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RESPONSE OF MAIZE (*ZEA MAYS* L.) HYBRIDS TO DIFFERENT LEVELS OF NITROGEN FERTILIZER AND PLANT DENSITY ON YIELD AND ITS COMPONENTS

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Abstract

Conventional planting, poor fertilizer management and improper row spacing are the major constraints in the reduction of yield and yield components of maize. The present investigation was carried out during 2017 and 2018 seasons at the Agricultural Research and Experiment Station, of Faculty of Agriculture, Cairo University, Giza. The objectives were to evaluate the effect of population density and row spacing on yield and other morphological characteristics of three commercial maize hybrids and study the effect of different plant density and various nitrogen fertilizer levels on yield and yield components. Three single cross hybrids were evaluated under three levels of plant density (control 57600, medium 72000 and high 86400 plants/ha) and three rats of N fertilizer (low 216, medium 288 and high 360 kg N/ha). A split-split-plot design in a randomized complete block arrangement was used with three replications. Results indicated that the effect of nitrogen rate, row spacing and cultivars on plant height, ear height, leaf area, number of leaves/plant, number of rows/ear, number of grains/row, ear weight/plant, 100-grain weight, grain yield/plant and grain yield/ha were significant. Nitrogen rates of high dose 360 kg/ha recorded the highest grain yield of (10.0-9.0 ton/ha), the high rate of plant density 86400 plant/ha produced highest grain yield of (10.8-10.4 ton/ha) and the best cultivar SC-P3444 recorded the highest grain yield of (9.8-9.0 ton/ha), respectively in both seasons were obtained. This study concluded that increasing maize grain yield was obvious by applying high rate of plant density 86400 plant/ha and high dose of nitrogen rates 360 kg/ha.

Key words: Maize, Plant density, Nitrogen fertilizer, Cultivars

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the world agricultural economy, both as food for man and feed for animals. It is a miracle crop. It has a very high yield potential, there is no cereal on the earth, which has so immense potentiality and that is why it is called 'queen of cereals'. In Egypt maize (*Zea mays* L.) is the third most important staple food crop in terms of area and production after wheat and rice. The total area under cultivation of maize in Egypt is 888329 ha about 25.17% of the total cultivated agricultural land while average yield is 7.80 ton ha^{-1}. Maize is about 21.90% of the total cereal production (FAO, 2017). Improving maize productivity has been a major goal of maize researchers in Egypt. The Egyptian government aims to decrease the gap between consumption and production increasing grain yield per unit area of the agricultural land. There are several approaches to increase crop productivity, improving farming practices, employing merging technology, using modern and high yielding maize hybrids, which have more efficiently for using nitrogen and more response to the high rate of nitrogenous fertilizer to create more grains.

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Several different cropping systems are followed in the Nile Valley and Delta areas of Egypt, depending on the soil type and crops; however, the low size of cultivated land per farmer and water deficit is the most problems associated with the cropping systems. In Egypt, there is a modern trend for growing crops on beds (100 – 140 cm width) according to population densities of field crops (wheat, corn, cotton, soybean etc.) to save irrigation water by about 15% compared with traditional practice on ridges 60-70 cm in width (Abouelenein *et al.*, 2009 and Ahmad *et al.*, 2009).

The productivity of crop decreased in recent years because of decline in soil fertility status. The major genetic contribution to the increase in yield has been to increase "crowding stress" tolerance (Duvick and Cassman, 1999) is tolerance has resulted in increased grain yield under high maize plant populations. Plant density is one of the most important cultural practices, determining grain yield, as well as other important agronomic attributes of this crop. Maize is most sensitive to variations in plant density than other members of the grass family. For each production system, there is a population that maximizes grain yield. Maize must be grown at high plant populations to maximize interception of solar radiation. However, at high plant densities efficient conversion of intercepted solar radiation of grain may be limited by apical dominance, protandry and delays in ear differentiation, asynchronous flowering and barrenness. Also, the optimum plant density (number of plants that maximizes grain yield) depends on the hybrid (Cox, 1996, Widdicombe and Elen, 2002). Optimum plant population density is usually higher for shorter-season than for full-season hybrids (Brown, 1970). Further improvement of corn yield interesting on increased tolerance to higher plant densities, due to corn's inadequate input use at lower plant populations (Tollenaar and Lee, 2002). However, increased plant population results in a more stressful environment, which could exacerbate the yield-reducing effects of continuously-grown corn. Maize grain yield per unit area involves multiplying the number of rows per ear, number of kernels per row and grain yield is affected by genotype and environment modified and may reduce or increase (Hejazi and Soleymani, 2014).

Studies conducted worldwide show that the maize yield potential per plant has remained unchanged for decades, while the yield potential per unit area has increased as a function of higher population density and year of hybrid introduction (Carlone and Russell, 1987). These results often encourage producers to increase plant density to pursue high yields during maize production (Tokatlidis and Koutroubas, 2004). However, high plant densities, in practice, result in interplant competition that increases crowding stress, which has a detrimental effect on grain yield (Tollenaar, 2006).

Nitrogen is the most important nutrient required in the greatest quantities for maize grain yield (Bender, 2013) and is the most frequently limited nutrients for maize production (Ciampitti, 2012). Supply of nutrients at an appropriate amount is always imperative for better growth and development of a crop. However, yield and quality parameters are greatly affected by inadequate availability of plant nutrients (Witt *et al.*, 2008). Nitrogen plays a vital role in growth. Higher nitrogen levels are reported to increase plant height, stem thickness, leaf area, leaf area index, dry matter accumulation; net assimilates ratio and yield per hectares (Cheema *et al.*, 2010).

Plant density and N fertilizer application are often considered the most important crop management practices to improve grain yield and N use efficiency (NUE) during intensive maize production (Tollenaar and Lee, 2002; Lee and Tollenaar, 2007). Grain yield and NUE decrease when maize is planted at a lower density because the plants grow to maturity without using all of the available soil N. However, plants compete for N at a higher density with crowding stress, thus decreasing the amount of N available per plant (Tollenaar *et al.*, 2006). When increases in plant density are insufficient to compensate for the reduced yield per plant optimal densities, crowding stress results in a lower yield and NUE (Tokatlidis *et al.*, 2011 and Antonietta *et al.*, 2014). High density planting, while important to increased yields, can also lead to greater competition for resources and morphological changes in the plant and caused lodging.

We hypothesized that a high plant density with crowding stress would reduce the ability of plants to use available soil N. Integrated agronomic management, in terms of optimal plant density and N management, has the potential to improve maize grain yield and NUE.

The objectives of this study were to: (1) evaluate the effect of population density and row spacing on yield and other morphological characteristics of three commercial maize hybrids; (2) study the effect of different plant density and various nitrogen fertilizer levels on yield and yield components of and (3) determine the optimum treatments should be used by farmers.

Materials and Methods

Experimental Site

A two-year study was carried out at the experimental and research station, Faculty of Agriculture, Cairo University, Giza, Egypt, during 2017 and 2018 summer seasons. A representative soil samples were taken from each site at the depth of 0 to 20 cm from the soil surface before planting. The experimental soil type was clay loam in both seasons. Soil physical analysis was conducted according to Klute (1986) and chemical analysis was done according to Page *et al.,* (1982). Mechanical and chemical properties of the experimental soil site during the two studied seasons are shown in table 1. Meteorological data for the experimental growth periods (2017 and 2018) were collected from the Ministry of Agriculture & Land Reclamation, Agricultural Research Center, Central Lab. for Agricultural Climate, Giza, Egypt Fig. 1.

Experimental design and treatments:

Table 1: Mechanical and chemical properties of experimental site (30 cm depth) in 2017 and 2018 seasons.

Character	Seasons	
	2017	2018
Mechanical analysis		
Coarse sand (%)	6	6
Fine sand (%)	33	34
Silt (%)	21	20
Clay (%)	40	40
Soil type	Clay loam	Clay loam
Chemical analysis		
Available N (kg/fed)	11.5	14.7
Available P (ppm)	1350	1097
Available K (ppm)	2860	3410
Organic matter (%)	1.6	1.9
PH	7.3	7.5
EC (m/Mohs/cm)	0.9	0.8

The experiment was laid out in a split-split plot design in randomized complete blocks arrangement with three replications. Nitrogen fertilizer was assigned to the main plots, while the plant density was randomly distributed in the subplots and maize cultivars were devoted to sub-sub plots. Each plot size was 12.6 m^2 included three beds; each bed was 3.0 m in length and 1.4 m in width.

Cultural practices:

The genetic materials used in this investigation included three maize cultivars, namely the single cross hybrids S.C. P3444, S.C. 30N11 and S.C. H66. The grains of the hybrids (S.C. P3444, S.C. 30N11 and S.C. H66) were obtained from Maize Research Section Agriculture Research Center, Ministry of Agriculture.

The preceding crop was barley (*Hordeum vulgare* L.) during both seasons of the study. Sowing dates were about15 and 26 of May for 2017 and 2018 seasons, respectively. Maize grain was sown in hills by hand at three plant densities as follows: 57600 (Maize was manually planted on both sides of the bed with hill spacing of 25cm), 72000 (Maize was manually planted on both sides and middle of the bed with hill spacing of 30 cm) and 86400 (Maize was manually planted on both sides and middle of the bed with hill spacing of 25cm) plants ha^{-1}. Plants were thinned to one plant per hill before the 1st irrigation.

Calcium super phosphate fertilizer (15.5% P_2O_5) at the rate of 60 kg P_2O_5 ha^{-1} was applied uniformly before sowing. Ammonium nitrate (33.5% N) at a nitrogen rate (216, 288 and 360 kg Nha^{-1}) was added in two equal doses before the first and second irrigations. Standard agricultural practices were followed throughout the growing seasons. The weed management was carried out during the growing season by hoeing twice times, before the 1st and the 2nd irrigations was done according to practices used at the experiment station. The other cultural practices were applied as recommended by the Agricultural Research Center (ARC), Giza, Egypt.

Data collection

After 75 days from planting five random maize plants were taken from each plot to determine number of leaves $plant^{-1}$ and flag leaf area. Leaf area was measured according to the method described by Pearce *et al.,* (1975) according to the equation, LA = K (L × B), where: LA= leaf area (cm^2), K= constant (0.75), L= leaf length (cm), B = maximum leaf width (cm). At harvest, random sample of ten guarded plants was taken from each plot to estimate plant height (cm), ear height (cm), number of rows/ear, number of grains/row, ear weight (g), 100 grain weight (g) and grain yield $plant^{-1}$(g). Grain yield ton ha^{-1} was calculated by weighting grain yield (Kg) from the whole area of each experimental unit (sub-sub plot, each

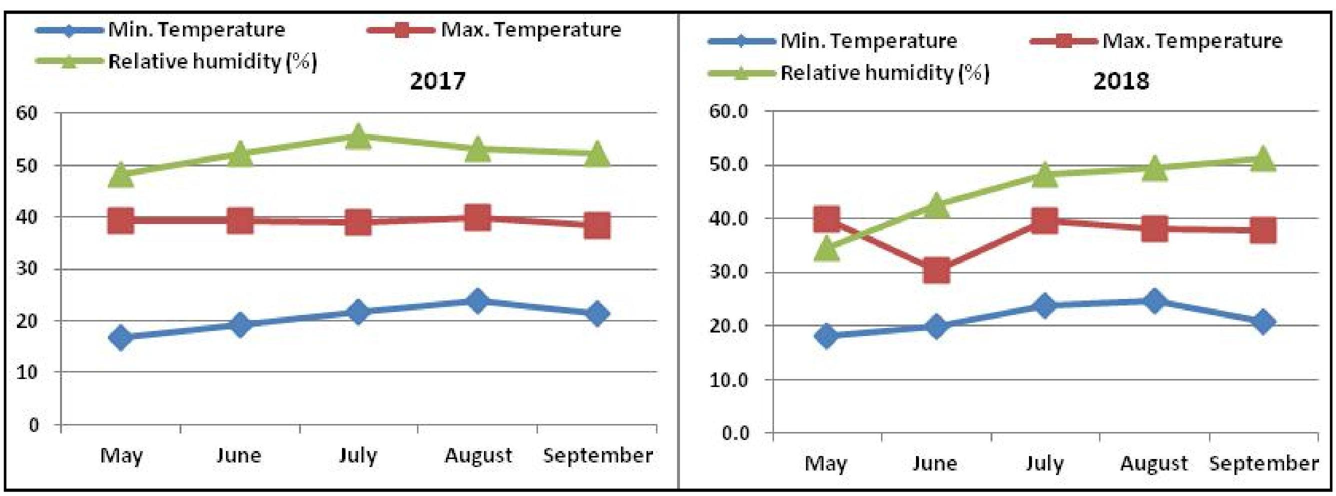

Fig. 1: Temperature (°C) and relative humidity (%) data for the 2017 and 2018 maize crop growing season.

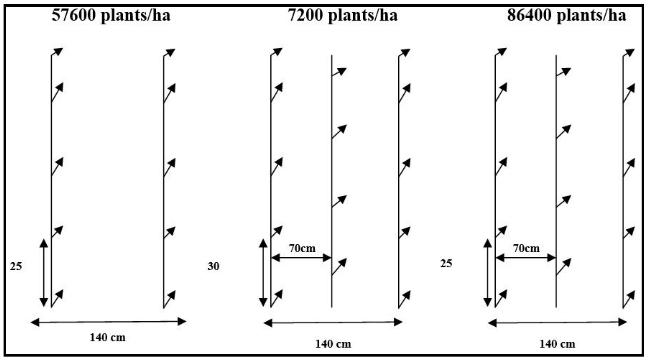

Fig. 3: Layout of the pattern distribution of plants on rows according to plant density.

sub-sub plot consists of 3 beds) and then adjusted into a ton per ha. The grain yield ton ha^{-1} was adjusted on the basis of 15.5% grain moisture content.

Statistical analysis

The collected data were checked out for normality distributions in each trait by Wilk Shapiro test (1965) and then the data were subjected to analysis of variance (ANOVA) technique as outlined by Snedecor and Cochran (1989) by using MSTAT-C computer software (Freed *et al.,* 1989) to test the null hypothesis of no significant differences between treatments. Least Significant Difference (LSD) test was applied for means separation and comparison after the significance of the ANOVA according to Snedecor & Cochran, (1994)

Results and Discussion

Effect of nitrogen fertilizer

In general, there was a significant increase in all

Table 2: Mean performance of all studied traits for nitrogen fertilizer, plant density and cultivars during 2017 and 2018 seasons.

Factors	Plant height (cm)	Ear height (cm)	Flag leaf area (cm^2)	No. of leaves ear^{-1}	No. of rows row^{-1}	No. of grains (g)	Ear weight $plant^{-1}$ (g)	Grain yield (g)	100-grain weight ($tonha^{-1}$)	Grain yield
1st Season										
Nitrogen fertilizer (kg N ha^{-1})										
216 kg N ha^{-1}	227.7	142.3	648.9	16.1	15.2	34.5	175.3	126.7	33.8	8.6
288 kg N ha^{-1}	231.7	142.2	624.9	16.2	15.1	35.6	157.1	119.5	33.7	9.8
360 kg N ha^{-1}	242.6	146.8	599.4	16.5	15.4	40.0	171.2	123.8	32.1	10.0
$LSD_{0.05}$	3.3	1.1	7.8	0.1	0.1	0.3	1.6	1.8	0.3	0.2
Plant density (plants ha^{-1})										
57600	234.3	141.7	668.9	16.7	15.4	37.2	169.9	126.6	34.3	7.7
72000	230.4	142.6	596.6	15.9	15.1	36.6	163.0	122.0	33.8	9.9
86400	237.3	147.0	607.6	16.3	15.2	36.4	170.8	121.2	31.5	10.8
$LSD_{0.05}$	2.6	3.2	7.9	0.3	0.4	0.5	3.5	2.0	0.5	0.2
Cultivars										
SC-P3444	225.5	146.8	549.4	16.7	16.1	33.3	169.2	128.7	35.6	9.8
SC-30N11	224.3	117.3	716.1	15.1	15.1	37.9	171.7	119.2	30.7	9.2
SC-H66	252.1	167.2	607.6	17.0	14.4	38.9	162.8	122.0	33.3	9.4
$LSD_{0.05}$	2.9	2.3	8.3	0.2	0.2	0.6	2.2	2.9	0.5	0.1
2nd Season										
Nitrogen fertilizer (kg N ha^{-1})										
216 kg N ha^{-1}	208.1	131.8	600.4	14.2	13.7	33.4	166.3	120.1	36.0	8.5
288 kg N ha^{-1}	210.4	132.3	594.5	14.1	13.7	34.0	168.6	116.0	36.1	8.9
360 kg N ha^{-1}	215.4	131.5	571.7	14.2	13.3	36.4	182.5	116.4	35.5	9.0
$LSD_{0.05}$	6.97	ns	1.39	ns	0.32	0.28	2.82	2.51	0.47	0.1
Plant density (plants ha^{-1})										
57600	208.5	126.8	625.4	14.0	13.7	34.5	188.6	121.0	37.2	6.9
72000	211.6	132.1	573.9	14.1	13.2	34.0	164.8	113.0	35.9	9.1
86400	213.8	136.7	567.2	14.3	13.8	35.3	164.0	118.5	34.5	10.4
$LSD_{0.05}$	2.5	2.1	3.6	0.1	0.4	0.4	2.4	1.9	0.5	0.3
Cultivars										
SC-P3444	206.2	132.7	519.2	14.8	14.4	32.2	177.3	123.7	38.2	9.2
SC-30N11	197.4	109.3	672.4	13.2	13.4	35.1	166.8	111.0	33.6	8.5
SC-H66	230.2	153.6	575.0	14.5	12.9	36.6	173.4	117.9	35.8	8.7
$LSD_{0.05}$	3.1	1.6	6.1	0.2	0.3	0.4	2.3	2.2	0.3	0.2

studied traits and yields of maize crop with increasing the application of nitrogen fertilizer in 2017 and 2018 seasons except flag leaf area and number of leavesplant^{-1} in second season only table 2.

In first season nitrogen fertilizer at 288 and 360kg Nha^{-1} were significantly increased plant height, ear height, number of leavesplant^{-1}, number of rowsear^{-1}, number of grainsrow^{-1}and grain yieldha^{-1} compared to corresponding 216 kg Nha^{-1}. While the flag leaf area, 100-grain weight and grain yieldplant^{-1} recorded significantly increased by using 216 kg Nha^{-1} compared to nitrogen fertilizer at 288 and 360 kg Nha^{-1}. However, in second season nitrogen fertilizer at 288 and 360 kg Nha^{-1} were significantly increased plant height, ear weight and grain yieldplant^{-1}. In other hand application of 216 kg Nha^{-1} was recorded significantly increase in flag leaf area, number of rowsear^{-1}, 100-grain weight and grain yieldplant^{-1} compared to nitrogen fertilizer at 288 and 360 kg Nha^{-1}.

Application of nitrogen at the rate of 360 kg ha^{-1} produced tallest plants (242.6 and 215.5 cm in both seasons), highest ear height (148.8 cm), highest number of leavesplant^{-1} (16.5), number of rowsear^{-1} (15.4), number of grainsrow^{-1} (40.0 and 36.4 in both seasons) and grain yieldha^{-1} (10.0 and 9.0 ton^{-1} in both seasons). Which were statistically with 216 kg N ha^{-1} of flag leaf area (648.9 and 600.4 cm^2), 100-grain weight (33.8 and 36.0 g) and grain yieldplant^{-1} (126.7 and 128.7 g, respectively) in both seasons. These findings were consistent with those obtained by Dawadi and Sah (2012), Kandil (2013), Shrestha (2015), Yasin (2016), El-Shahed *et al.,* (2017) andEL-Metwally *et al.*, (2019) who indicated that increasing N- level caused an increase in yield and its components of maize.

Table 3: Mean performance of studied traits for the interaction among nitrogen fertilizer, plant density and cultivars during season 2017.

Nitrogen fertilizer (kg N ha^{-1})	Plant density (plants ha^{-1})	Cultivars	Plant height (cm)	Ear height (cm)	Flag leaf area (cm^2)	No. of leaves	No. of rows ear^{-1}
216	57600	SC-P3444	216	141.48	644.46	16.45	17.05
		SC-30N11	212.4	109.08	795.04	15.12	14.22
		SC-H66	251.64	154.98	773.36	18.18	15.3
	72000	SC-P3444	217.78	139.5	549.29	15.8	15.48
		SC-30N11	218.7	119.16	694.6	14.83	15.31
		SC-H66	240.22	166.5	562.4	15.84	13.32
	86400	SC-P3444	214.92	153.36	559.13	16.11	16.56
		SC-30N11	216.9	120.6	704.07	15.3	14.4
		SC-H66	260.44	175.86	557.52	17.28	14.76
288	57600	SC-P3444	218.61	141.93	570.73	16.83	15.93
		SC-30N11	224.1	109.8	778.87	15.06	15.02
		SC-H66	259.02	167.4	634.93	18.47	14.93
	72000	SC-P3444	225.9	146.34	515.16	15.83	14.71
		SC-30N11	215.1	126	685.26	15.09	15.84
		SC-H66	235.98	156.96	570.77	16.56	14.4
	86400	SC-P3444	235.98	156.96	570.77	16.56	14.4
		SC-30N11	233.28	112.5	761.27	14.59	15.47
		SC-H66	248.04	173.7	583.55	16.63	14.04
360	57600	SC-P3444	234.36	149.04	558.36	17.5	16.61
		SC-30N11	230.04	120.1	615.03	15.67	13.93
		SC-H66	262.44	181.44	649.35	17.14	15.49
	72000	SC-P3444	242.1	157.86	515.74	16.71	16.2
		SC-30N11	230.04	117	683.41	15.78	16.02
		SC-H66	247.5	154.08	592.42	16.56	14.4
	86400	SC-P3444	234.72	146.34	508.48	18	16.63
		SC-30N11	237.96	121.14	727.3	14.89	16.01
		SC-H66	264.06	173.88	544.14	16.56	13.08
		$LSD_{0.05}$	8.73	7.42	24.59	0.65	0.66

An increase in yield of maize with increasing rate of nitrogen has been reported by many researchers (Khan *et al.*, 1994). Ogola *et al.*, (2002) who reported that the high nitrogen fertilization results in increased grain yield (43-68%) and biomass (25- 42%) in maize. Bakht *et al.*, (2006) reported that maximum amount of leaf plant^{-1}, number of cobs plant, number of grains cob, taller plants, grain and biological yield was recorded in the application of 200kg N ha^{-1}. EL-Metwally *et al.,* (2019) indicated that increasing N rates from 90 to 120 kg fed^{-1} and from 120 to 150 kg fed^{-1} increased grain yield plant^{-1} by about 5.2% and 1.9% in the 1st season, corresponding to 2.9 % and 1.9% in the 2nd season, respectively. Increasing N rates from 90 to 120 kg fed^{-1} and from 120 to 150 kg fed^{-1} increased grain yield fed^{-1} by about 24.6% and 12.8 % in the 1st season, corresponding to 25.9 % and 12.1 % in the 2nd season, respectively.

In this concern, many investigations highlighted the importance of using the high level of nitrogen fertilizer to avoid the decrease of grain yield with high plant density (Hejaziand Soleymani, 2014; Hafez and Abdelaal, 2015; Imran, 2015; Mahdi and Ismail, 2015; Ali and Anjum, 2017; Shrestha *et al.*, 2018; Zeleke *et al.*, 2018 and Greveniotis *et al.*, 2019).

Effect of plant density

According to the results in table 2 we observed that all studied traits were significantly affected by plant density levels. In first season each ofplant height, ear height, ear weight and grain yieldha^{-1} recorded the highest value under high level of plant density 86400 plant ha^{-1}(237.3 cm, 147cm, 170.8 g and 10.9ton ha^{-1}), respectively and this decrease in other studied traits due to the adverse effect of high plant density on these parameters. While the highest value of flag leaf area, number of leaves$plant^{-1}$, number of rowsear^{-1}, number of grainsrow^{-1}, grain yield$plant^{-1}$ and 100-grain weight were recorded under low level of plant density (57600 plants ha^{-1}) (668.9, 16.7, 15.4, 37.2, 126.6 g, 34.3 g), respectively and this increase due to the low competition effect of plant density on sunlight, water requirements and free spacing between the plants in these traits.

In second season the highest value of plant height (213.8 cm), ear height (136.7 cm), number of leaves$plant^{-1}$ (14.3), number of rowsear^{-1} (13.8), number of grainsrow^{-1} (35.3) and grain yieldha^{-1} (10.9 ton) were recorded under high level of plant density 86400 plant ha^{-1}, while the highest value of flag leaf area (625.4 cm^2), ear weight $plant^{-1}$ (188.6 g), grain yield $plant^{-1}$ (121.0 g) and 100-grain weight (37.2 g) were recorded under low level of plant density (control) 57600 plant ha^{-1}.

The difference may be attributed to plant population, which plays an important role in the maize hybrids. These findings are in agreement with those obtained by Kandil (2014), Shrestha (2015), Yan *et al*., (2017), Shoaib *et al*., (2018), Xuelian *et al*., (2018) and Gomaa *et al*., (2019). As well as, Kareem *et al.,* (2017) studied the effect of two population densities (95,556 and 53,333 plants/ha) on growth and yield of two maize cultivars. They found that increasing plant density from 53,333 to 95,556 plants /ha led to significant increase in grain yield/ha. On the other hand, number of kernels/row, number of kernels/ear, 100-kernel weight and shelling percentage were significantly decreased due to increasing plant density. Revathi *et al.,* (2017) found that maximum grain yield ha^{-1} was recorded with 83,333 plants ha^{-1}. On the other direction, weight of kernels ear^{-1}, number of rows ear^{-1} and 100-kernel weight were not significantly influenced by planting density.

Tahmasbi and Mohasel (2009) showed that increase plant density significantly cause to grain yield growth and highest grain yield was recorded from 85000 $Plantha^{-1}$ with 11.13 $tonha^{-1}$. Saadat *et al*., (2010) indicated that the highest number of $rowsear^{-1}$ and number of $grainsear^{-1}$were found from 40000 plant ha^{-1}. Yield was increased by 4% with increasing plant density Shapiro and Wortmann (2006). Maximum yield per unit area may be obtained by growing maize hybrids that can withstand high plant density, up to 100,000 plants ha^{+1} (Gozubenli *et al*., 2003).

In this concern, many investigations highlighted the importance of using the high level of nitrogen fertilizer to avoid the decrease of grain yield/ha with high plant density (Amanullah *et al*., 2009; Arif *et al*., 2010;Al-Naggar *et al*., 2015; Mahdi *et al*., 2015; Al-Naggarand Atta 2017; Zeleke *et al*., 2018**;**Jiang *et al*., 2018).

Effect of maize cultivar

Results in table 2 showed that there was a significant increase in all studied traits and yields of maize crop between the three cultivars in both seasons. SC-H66 cultivar exceeded SC-P3444 and SC-30N11 cultivars in plant height (252.1 and

Table 4: Mean performance of studied traits for the interaction among nitrogen fertilizer, plant density and cultivars during season 2017.

Nitrogen fertilizer (kg N ha^{-1})	Plant density (plants ha^{-1})	Cultivars	No. of grains row^{-1}	ear weight (g)	Grain yield $plant^{-1}$	100-grain weight (g)	Grain yield (ton ha^{-1}
216	57600	SC-P3444	30.01	203.14	153.53	38.52	7.63
		SC-30N11	35.1	197.86	149.6	32.79	7.46
		SC-H66	39.42	189.32	124.33	33.79	6.67
	72000	SC-P3444	30.24	174.42	139.07	38.26	10.1
		SC-30N11	36.36	165.24	119.18	32.51	9.14
		SC-H66	35.46	162	117.05	32.35	8.01
	86400	SC-P3444	33.66	167.94	115.61	34.77	9.72
		SC-30N11	32.76	149.58	97.38	30.15	8.58
		SC-H66	37.26	167.94	124.13	31.26	10.27
288	57600	SC-P3444	30.78	160.87	117.56	36.76	7.44
		SC-30N11	37.26	141.8	107.44	33.26	8.06
		SC-H66	40.5	154.87	117.75	35.93	7.86
	72000	SC-P3444	32.04	143.1	116.72	38.46	11.11
		SC-30N11	36.54	172.8	118.91	29.68	9.61
		SC-H66	34.92	147.31	118.32	32.73	10.04
	86400	SC-P3444	34.92	147.31	118.32	32.73	10.04
		SC-30N11	34.92	151.2	118.22	30.57	11.06
		SC-H66	39.6	165.24	123.41	32.39	11.49
360	57600	SC-P3444	35.46	159.08	125	32.16	7.57
		SC-30N11	42.12	172.8	127.5	29.43	8.24
		SC-H66	43.74	149.26	116.99	35.84	8.48
	72000	SC-P3444	38.16	158.76	123.37	35.5	11.29
		SC-30N11	46.26	177.12	121.44	32.77	10.56
		SC-H66	39.06	166.32	124.37	32.35	9.39
	86400	SC-P3444	35.46	178.2	130.45	33.05	11.89
		SC-30N11	39.78	216.54	112.89	24.92	10.35
		SC-H66	40.14	163.08	131.84	33.17	11.98
		$LSD_{0.05}$	1.75	7.54	8.12	1.53	0.49

230.2 cm) and ear height (167.2 and153.6 cm) in both seasons, respectively and number of grains row^{-1} in first season only (38.9). In contrast with above traits response, SC-P3444 cultivar was the best for number of leaves plant^{-1} (16.7 and 14.8), number of rows ear^{-1} (16.1 and 14.4), 100-grain weight (35.6 and 38.2 g), grain yield plant^{-1} (128.7 and 123.7 g) and grain yield ha^{-1} (9.8 and 9.2 ton) in both seasons, respectively and ear weight plant^{-1} in second season only (177.3 g). While SC-30N11 cultivar exceeded SC-P3444 and SC-H66 cultivars in flag leaf area in both seasons (716.1 and 672.4 cm^2) and ear weight^{-1} in first season only (171.1 g).

Superiority of SC-P3444 under different rates of nitrogen and plant density in the present study were accompanied by superiority of this cultivar in number of leaves plant^{-1}, number of rows ear^{-1}, ear weight, 100-grain weight, grain yield plant^{-1} and by superiority in grain yield ha^{-1}in both seasons table 2. The difference between the three cultivars may be attributed to the differences in genetic constitution. We can confirm that, in the current period we need to focus on new maize cultivars characterized by highly plant density by breeding programs of maize crop to cope with the shortage of limited cultivated area and low production under Egyptian conditions.

Shapiro and Wortmann (2006) reported that maize is one of the major cereal crops in the world optimizing harvestable grain yield is requires matching new maize hybrids and optimal plant densities. Mansfield and Mumm (2014) studded the relationship between plant density and grain yield was assessed for some hybrids, with a wide range of responses observed. Five hybrids showed substantial tolerance to plant densities ≥ 116,000 plants ha^{-1} based on grain yield performance. High plant population imposed a variety of stresses on corn plants, including competition for light, water, and nutrients (Boomsma *et al*., 2000), as well as enhanced incidence and severity of ear rots and caused leaf diseases (Esechie H.A., 2009 and Ahmad *et al*., 2018).

Table 5: Mean performance of studied traits for the interaction among nitrogen fertilizer, plant density and cultivars during season 2018.

Nitrogen fertilizer (kg N ha^{-1})	Plant density (plants ha^{-1})	Cultivars	Plant height (cm)	Ear height (cm)	Flag leaf area (cm^2)	No. of leaves	No. of rows ear^{-1}
216	57600	SC-P3444	195.15	134.24	598.45	14.19	15.16
		SC-30N11	193.63	100.39	734.07	13.16	12.83
		SC-H66	231.24	148.39	714.26	15.19	13.08
	72000	SC-P3444	201.03	124.84	524.41	14.18	13.81
		SC-30N11	192.74	116.31	650.15	13.55	13.48
		SC-H66	240.82	158.79	530.6	14.13	11.86
	86400	SC-P3444	203.87	135.32	533.88	14.86	15.59
		SC-30N11	194.17	109.65	610.35	13.24	13.65
		SC-H66	220.11	158.14	507.14	15.11	13.48
288	57600	SC-P3444	202.93	130.16	531.75	14.3	14.01
		SC-30N11	195.34	100.8	719.23	13.16	14.49
		SC-H66	226.22	161.63	589.09	14.56	13.56
	72000	SC-P3444	209.55	129.06	489.01	14.62	13.27
		SC-30N11	193.72	118.58	691.24	13.56	14.62
		SC-H66	224.17	145.88	547.89	14.13	12.67
	86400	SC-P3444	224.17	145.88	547.89	14.13	12.67
		SC-30N11	197.37	106.81	720.92	12.92	14.29
		SC-H66	237.49	161.23	557.84	14.69	12.83
360	57600	SC-P3444	207.04	127.28	520.23	14.38	15.03
		SC-30N11	193.67	98.15	572.1	12.83	11.7
		SC-H66	231.33	139.86	649.62	14.5	13.11
	72000	SC-P3444	218.89	141.9	495.47	15.35	14.46
		SC-30N11	204.67	110.46	654.96	13.16	11.21
		SC-H66	218.81	143.28	581.37	14.3	13.65
	86400	SC-P3444	210.89	134.75	475.5	15.76	14.78
		SC-30N11	211.61	122.4	698.54	13.16	14.61
		SC-H66	237.49	161.23	557.84	14.69	12.83
		$LSD_{0.05}$	10.28	11.37	16.02	0.97	1.74

Effect of the interaction of maize cultivars × plant density × nitrogen fertilizer

Results in tables 3, 4, 5 and 6 indicated that the interaction of nitrogen fertilizer × plant density × maize cultivars significantly affected on all studied traits in both seasons. The highest value of plant height (264.06 and 241.72 cm), ear height (173.8 and 165.04 cm) was recorded with the application of SC-H66 cultivar combined with high level of plant density (84600 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha-1) in both seasons, leaf area (795.04 and 734.07 cm) was recorded with the application of SC-30N11cultivar combined with medium level of plant density (72000 plant ha^{-1}) and low rate of nitrogen fertilizer (216 kg N ha^{-1}) in both seasons, number of leaves/plant (18.47), was recorded with the application of SC-H66 cultivar combined with low level of plant density (57600 plant ha^{-1}) and medium rate of nitrogen fertilizer (288 kg N ha^{-1}) in first season and (15.76) with the application of SC-P3444 cultivar combined with high level of plant density (86400 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in second season, number of rows (17.05 and 15.16) was recorded with the application of SC-P3444 cultivar combined with low level of plant density (57600 plant ha^{-1}) and low rate of nitrogen fertilizer (216 kg N ha^{-1}) in both seasons, number of grains/row (46.26 g) was recorded with the application of SC-30N11 cultivar combined with medium level of plant density (72000 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in first season and (40.04) by application of SC-H66 cultivar combined with high level of plant density (86400 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in second season, ear weight/plant (216.54g) was recorded with the application of SC-30N11 cultivar combined with high level of plant density (86400 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in first season and (204.68 g) by application of SC-30N11 cultivar combined with low level of plant density (57600 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in second season, grain yield/plant and 100-grain weight (153.53-145.34 and 38.52-41.58 g, respectively) was recorded with the application of SC-P3444 cultivar combined with low level of plant density (57600 plant ha^{-1}) and low rate of nitrogen fertilizer (216 kg N ha^{-1}) in both seasons and grain yield/ha (11.89 and 10.99 ton) was recorded with the application of SC-P3444 cultivar combined with high level of plant density (84600 plant ha^{-1}) and high rate of nitrogen fertilizer (360 kg N ha^{-1}) in both seasons.

Table 6: Mean performance of studied traits for the interaction among nitrogen fertilizer, plant density and cultivars during season 2018.

Nitrogen fertilizer (kg N ha^{-1})	Plant density (plants ha^{-1})	Cultivars	No. of grains row^{-1}	ear weight (g)	Grain yield plant^{-1}	100-grain weight (g)	Grain yield (ton ha^{-1})
216	57600	SC-P3444	28.32	183.24	145.34	41.58	6.79
		SC-30N11	32.65	187.23	141.74	35.52	6.25
		SC-H66	39.23	176.66	118.88	36.9	6.1
	72000	SC-P3444	32.16	164.96	123.2	39.66	9.87
		SC-30N11	33.79	158.87	110.87	33.57	8.55
		SC-H66	33.46	158.87	111.8	34.37	8.55
	86400	SC-P3444	32.73	164.96	125.93	37.09	9.94
		SC-30N11	32.33	136.7	85.51	32.37	10.16
		SC-H66	35.66	165.45	117.75	33.09	10.22
288	57600	SC-P3444	28.75	185.19	112.84	39.79	7.22
		SC-30N11	35.09	170.57	103.64	36.31	6.76
		SC-H66	37.52	195.91	112.89	39.54	6.98
	72000	SC-P3444	32	166.67	112.43	40.95	10.35
		SC-30N11	34.19	170.57	115.56	32.03	8.55
		SC-H66	32.81	148.25	115.89	34.3	9.07
	86400	SC-P3444	32.81	148.25	115.89	34.3	9.07
		SC-30N11	35.25	144.25	110.44	33.15	10.4
		SC-H66	38.5	174.47	124.62	34.85	10.32
360	57600	SC-P3444	32.73	199.81	119.48	35.1	7.27
		SC-30N11	39.47	204.68	121.89	31.27	7.71
		SC-H66	37.04	194.45	112.3	38.9	7.1
	72000	SC-P3444	35.17	178.85	120.21	39.47	9.54
		SC-30N11	37.04	166.18	90.11	33.32	8.78
		SC-H66	35.09	170.08	116.88	35.15	8.8
	86400	SC-P3444	35.58	190.55	118.04	36.13	10.99
		SC-30N11	35.66	161.79	118.82	35.06	9.64
		SC-H66	40.04	176.41	130.19	35.15	11.47
		$LSD_{0.05}$	1.28	7.03	6.48	1.07	0.55

Increasing grain yield/ha of maize with application of high level of plant density 86400 plant ha^{-1} is due generally to the avoid higher number of plants/ha to adverse effects of a shortage of fertilizer needs for plants by using high level of nitrogen fertilizer.

These results agree with the findings of Turgut (2000) who reported that plant density and N interaction has significant effects on seed number per ear, number of ears per plant and grain yield of maize. These results are supported by (Aziz *et al*., 2007) who stated that increase in grain yield at optimum planting densities may be due to the availability of more nutrients which led to more growth and higher assimilates translocation to grains (Sher *et al*., 2015). Significant increases in grain yield, biomass and N efficiency were observed when density increased from 67,500 to 97,500 plantha^{-1} (Wei *et al*., 2017). While Wei *et al*., 2019 found that kernel weight, the maximum grain-filling rate and the kernel weight increment achieving were all significantly depressed under high density conditions, but increased N supply partially offset the losses.

These results are supported by Gomma *et al.,* (2019) revealed that number of rows ear^{-1}, number of grains row^{-1}, 100-grains weight and grain yield ha^{-1} of maize hybrid were, significantly, affected by plant population and nitrogen fertilizer rates, where the highest grain yield was obtained by growing maize plant hybrid 3444 at a population of 75000 plant ha^{-1} under the application of 360 kg N ha^{-1} under the environmental conditions of Alexandria, Egypt. Fathy et *al*., (2019) found that sowing maize cultivar TWC 352 with dense planting of 30000 plantsfad^{-1} and raising nitrogen level up to 80 kg Nfad^{-1}, with addition of farmyard manure to maximize grain yield fad^{-1}, under the experimental site and other likely environmental condition.

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