

## Effect of Plant Density on Yield and Yield Components of Different Corn (*Zea mays* L.) Hybrids

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**Abstract:** A field experiment was conducted to determine the effect of plant density on yield and yield components of three corn hybrids at Markazi Province- Iran. The experiment was arranged at factorial in randomized complete blocks design with four replications. Experiment factors were three Maize hybrids (KSC260, KSC302 and KSC500) and three levels of plant density (7, 9 and 13 plant/m<sup>2</sup>). Result indicated that plant density had significant effect on yield and yield components of maize hybrids. The grain yield varied between 8.45 ton/ha at 7 plants/m<sup>2</sup> and 9.35 ton/ha at 13 plants/m<sup>2</sup>. The highest number of grains/row (47.85), number of kernels/ear (874.6), harvest index (60.55%), ear length (19.6cm), ear diameter (50.6 mm) and stem diameter (20.4 mm) recorded at 7 plants/m<sup>2</sup>, while 13 plants/m<sup>2</sup> showed the highest values of plant height (200.5 cm). The number of row/ear and the number of ears/plant did not affected in maize hybrids by levels of plant density. Maize hybrids had different response to studied characteristic. KSC500 Hybrid had significantly higher grain yield (9.30 ton/ha), number of grains/row (47.95), number of rows/ear (19.15), number of kernels/ear (829.5), plant height (198.4 cm), ear length (19.3 cm), ear diameter (48.2 mm) and higher harvest index (56.80%) as compared with other hybrids. The number of cobs/plant and stem diameter did not affected in maize by hybrids. In conclusion, it can be suggested that KSC500 hybrid should be applied and the plant density should be adjusted to 13 plant/m<sup>2</sup> in conditions of Arak, Iran.

**Key words:** Plant density % Hybrids % Corn% Yield % Yield component

### INTRODUCTION

Corn (*Zea mays* L.) is one of the most important cereal crop grown principally during the summer season in Iran [1]. Based on area and production, maize is the 3<sup>rd</sup> most important cereal crop after wheat and rice in the world [2]. Yield of maize in Iran is very low as compared to other maize producing countries due to many reasons [1]. Among these, low or high plant population per unit area is the major one [3]. Plant density is one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop. Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition [4]. 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 the utilization of available resources, allowing the expression of maximum attainable grain yield on that environment [5]. Plant population density resulting in interplant competition, has important effects on vegetative [6] and reproductive development of maize [7-9]. Maize yield is low with low plant density because of little plasticity in leaf area per plant [10,8,11] and weed extension [12]. Additionally, maize plants have small capacity to develop new reproductive structures in response to an increase in available resources per plant [13,14]. On the other hand, if plant density is too high, the reduce of the availability of resources per plant in the period surrounding silking generates a marked fall in yield per plant that is not offset by increasing plants number [15,16]. On the other hand, photosynthetic efficiency and

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growth in maize are strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy. Increasing plant density is one of the ways for increasing the capture of solar radiation within the canopy. However, the efficiency of the conservation of intercepted solar radiation in to maize yield decreases with a high plant population density because of mutual shading in the plants [9]. On the other hand, the use of high populations heightens interplant competition or light, water and nutrients. This may be detrimental to final yield because it stimulates apical dominance, induces barrenness and ultimately decreases the number of ears produced per plant and kernels set per ear [17]. Maize grain yield declines when plant density is increased beyond the optimum plant density primarily because of decline in the harvest index and increased stem lodging [12]. When the number of individuals per area is increased beyond the optimum plant density, there is a series of consequences that are detrimental to ear ontogeny and result in barrenness [5]. First, ear differentiation is delayed in relation to tassel differentiation. Later-initiated ear shoots have a reduced growth rate, resulting in fewer spikelet primordia transformed into functional florets by the time of flowering [18]. Functional florets extrude silks slowly, decreasing the number of fertile spikelets due to the lack of synchrony between anthesis and silking. Limitations in carbon and nitrogen supply to the ear stimulate young kernel abortion immediately after fertilization [5]. Tollenaar [19] found that high plant density produced an increase in total dry matter production and a decrease in harvest index and that optimum plant density was a trade off of both effects.

Each year farmers select specific hybrids to be placed in certain fields, to help maximize yield potential [20]. Corn hybrids respond differently to high plant density [21,22]. On the other hand, the response of hybrid to plant density depends upon the geography [20]. Nafziger [23] suggested that new hybrids have greater grain yield at higher plant densities than older hybrids. This occurs because early hybrids are normally smaller, produce less leaves, have lower leaf area per plant and present fewer self-shading problems than late cultivars. Therefore, for early hybrids it is necessary to have a greater number of plants per area to generate the leaf area index that provides maximum interception of solar radiation, an essential step to maximize grain yield [5]. The development of earlier hybrids, with shorter plant height, lower leaf number, upright leaves, smaller tassels and more synchronized floral development improved maize ability to withstand high plant densities without

presenting a higher percentage of barren plants. It is important to know how the grain per ear of each hybrid will be affected at different populations and try to maximize it while carefully weighing the potential of the hybrid for stalk lodging at higher populations [20].

Many studies have been conducted with the aim of determining the optimum plant density for maize hybrids [22,24]. Maize population for maximum economic grain yield varies between 30,000 to over 100,000 plants per hectare [25]. The optimum plant density depends on producing goal. Cox and Otis [26] reported that the maximum dry matter yield recorded at 81500 plants ha<sup>-1</sup> and the maximum grain yield at 74100 plants ha<sup>-1</sup>. However, the maximum forage yields have also been recorded at 79000 plants ha<sup>-1</sup> [27] and 100000 plants ha<sup>-1</sup> [28].

Unfortunately, there is no single recommendation for all conditions, because optimum density varies depending on nearly all environmental factors as well as on controlled factors, such as soil fertility, hybrid selection, planting date, planting pattern and harvest time, among others [5, 29]. Then specific hybrid and population recommendations should be based on local data and experience, while considering broad general concepts [20].

The aim of this study was to determine the effects of plant density on yield and yield components of some maize hybrids and find out better variety and proper plant population for obtaining maximum yield of maize in Markazi province- Arak, Iran.

## MATERIALS AND METHODS

**Experimental Site Description:** This study was conducted on the Experimental Farm of the Faculty of Agriculture, Islamic Azad University\_ Arak Branch, Arak, Iran (34°03'08" N, 49°48'26" W; 1711 m above sea level) during the 2007 growing season. The soil of the experimental site is sandy loam throughout its profile (52% sand, 36% silt and 12% clay). Climatically, the area placed in the semi-arid temperate zone with cold winter and hot summer. Average rainfall is about 341.7 mm that most rainfall concentrated between winter and spring. The mean, maximum and minimum annual temperature is 13.7, 35.7 and -5.6°C, respectively.

**Agronomic Practices:** Nitrogen fertilizer was applied at a rate of 300 kg/ha in the form of urea (46%) in two periods: 50% at cultivation time and 50% at 8-9 leaves stage. Phosphorus fertilizer was applied at a level of 350 kg/ha as triple superphosphate (46% P<sub>2</sub>O<sub>5</sub>). Whole of phosphorus

was applied basally before sowing in all treatments. Before sowing of the crop, the field was well prepared by plowing twice with tractor followed planking to make a fine seed bed. Corn seeds were planted in the 3<sup>rd</sup> week of May. Two seeds/ hole were sown and at 4 leave stage thinned to one plant/hill. The field was immediately irrigated after planting. Other irrigations were performed in regard to plant's need. Weed, pests and diseases control were done in a timely manner.

**Experimental Design and Treatments:** The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement and four replications. Experiment factors were three corn hybrids (KSC260, KSC302 and KSC500) and three levels of plant density (7, 9 and 13 plant/m<sup>2</sup>). Row spacing was 75 cm and distances between plants in the rows were 20, 15 and 10 cm for 7, 9 and 13 plant/m<sup>2</sup> sowing densities, respectively. Plot area was 6×3.75 m with 5 rows/plot. Blocks were separated by 2 m unplanted distances.

**Parameter Assessments and Statistical Analysis:** After physiological maturity, harvest sample was taken of 3 m long from the 3 middle rows for measuring harvest index and grain yield. Corn yield was adjusted to water content of 14%. The other traits studied in this research were determined in the following methods [30]:

**Plant Height:** Mature plant heights of ten random plants/plot were measured in cm as the distances from ground level to the lowest branch of the panicle.

**Number of Kernel/ear:** Number of kernels in ten ears was counted after they had been shelled and was divided by the number of ears.

The other characteristics such as 1000 grains weight, ear length, ear diameter, number of grains/row, stem diameter and the number of rows were determined in the center 3 rows of each plot. Analysis of the data were performed using SAS 9.1 software package. Treatment means were compared using Duncan's multiple range test at 5% probability level [31].

## RESULTS AND DISCUSSION

The analysis of variance on studied traits demonstrated that density had significant effects on grain yield, 1000-grain weight, plant height, number of kernels/ear, number of grains/ row, harvest index, Ear length, ear diameter and stem diameter. Similarly, maize hybrids had significant effects on these characteristics except harvest index and stem diameter (Table 1). The interaction between hybrid and density had not significant effect on studied traits.

**Grain Yield:** The grain yield varied between 8.45 ton/ha at 7 plants/m<sup>2</sup> and 9.35 ton/ha at 13 plants/m<sup>2</sup> (Table 2). Similar trend in yield differences across planting density have been reported by Seyed Sharifi *et al.* [1] and Zhang *et al.* [9]. Xue *et al.* [32] reported that grain yield increased with increasing plant density from 54000 to 94000 plants/ha. Yield increased with increasing plant density up to an optimum number for a corn genotype grown

Table 1: Analysis of variance for the effects of plant density on evaluated traits in maize hybrids.

S.O.V.	Mean of Squares									
	Grain yield	grains/ row	No.of ears	kernels/ear	ears/plant	Harvest index	Plant height	Ear length	Ear diameter	Stem diameter
Hybrid (H)	1.09*	55.55*	5.98**	1764.70**	0.33	56.08	134.68*	5.10**	26.81**	3.05
Density (D)	3.30**	82.14**	2.18	3537.37**	0.91	363.52**	257.07**	8.45**	81.24**	8.16**
H × D	2.28	97.20	7.99	3186.50	0.047	84.46	552.22	20.79	29.49	5.86
Error	0.303	12.83	0.28	1477.53	0.078	8.56	25.36	0.52	5.94	1.32
CV (%)	6.09	7.78	2.89	4.70	7.24	5.39	2.57	3.86	5.15	5.77

\*\* show significant differences at 0.05 and 0.01 probability level respectively.

Table 2: Mean comparison of studied characteristics of maize in different treatments.

Treatments	Grain yield (ton/ha)	grains/ row	rows /ear	kernels/ ear	ears/ plant	Harvest index (%)	Plant height (cm)	Earz length (cm)	Ear dia. (mm)	Stem dia. (mm)
Density (Plant/m <sup>2</sup> )										
13	9.35 a	43.10 c	18.80 a	767.4 c	1.01 a	50.10 b	200.5 a	17.9 c	45.3 c	18.1 b
9	9.30 a	47.25 b	18.42 a	800.4 b	1.02 a	52.45 b	195.5 b	18.6 b	48.6 b	20.2 a
7	8.45 b	47.85 a	17.95 a	874.6 a	1.01 a	60.55 a	185.2 c	19.6 a	50.6 a	20.4 a
Hybrids										
KSC260	8.70 b	43.75 b	17.7 c	796.7 b	1.01 a	52.75 b	169.9 b	18.1 b	45.6 b	19.2 a
KSC302	9.15 ab	46.45 ab	18.30 b	816.3 ab	1.0 a	53.40 b	182.0 a	18.9 a	47.9 a	20.1 a
KSC500	9.30 a	47.95 a	19.15 a	829.5 a	1.02 a	56.80 a	198.4 a	19.3 a	48.2 a	19.9 a

Mean with similar letters are not significantly difference at the 0.05 probability level according to Duncan's multiple test.

under a set of particular environmental and management conditions [19]. Our findings were the same with Bangarwa *et al.* [33], Farnham [34] and Mobasser *et al.* [35]. Widdicombe and Thelen [24] reported that plant density had a significant effect on grain yield and the highest plant density level evaluated (90000 plants/ha) resulting in the highest grain yield may have been too low to establish the true plant density for maximum yield. Porter *et al.* [36] reported inconsistent optimal plant density levels ranging from 86000 to 101270 plants/ha for corn grain yield across three Minnesota locations. Farnham [34] revealed that corn grain yield was increased from 10.1 to 10.8 ton/ha as plant density increased from 59000 to 89000 plants/ha. The maximum grain yield was produced by KSC500 hybrid (9.30 ton/ha). While the minimum by KSC260 hybrid (8.70 ton/ha). These results are in agreement with harvest index. This might be related to correlation between grain yield with harvest index. At low densities, many modern maize hybrids don't tiller effectively and quite often produce only one ear per plant. Therefore, grain yield and harvest index of maize is low with low plant density, because of little plasticity in leaf area per plant [10, 8,11] and weed extension [12]. Additionally, maize plants have small capacity to develop new reproductive structures in response to an increase in available resources per plant [13, 14].

**The Number of Grains/ Row:** Data regarding the effect of maize hybrids and plant density on the number of grains/row are given in Table 2. The number of grains/row was decreased with increasing plant densities. The maximum (47.85) and minimum (43.10) number of grains/row was observed at 7 and 13 plant/m<sup>2</sup>, respectively. This result might be attributed to the competition between plants being more enhanced at high densities, which, in turn, led to a reduced quantity of dry matter and, consequently, a reduction of grains/ear row [37,38]. on the other hand, limitations in carbon and nitrogen supply to the ear stimulate young kernel abortion immediately after fertilization [5]. Means comparisons indicated that the highest number of grains/row (47.95) was observed for KSC500 hybrid and the minimum value (43.75) was observed for KSC260 hybrid. Our result is in accordance by Seyed Sharifi and Taghizadeh (2009), who reported that the maximum number of grains per row (33.5) was observed for SC-504 hybrid and the minimum value (25.0) for DC-370 hybrid. Similar results have been reported by Seyed Sharifi *et al.* [1] and Zhang *et al.* [9], who reported that the number of grains/row of corn had significantly affected by maize hybrids.

**The Number of Rows per Ear:** Data recorded on average the number of rows of maize hybrids is represented in Table 2. Means comparisons indicated that the maximum (19.15) and the minimum (17.7) number of rows per ear was observed for KSC500 and KSC260 hybrids, respectively. Our results are in agreement by Seyed Sharifi and Taghizadeh [39], who reported that the maximum number of rows per ear (18.6) was observed for SC-504 hybrid and the minimum value (16) for DC- 370 hybrid. Similar results have been reported by Seyed Sharifi *et al.* [1] and Ma *et al.* [40], who reported that the number of rows per ear was significantly affected by maize hybrids.

**Number of Kernels/ear:** Data regarding the effect of maize hybrids and plant density on number of kernels/ear are given in Table 2. Across planting density the maximum number of kernels/ear was recorded 7 plant/m<sup>2</sup> (874.6) and the minimum it was recorded at 13 plant/m<sup>2</sup> (767.4). On the other hand, the number of kernels/ear was increased with reducing plant density. Lower number of kernels/ear at the high plant density (13 plants/m<sup>2</sup>) may have resulted from fewer flower initials being formed, poor pollination resulting from asynchrony of tasseling and silking, or abortion of kernels after fertilization [41,42]. Our results are in agreement with those obtained by Seyed Sharifi *et al.* [1] and Zhang *et al.* [9], who reported that the kernels number decreased with increasing plant density. Similar results have been reported by Mobasser *et al.* [35] in rice cultivars. Increase in kernels/ear from lower planting density might be due to the lower competition for radiation and nutrient that allowing the plants to accumulate more biomass with higher capacity to convert more photosynthesis into sink resulting in more kernels/ear. The response of maize hybrids was significant to number of kernels/ear. On the other hand, means comparisons indicated that the maximum number of kernels/ear (829.5) was recorded for the KSC500 hybrid and the minimum value (796.7) was recorded for the KSC260 hybrid. The results are as the same with those obtained by Seyed Sharifi and Taghizadeh [39], who reported that the maximum number of kernels per ear (568.6) was recorded for SC-504 hybrids and the minimum (488.2) for SC-301 hybrid. Number of kernels/ear plays an important role to determining grain yield [5].

**Number of Ears/plant:** Plant density and maize hybrids did not show any significant variation in respect of number of ears/plant (Table 1). The findings are in agreement with those reported by Ma *et al.* [40] and Sanjeev and Bangarwa [43] who reported that number of

cobs/plant had not significantly affected by plant density. Seyed Sharifi and Taghizadeh [39] and Gonzalo *et al.* [29] have been reported that number of cobs/plant had not significantly affected by maize hybrids.

**Harvest Index:** The physiological efficiency and ability of a crop for converting the total dry matter into economic yield is known as harvest index (HI). Plant densities showed significant difference for HI. Crop sown at density 7 plants/m<sup>2</sup> had maximum HI (60.55%), followed by 9 plants/m<sup>2</sup> (52.45%), which was similar to 13 plants/m<sup>2</sup> (50.10%) (Table 2). On the other hand, with increasing plant density HI was decreased. Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition [4]. Mobasser *et al.* [35] reported that harvest index in rice declines when plant density increases. The yield reduction/plant may be due to the effects of interplant competition between plants for using of light, water, nutrients and other yield-limiting environmental factors. Means comparison indicated the maximum harvest index (56.80%) was recorded for KSC500 hybrid and minimum value (52.75%) was recorded for KSC260. Similar results have been reported by Li *et al.* [44] in maize hybrids and Mobasser *et al.* [35] in rice cultivars.

**Plant Height:** Plant height was significantly affected by corn hybrids and plant densities. Plant height increased with increasing plant densities. Data regarding the effect of maize hybrids and plant density on plant height are given in Table 2. In general, the the maximum plant height (200.5 cm) was obtained with the highest plant density (13 plant/m<sup>2</sup>), while the least value (185.2 cm) was recorded at the lowest plant density (7 plant/m<sup>2</sup>). When plant density is increased, plants are closer to each other which enhances the amount of FR reflected by competing seedlings, leading ultimately to a higher FR/R ratio [45]. An increased FR/R ratio derived from close-spaced plants suppress the development of tillers in wheat [46], stimulating apical dominance. An intense crowding increases the FR/R ratio, triggering physiological events that will lead to prioritization in the allocation of new assimilates to the main stem and increasing plant height. Similar results have been reported by Seyed Sharifi *et al.* [1] and Zhang *et al.* [9]. Konuskan [47] found that plant height increased with increasing plant density up to 100000 plant/ha. Means comparison for maize hybrids indicated the tallest plants (198.4 cm) were measured from KSC500 hybrid and the shortest plants (169.9 cm) were

measured from KSC260 hybrid (Table 2). The previous studies indicated that there were genotypic difference in plant height by Gozubenli *et al.* [48] and Konuskan [47].

**Ear Length:** Ear length was decreased with increasing plant density. Low plant density (7 plants/m<sup>2</sup>) had the longest ear (19.6 cm) and the shortest (17.9 cm) was in high plant density (13 plants/m<sup>2</sup>) (Table 2). This may be due to the effects of interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water [5]. Similar trend was also reported Zhang *et al.* [9]. The effect of hybrids on cob length was significant (Table 1) and the longest cob (19.3 cm) produced by KSC500 hybrid and the shortest it (18.1 cm) was KSC260 hybrid (Table 2). Similar results were reported by Seyed Sharifi and Taghizadeh [39], who reported that the longest cob (167.4 mm) was produced by SC-504 hybrid and the shortest one (152.2 mm) by SC-301 hybrid.

**Ear Diameter:** Ear diameter decreased with increases in plant density. The thickest ears (50.6 mm) were obtained at low plant density (7 plants/m<sup>2</sup>) and the thinnest ears (45.3 mm) were obtained at high plant density (13 plants/m<sup>2</sup>) (Table 2). Konuskan (2000)[47] reported plant densities affected ear diameter and thinner ears were obtained at high densities. Similar results have been reported by Seyed Sharifi *et al.* (2009)[1]. Maize hybrids and plant density significantly affected ear diameter. Maximum ear diameter was recorded by KSC500 hybrid (48.2 mm) and minimum it was recorded by KSC260 hybrid (45.6 mm). Gozubenli *et al.* [48] and Konuskan [47] indicated that ear diameter was affected by genotypes. Seyed Sharifi *et al.*[1] reported that the thickest ears were obtained by SC-504 hybrid with 45.2 mm and the thinnest ears were obtained by DC-370 hybrid with 38.3 mm.

**Stem Diameter:** Plant density significantly affected stem diameter. Stem diameter decreased with increasing plant density and the highest stem diameter (20.4 mm) was determined at 7 plants/m<sup>2</sup> and the lowest stem diameter (18.1 mm) was determined at 13 plants/m<sup>2</sup> (Table 2). Stem diameter is strongly influenced by environmental conditions during stem elongation. This may be due to the effects of interplant competition for light that stimulates apical dominance [5]. Konuskan [47] and Mobaser *et al.* [35] reported that stem diameter were lower in higher plant densities as a consequence of inter plant competition. Maize hybrids did not significantly affect the stem diameter.

## CONCLUSION

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 to grain may be limited by apical dominance, protandry and delays in ear differentiation, asynchronous flowering and barrenness. Results showed that hybridism differences were significant and the highest grain yield and harvest index were obtained from KSC500 hybrid. Plant density can be increased to provide maximum grain yield. In conclusion, KSC500 hybrid should be applied and the plant density should be adjusted to 13 plant/m<sup>2</sup> to provide maximum grain yield in conditions of Markazi province- Arak, Iran.

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