing characters of maize. J. Bangladesh Agril. Univ., 14 (1): 43-48.

Rehman K, Ali S, Pervez MW, Rehman M, Hussain S, Aishia G, Khalid MS, 2014. Performance of autumn planted maize hybrids under different fertilizer treatments in semi-arid Punjab Pakistan. J. Glob. Innov. Agric. Soc. Sci., 2 (3): 107-111.

Robles, M., I. A. Ciampitti and T. J. Vyn (2012). Responses of maize hybrids to twin-row spatial arrangement at multiple plant densities. Agron. J., 104 (6):1747–1756.

Sallah, P. Y. K., S. Mukakalisa, A. Nyombayire and P. Mutanyagwa (2009). Response of two maize varieties to density and nitrogen fertilizer in the highland zone of Rwanda. J. Appl. Biosci., 20: 1194-1202.

Shafi, M., J. Bakht, S. Ali, H. Khan, M. A. Khan and M. Sharif (2012). Effect of planting density on phenology, growth and yield of maize (*Zea mays,* L.). Pak. J. Bot., 44(2): 691-696.

Sharanabasappa, H. C., M. A. Basavanneppa and Koppalkar, B. G. (2017). Productivity of quality protein maize (*Zea mays*, L.) and soil fertility as influenced by plant population and fertilizer levels under irrigated ecosystem. Int. J. Adv. Biol. Res., 7 (3): 504-508.

Sharifi, R. S. and A. Pirzad (2011). Study of physiological growth indices in maize (*Zea mays*, L.) hybrids under different plant densities application. Int. J. Agric. Res. & Rev., 1(1): 26-32.

Sharifi, R. S., M. Sedghi and A. Gholipouri (2009). Effect of population density on yield and yield attributes of maize hybrids. Res. J. Biol. Sci., 4(4): 375-379.

Stickler, F.C. (1964). Row Width and Plant Production Studies. Sixth edition, Iowa state Univ. Press, Ames. U.S.A.

Timlin, D. J., D. H. Fleisher, A, R. Kemanian and V. R. Reddy (2014). Plant density and leaf area index effects on the distribution of light transmittance to the soil surface in maize. Agron. J., 106 (5): 1828-1837.

Zamir, M. S. I., A. H. Ahmad, H. M. R. Javeed and T. Latif (2011). growth and yield behaviour of two maize hybrids (*Zea mays*, L.) towards different plant spacing. Cercetări Agronomice în Moldova, XLIV, 2 (146): 33-40.

Zeleke, A., G. Alemayehu and G. S. Yihenew (2018). Effects of planting density and nitrogen fertilizer rate on yield and yield related traits of maize (*Zea mays*, L.) in Northwestern, Ethiopia. Adv. Crop Sci. Tech., 6 (2): 1-5.