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Response of Corn (*Zea mays* L.) To Planting Pattern and Density in Iran

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Abstract: The effect of planting pattern (single-row, simple twin-rows and zigzag twin-rows planting) and planting density (7, 10 and 13 plant m^{-2}) were evaluated on yield and agronomic traits of modern long maturity seed corn variety KSC700 in the west of Iran in 2006. Results showed that planting pattern had significant effect on grains per row, grain yield, light interception and leaf area index. Grains per row, grains per ear, grain yield, light interception, leaf area index and harvest index were significantly influenced by planting density. There were significant differences in grains per row, grains per ear, grain yield and light interception due to different planting pattern × density intractions. Higher LAI caused more light interception in twin-rows patterns than single –row pattern, with increasing in corn density. The highest grain yield was obtained for twin-rows planting from 10 plant m^{-2} as a function of more grains per row. Single-row pattern in 13 plant m^{-2} produced the lowest grain yield.

Key words: *Zea mays* • Planting pattern • Planting density • Yield • Light interception

INTRODUCTION

Corn (*Zea mays* L.) is the most important grain forage crop in Iran. The average grain yield of corn is more than 8 ton ha^{-1} and is increasing annually. In order to optimize the use of moisture, nutrients and solar radiation, grain corn must be grown under optimum planting pattern and seed density.

Studies on different crops show that increasing number of rows per ridge is more successful than one row per ridge. Hassan [14] reported that increasing number of rows per ridge from 1 to 3 increased total yield of onion and decreased average bulb weights. Widening in-row spacing from 5 to 10 and to 15 cm decreased total yield, but increased average bulb weights, percent large bulbs, doubles and bolters. Growing tulips as one doubles row in each ridge produced more bulbs yield than as one ridge or bed [19]. Improvement of plant spatial arrangement by zigzag planting in potato with increasing the row spacings of 90 cm and 105cm was more successful than by one row per each ridge, but less successful than the row spacings of 75 cm with one row per ridge [15]. Ridges 50 cm wide with two rows of rice produced more yield than wide ridges 1 m wide with six rows [7].

Corn is among the least tolerant of crops to high plant population densities [22]. Akman [2] stated that plant height and ear yield of sweet corn increased as the plant density increased, but ear lengh, ear diameter and filled ear length decreased in high plant density. Raising of cron plant population from 53333 to 88888 plants ha^{-1} significantly increased the fresh ear yield [18]. Akbar *et al.* [1] reported that the most proper sowing density in corn was 100000 plants ha^{-1}.

Cox *et al.* [6] stated that twin-rows (0.19m on 0.76m centers) had graeter corn silage dry matter (17.2 mg ha^{-1}) than single-row planting (16.6 mg ha^{-1}). Higher plant density combined with narrow row spacing results in a more equidistant planting pattern that is expected to delay initiation of intra specific competition [8] while early crop growth is increased [5].

Crop growth rate is directly related to the amount of radiation intercepted by the crop [12]. Therefore, the response of grain yield to narrow rows can be analyzed in terms of the effect on the amount of radiation interception at the critical periods for kernel set. In some cases, full radiation interception during these periods may not be achieved with wide row [3]. Andrade *et al.* [3] found that corn yield response to decreased row spacing was negatively correlated to radiation interception at pollination time with the wider spacing.

This experiment was conducted to determine the best planting pattern and density for modern long maturity corn variety (KSC700) in the west of Iran.

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MATERIALS AND METHODS

This study was conducted at the field of Sarab Changaie station in the Lorestan agricultural and natural resources research center, Khorramabad, Iran. The treatments comprised three planting patterns (one row, simple twin rows and zigzag twin rows planting on each ridge) and three planting densities (7, 10 and 13 plant m^{-2}). The conventional seed density and planting pattern is about 7 plant m^{-2} and one row planting of 0.75 m, respectively.

The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement and four replications, using a plot size of 21 sq m (3×7 m) and consisted of 4 rows. Distance between rows was 75 cm. The variety modern long maturity single cross 700 seed corn was used.

The fertilizer dose used was 200-100-50 (N.P.K.) kg ha^{-1}. half nitrogen and whole phosphorous and potassium in the froms of urea, ammonium phosphate and potassium sulphate, respectively, were applied at the time of planting, while remaining half dose of nitrogen was applied at side dressing after thinning.

The seed were sown at a 5-6 cm depth with 3 seeds per hill on the 10th of may, 2006. Thinning was practiced at 4-6 leaf stage. Hand weeding was practiced to control weeds. Standards cultural practices were carried out until the plant was matured.

Ten plants (excluding border plants) were randomly selected from each plot prior to harvest for measure yield components. Grain yield determined from harvest area of 7 m^2 adjusting to 14% moisture content.

A factorial statistical analysis of variance and least significant difference (LSD) tests at 5% probability level [21] was conducted on the data, using MSTAT-C program.

RESULTS

Planting Pattern: Results showed that planting pattern had significant effect on grains per row, grain yield, light interception and leaf area index (Table 1 and 2). These traits were significantly greater with twin-rows planting than with one-row, but there were no significant differences among simple and zigzag twin-rows planting (Table 3). Planting pattern had not significant effect on rows per ear, 1000 grains weight, plant height, ear diameter, grains depth, biological yield and harvest index.

The highest grains per row were obtained in simple and zigzag twin-rows (39.6 and 39.4, respectively) while the lowest of 37.7 was produced in one- row planting (Table 3).

Grain yield for one-row planting was 9311.0 (kg ha^{-1}) while for zigzag twin-rows planting was 10609.2 kg ha^{-1} (Table 3).

Table 1: Mean square values in the analysis of variance for number of rows per ear, number of grains per row, number of grains per ear, 1000 grains weight and grain yield during summer 2006

S.O.V.	df	No. of Rows ear^{-1}	No. of Grains row^{-1}	No. of grains ear^{-1}	1000-grain Weight (g.)	Grain yield (kg ha^{-1})	Light interception
Replications	3	1.55	3.76	1887.89	1499.21	58916.63	1.43
Planting Pattern(PP)	2	0.232	13.10*	4744.72	78.25	6190290.11*	25.97**
Planting Density(PD)	2	0.320	86.15*	21869.61**	950.08	23582899.53**	52.94**
PP× PD	4	0.822	11.61*	11770.32*	89.58	4240744.44*	0.45
Error	24	0.476	3.59	1584.03	481.67	1293682.90	1.19
CV	4.7	4.9	7.0	7.09	11.2	8.2	

*,** significant at p=0.05 and p=0.01 probability –levels, respectively

Table 2: Mean square values in the analysis of variance for leaf area index, plant eight, ear diameter, grains depth, biological yield and harvest index during summer 2006

S.O.V.	df	Leaf area index	Plant height (cm)	Ear diameter (cm)	Grains depth (cm)	Biological yield (kg ha^{-1})	Harvest index
Replications	3	0.09*	82.44	0.12	0.05	8774624.92	0.0005
Planting Pattern(PP)	2	0.144*	278.52	0.09	0.06	5350729.53	0.005
Planting Density(PD)	2	0.172*	246.39	0.08	0.01	33542120.44	0.77**
PP× PD	4	0.008	135.19	0.01	0.01	984475.49	0.008
Error	24	0.035	159.90	0.30	0.08	1825978.80	0.003
CV	5.6	10.2	8.5	11.3	6.3	11.6	

*,** significant at p=0.05 and p=0.01 probability –levels, respectively

Table 3: mean comparison of morphological characteristics of corn in different treatments.

PP	PD	No . of grains rowG^1	Leaf area index	No . of grains earG^1	Grain yield (kg/haG^1)	Light interception (%)	Biological yield (kg haG^1)	Harvest index (%)
I		37.7b	3.4b	546.0b	9311.0b	87.6b	20745.6 b	0.45b
II		39.6a	3.6a	583.5a	10492.7a	89.9a	22007.3 a	0.48a
II		39.4a	3.6a	576.3ab	10609.2a	90.3a	21755.5ab	0.49a
LSD		1.596	0.1642	33.53	958.4	1.161	1139	0.0462
	7	38.8b	3.3b	574.0b	9994.4b	87.3c	19697.6c	0.51a
	10	41.6a	3.6a	608.3a	11605.6a	89.1b	21812.9c	0.53a
	13	36.2c	3.7a	523.4c	8812.8c	91.4a	22997.9a	0.38b
	LSD	1.596	0.1642	33.53	958.4	1.161	1139	0.046
I	7	38.5bc	3.2b	565.5ab	10416.8b	85.2d	19311.5d	0.5b
I	10	40.0ab	3.5ab	590.2a	9738.8b	87.5cd	21158.5bcd	0.5b
I	13	34.5d	3.6a	482.2c	7777.5c	90.0ab	21766.8bc	0.4c
II	7	39.1bc	3.4ab	568.7ab	9622.3b	88.0bc	19773.0d	0.5b
II	10	42.4a	3.6a	617.5a	12744.8a	89.6bc	22110.0b	0.6a
II	13	37.3bc	3.7a	564.2ab	9111.0bc	92.1a	24110.0a	0.4c
II	7	39.0bc	3.4ab	587a	9944.3b	88.6bc	20008.2cd	0.5b
II	10	42.3a	3.7a	617.1a	12333.3a	90.1ab	22141ab	0.6a
II	13	36.9c	3.7a	523.9bc	9550.0b	92.1a	23117.3ab	0.4c
	LSD	2.765	0.3285	58.08	1660.0	2.012	1972	0.0799

PP = Planting pattern (I, II and *II* are single-row, simple and zigzag-rows, respectively).

PD = Planting density (7,10 and 13 plant mG^2).

Mean with similar leter(s) in each column are not significantly different at the 0.05 probability level according to LSD.

Results showed that LAI in one -row planting was 3.4 and in both simple and zigzag twin-rows planting was 3.6.

The highest light interception of 89.9% and 90.3% were obtained from simple and zigzag twin-rows pattern, respectively, while the lowest light interception of 87.6% was obtained from one -row planting pattern.

The highest biological yield (22007.3 kg haG^1) and the least biological yield (20745.6 kg haG^1) were produced in simple twin-row and single row pattern, respectively.

Planting Density: Grains per row, grains per ear, grain yield, light interception, leaf area index and harvest index were significantly influenced by planting density (Table 1 and 2).

Grains per row, grains per ear and grain yield were increased by increasing plant density from 7 to 10 plant mG^2, but dereased in the highest density (13 plant mG^2). The highest grains per row (41.6), grains per ear (608.3) and grain yield (11605 kg haG^1) were observed in 10 plant mG^2 and the lowest (36.2, 523.4 and 8812.8 kg haG^1, respectively) were determind in 13 plant mG^2 (Table 3).

LAI was significantly lower in 7 plant mG^2 than higher planting density, but there were no significant defferences among 10 and 13 plant mG^2. LAI in 7,10 and 13 plant mG^2 was 3.4, 3.6 and 3.7, respectively (Table 2). Light interception was increased linearly as planting density increased from 7 to 10 and to 13 plant mG^2 (87.3, 89.1 and 91.4%, respectively).

The highest biological yield (22997.9 kg haG^1) was produced in the highest plant density (13 plant mG^2), while the least plant density (7 plant mG^2) produced the lowest biological yield (19697.6 kg haG^1). Harvest index was highest (0.53%) in 10 plant mG^2, while the least (0.38%) was obtained from 13 plant mG^2 planting density.

Interaction Effects: The statistical analysis of the data showed that there were significant differences in grains per row, grains per ear and grain yield due to different planting pattern × density interactions (Table 1). Interaction effect mean showed that there were no significant differences among both simple and zigzag planting pattern in different levels of planting density (Table 3).

Results showed that highest grain yield (12744.8 and 12333.3 kg ha^{-1}) were produced in simple and zigzag twin-rows planting pattern, respectively, in case of 10 plant m^{-2} (Table 3). On the contray, the least grain yield (7777.5 kg ha^{-1}) was obtaind at single-row planting pattern in the highest planting density (13 plant m^{-2}). The highest grains per row (42.4) and grains per ear (617) were obtained from both twin-rows planting pattern in 10 plant m^{-2}.

Interaction effect mean showed that the highest light interception (92.1%). was achieved by both twin-rows pattern in the highest plant density (13 plant m^{-2}), while the least light interception was obtained in one-row planting pattern in case of the lowest plant density (7 plant m^{-2}) (Table 3).

DISCUSSION

As the planting density increased, leaf area index and light interception followed an increasing trend. Higher LAI caused more Light interception (90%) in twin-rows planting than single-row planting (87.6%)(Table 3). The significant differences for LAI (Table 1) and its rise with high density and twin-rows pattern (Table 3) could be due to increased inter plant competition for sunlight [3].

Some researchers have reported increased light interception by crops such as corn due to higher plant population and narrower row spacing [4, 17], because decreasing row spacing in twin-rows patterns at equal plant densities produces a more equidistant plant distribution [11]. Twin-rows planting produced more yield than single-row planting (Table 3). Andrade *et al*. [3] reported that grain yield increase in response to narrow rows was closely related to the improvement in light interception during the critical period of grain set. Shapiro *et al*. [20] stated that grain yield was 4% higher with 0.51-vs. 076-m row spacing.

The highest grain yield and harvest index obtained from 10 plants m^{-2} and for biological yield from 13 plants m^{-2} that means optimum density for yield per unit area is lower than for biological yield (Table 3). This result of grain yield is supported by achievement of Hashemi *et al.* [13]. The increase grain yield observed at twin-rows pattern in 10 plant m^{-2} is a function of more number of grains per row which is produced as a result of more grains per ear. Duncan [9] has suggested that such an interaction should occur with a greater advantage with narrower row spacing at high planting density than at lower one. Edmeads and Daynard [10] reported that the effect of high plant densities on the mean grain yield per plant was reflected in the grain number per plant and grain weight per 100 kernels, but kernel weight had not affected by planting density in our study.

The lowest grain yield was achived at single row pattern in 13 plant m^{-2}, because of lower grains per ear. At the highest density (13 plant m^{-2}), many kernels may not develop, due to poor pollination resulting from a delayed silking period compared with tassel emergence [16] and/or due to a limitation in assimilate supply that caused kernel and ear abortion [23].

The absence of a planting pattern and density and their interaction effects on biological yield may be due to the great plant growth, resulting in canopy interception of a very large proportion of the incident incoming photosynthetically active radiation at both narrow and wide row spacing [17].

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