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Study of effects of cultivar, weeds and plant density on yield and yield components of sweet corn under Iranian warm environment

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Abstract

The objective of the study was to determine important agronomic traits of sweet corn hybrids under weeds fully controlled and not-controlled conditions at different plant densities. The study was carried out in Hajiabad, Hormozgan, Iran in 2006. It was a split-split plot design based on a randomized complete block design with four replications. The main plots included sweet corn hybrids, namely KSC403 and Shimmer, the sub-plots included two levels, namely weeds fully controlled and not-controlled conditions, and the sub-sub-plots included three densities of 53000, 67000 and 89000 plants/ha. The results of analysis of variance showed that the variations of Shimmer and KSC403 in grain yield, 100-grain weight, grain number/row and row number/ear were significant. Also, weeds full control increased the grain yield by 7.8%. The highest grain yield was 9700 kg/ha for Shimmer at the density of 89000 plants/ha under weeds fully controlled conditions. In total, Shimmer exhibited superior traits over KSC403. In addition, Shimmer produced the highest grain yield at the density of 89000 plants/ha under weeds fully controlled conditions.

Keywords: sweet corn; weeds controlling; plant density; KSC403; Shimmer.

Introduction

Selecting high-yield cultivars adaptive to regional climate, controlling weeds and selecting suitable plant density/unit area are some important factors in achieving the maximum efficiency in sweet corn production. Realizing the highest possible yield depends upon adequate moisture availability, soil fertility and crop genetic capacities. The maximum production efficiency is likely to be obtained considering plant density and increasing plant number/ha in row crops. Seed number recommendations, row spacing and plants spatial arrangement have been traditionally determined by experiments over the time (Hashemi-Dezfuli *et al*., 2001). Studies show that as plant density increases, the flowers and fruits do not form or are sterilized (Kiniry and Ritchie, 1985). To have a suitable plant density, row spacing and plant spacing on rows can be changed, by which plants can have access to optimum moisture and radiation and as a result, their yield can effectively increase. In a study on suitable plant density of sweet corn in the north-eastern U.S., Morris *et al*. (2000) reported that most cultivars produced the highest yield at densities of 59300-69200 plants/ha. They found that if only ears with over 17.78 cm in length were counted, the densities of 35500-59300 plants/ha should be used depending on the cultivar. Garrison (2002) reported that the best plant density was on plant spacing of 20.3-30.5 cm with a row spacing of 76.2 cm. In a study on the effect of plant density and cultivar on ear yield and quality of early-planting sweet corn in New York region, Rangarajan *et al*. (2002) reported that cultivar and plant spacing on rows had significant effects on ear yield and length. They used plant spacing of 15.2-22.9 cm and row spacing of 76.2 cm. In response to different densities, mean ear length of cultivars varied in the range of 0.5-1.5 cm. They found that the cultivars with shorter plant height were less affected by plant density. Peet (2004) recommended the density of 44400-54300 plants/ha with a row spacing of 76.2-106.6 cm and plant spacing of 15.2-30.4 cm for the southern US. Hashemi-Dezfuli *et al*. (2001) reported that the density of 75000 plants/ha was not appropriate in Khoozestan, Iran due to incomplete canopy coverage of the field. They speculated that higher densities might produce higher yield. Gardner *et al*. (2000) recommended the density of 50000 plants/ha as the best plant density for sweet corn. Smith *et al*. (1996) reported that sweet corn was planted with different densities in California, plant spacing was 17.5-25 cm and row spacing was 16-76 cm for planting one or two rows on one furrow. But they reported 47000-50000 plants/ha as the best density. Earley *et al*. (2001) found that cob diameter and length decreased as light faded. In maize, it has been observed that as the plant density increases, the ratio of net energy at soil surface to that above plant canopy decreases. Under such density, this ratio increases as row spacing decreases. For example, when row spacing is 60 cm, the available energy for photosynthesis will increase by 15-20% compared to the row spacing of 100 cm. Therefore, narrower rows intercept greater amount of radiation than wider rows. Since upper leaves are well-exposed to solar radiation, they are usually at photo-saturation status, while lower leaves that face radiation deficiency are the first supplying source of carbohydrates for roots. So, plant density can affect suitable distribution of radiation and decrease radiation deficiency of lower leaves. Williams *et al*. (1985) studied flint corn at seven densities of 17500-125000 plants/ha in a square planting pattern and found that as the density increased, the maximum grain yield declined. Also, with the increase in plant density, grain dry weight/plant decreased. Moreover, with the increase in plant density up to 125000 plants/ha, leaf angle exceeded 34°, i.e. they became more vertical. In addition, leaf area index increased. Stickler and Loude (1995) studied maize in three densities of 39000, 49000 and 59000 plants/ha under irrigation and rain-fed conditions with row spacings of 51, 76 and 102 cm and reported that the plant density significantly affected yield and the lowest yield was obtained at the density of 39000 plants/ha. In addition, row spacing of 51 cm produced higher yield.

From the viewpoint of competition and presence of weeds and its effect on crop yield, it can be said that the yield decrease/unit weed is lower when the density of weeds is higher in some spots of the farm than when weeds are uniformly distributed throughout the farm because the uniform distribution of weeds decrease inter-species competition of weeds and intensifies their competition with maize (Kropff and Lotz, 1993). It should be noted that the non-uniform distribution of weeds throughout the farm may affect the samples taken from the field, which may at last lead to using greater amount of herbicides which will not be cost-effective (Johnson *et al*., 1993). The studies on weeds show that different species have different competition capacity which in addition to species and density depends on environmental factors, too (Koocheki *et al*., 1992). In a study, it was shown that dicot weed species had a higher competition capacity than monocot ones at low plant densities. Moeching *et al*. (1999) indicated that foxtail, lamb's-quarter and velvetleaf decreased maize yield by 10, 11 and 18%, respectively. The decrease in maize yield by weeds varies in different years and places, e.g. the yield decrease by lamb's-quarter was reported as 12% in Illinois in 1985, while no decrease was seen in 1986. Most annual weeds like lamb's-quarter have a high seed production potential and so, they can simply keep their presence in farm and interfere with crops. The final success of a plant in occupying a region depends in long term on its reproduction capacity in order to preserve its population over time. In the case of annual weeds, seeds are the mere bridge between successive generations and locacions. To realize their seed production potential, they are affected not only by climatic conditions, soil fertility and crop competition but also by density and emergence time. Annual weeds like lamb's-quarter can rather stably adjust and sustain their reproduction capacity by growth responses associated with density, adaptability and mortality (Koocheki *et al*., 1992). In a study on two densities of 11300 and 45300 plants/ha of some maize hybrids, Peneleit and Egli (1998) found that the grains were smaller and fewer at higher densities. They reported 20% decrease in yield, from which 6% was due to lower grain weight and the remaining 14% was due to lower grain number. Reed *et al*. (1999) reported that when plants were kept under shadow during vegetative period, grain number and yield/plant were decreased by 5% and 12%, respectively, but shadow did not greatly affect

Table 1. Analysis of variance for grain yield and yield components.

Source of variation	df	Means of squares			
		Grain yield	1000-grain weight with 14% moisture	Grain no./row	Row no./ear
Replication	3	287.21*	8.041^{ns}	9.3^{ns}	1.86^{ns}
Hybrid (SU)	1	37065.2*	154.2*6	31.69^{ns}	2.08^{ns}
Error	3	3911.85	11.18^{ns}	23.91^{ns}	6.53^{ns}
Weeds control (W)	1	4413.5^{ns}	3.53^{ns}	1.02^{ns}	0.08^{ns}
SU × W	1	2451.17^{ns}	0.28^{ns}	2.52^{ns}	0.08^{ns}
Plant density (D)	2	20834.3**	5.36^{ns}	80.08*	4.33^{ns}
SU × D	2	114.93*	3.06*	33.25^{ns}	6.33^{ns}
W × D	2	5614.88*	7.35^{ns}	18.08^{ns}	0.33^{ns}
SU × W × D	2	874.29*	0.87^{ns}	10.08^{ns}	2.33^{ns}
Total error	30	109.05	5	15.85	3.93
Source of variation percentage		14.15	9.81	11.18	12.35

* and ** show significance at 1% and 5% probability level, respectively and ^{ns} shows non-significant

grain weight. When they were kept under shadow during flowering period, grain number decreased by 21%. When shadow was imposed during grain filling period, 1000-grain weight and grain number/row decreased by 13% and 5%, respectively. Major *et al*. (1991) indicated that with the increase in maize planting density, solar radiation use efficiency increased, for which the likely reason was the increase in leaf area index, because when leaf area index is lower, either leaves are smaller or fewer, so they are photo-saturated sooner and consequently, their solar energy use efficiency decreases.

Materials and Methods

The study was carried out in Agriculture Research Station of Hajiabad, Hormozgan province, Iran (Lat. 28°17´ N., Long. 55°55´ E.) during summer and autumn in 2006. The experiment was a split-split-plot based on a randomized complete block design with four replications. The main plot consisted of two sweet corn hybrids [KSC304 (SU1) and Shimmer (SU2)], weeds controlling and not-controlling constituted the sub-plot and three plant densities including 53000, 67000 and 89000 plants/ha (with plant spacings of 25, 20 and 15 cm on rows, respectively) were the sub-sub-plots. There were 48 experimental plots. The replications were 2 m apart, main plots were 1.5 m apart and sub-plots and sub-sub-plots were 0.75 m apart. Each plot consisted of 5 planting rows of 5 m length and 0.75 m apart. Before planting, furrows were made on ridges with an approximate depth of 7 cm, then seeds were sown on furrows with spacings of 15, 20 and 25 cm. Afterwards, the seeds were covered with soft soil and irrigated by traditional furrow method. Thinning and plant density adjustment operations were carried out at 4- and 7-leaf stages. Half of the plots were continuously weeded by hand from planting until final stages. The subsequent irrigations were conducted in 7-day intervals up to grain harvest stage. To provide adequate nutrition for plants, 300 kg ammonium phosphate/ha + 50% of required urea (200 kg/ha) were applied before planting. The remaining 50% of urea was applied at 8-9-leaf stage as top dressing. To have precise statistical results and eliminate margin effect, three middle rows from all five rows in each plot were selected for sampling and the side rows in each plot were left as margins. The seeds o sweet corn KSC304 was provided by Seeds and Plant Improvement Institute, Karaj, Iran and the hybrid Shimmer was procured from foreign germplasms. These hybrids are used as fresh food as well as in canning industry. After the harvest, their fodder is used in feeding. In this study, the traits which were statistically analyzed included grain yield, 1000-grain weight with 14% moisture, grain number/row and row number/ear. Analysis of variance and means grouping were done on the basis of Duncan Multi-range Test (at 95% level) using the software MSTAT-C. The graphs were drawn by the software MS-Excel.

Results and Discussion

The results of analysis of variance of grain yield of different hybrids showed that the hybrids KSC403 and Shimmer were significantly different regarding grain yield/unit area, but such a difference was not observed in the case of grain number/main ear and row number/ear. As can be seen in Table 1, the grain weights of hybrids were significantly different at 95% level which can be the main cause of significant difference in

Table 2. Means comparison of main effects and interactions of treatments on grain yield and yield components

Treatment	Grain yield (t/ha)	1000-grain weight	Grain no./row	Row no./ear
Hybrid (SU)				
KSC403 (SU1)	6.5 a	21 b	34.8 a	15.8 a
Shimmer (SU2)	8.3 b	24.6 a	36.4 a	16.3 a
Weeds (W)				
Full controlling (W1)	7.7 a	23 a	35.8 a	16.1 a
Not controlling (W2)	7.1 a	22.5 a	35.5 a	16 a
SU × W				
SU1 × W1	6.6 a	21.2 a	35.2 a	15.8 a
SU1 × W2	6.4 a	20.8 a	34.4 a	15.8 a
SU2 × W1	8.8 a	24.9 a	36.3 a	16.3 a
SU2 × W2	7.7 a	24.2 a	36.5 a	17.2 a
Plant density (plants/ha)				
53000 (D1)	6.4 b	23.4 a	38.2 a	16.6 a
67000 (D2)	7.1 ab	22.2 a	34.3 b	15.6 a
89000 (D3)	8.6 a	22.8 a	34.3 b	15.9 a
SU × Plant density				
SU1 × D1	5.5 c	21.25 ab	35.88 a	16.5 a
SU1 × D2	6.2 bc	20.3 b	34.88 a	14.75 a
SU1 × D3	7.8 ab	21.46 ab	33.63 a	16.25 a
SU2 × D1	7.3 abc	25.54 a	40.5 a	16.75 a
SU2 × D2	8.1 ab	24.16 ab	33.75 a	16.5 a
SU2 × D3	9.4 a	24.06 ab	35 a	15.5 a
Means comparison of W × D				
W1D1	6.1 c	22.88 a	37.13 a	16.75 a
W1D2	8.1 abc	22.87 a	34.88 a	15.75 a
W1D3	8.8 a	23.45 a	35.25 a	15.75 a
W2D1	6.6 bc	23.9 a	39.25 a	16.5 a
W2D2	6.2 bc	21.6 a	33.75 a	15.5 a
W2D3	8.4 ab	22.07 a	33.38 a	16 a

The same letter(s) in each column shows significant difference on the basis of Duncan Test at the level of 5%.

their yield. Table 2 shows means comparison of grain yield in different hybrids by Duncan Method (95%). In this study, Shimmer not only produced 1.8 t/ha higher yield than KC403, but also it had higher 1000-grain weight, i.e. it increased from 21 g to 24.6 g. Therefore, the difference of hybrids in 1000-grain weight can be the cause of their significant difference in yield. The reason is the lack of significant difference in grain number/row and row number/ear.

Means comparison of grain yield and yield components under weeds controlled and not-controlled conditions indicated that the weeds were not able to make significant differences in yield (Table 2). This is important because unlike grain corn and forage corn hybrids whose grain yields were significantly affected by weeds control, sweet corn hybrids have the ability of producing multiple tillers. This ability of tillering in turn decreases weeds competition potential. This is why they did not make significant differences at the probability level of 95%.

Also, different plant densities/unit area affected grain yield at probability level of 1%, so that in Hajiabad, the densities of 89000 and 53000 plants/ha had the highest (8.6 t/ha) and lowest (6.4 t/ha) grain yields, respectively. Also, means comparison showed that by the increase in plant density from 53000 to 89000 plants/ha, the grain yield could be increased by 26% (Table 2). The variation of plant density/ha affected row number/ear at the probability level of 95% too, so that the density of 53000 plants/ha had the highest grain number/row (38 grains/row) and the density of 67000 and 89000 plants/ha had the lowest one (34 grains/row). Row number/ear and 1000-grain yield were not affected by the variations in plant density. In some studies, the increase in grain yield due to the variations in plant density has been related to the increase in grain number and weight, and grain number has been mentioned as the main cause of the increase in corn grain yield at different plant densities (Duncon, 1993; Kiniry and Ritchie, 1985). Stickler and Loude (1995) studied the corn in three planting densities of 39000, 49000 and 59000 plants/ha under irrigated and rain-fed farming with three row spacing of 51, 76 and 102 cm and

Table 3. Means comparison of the main effects and interactions of treatments on grain yield and yield components.

Treatment	Grain yield (t/ha)	1000-grain weight (g)	Grain no./row	Row no./ear
		Hybrid × weeds × plant density		
SU1 × W1 × D1	5.1 c	20.55 a	35.5 a	16.5 a
SU1 × W1 × D2	6.6 b	20.71 a	34.75 a	14.5 a
SU1 × W1 × D3	8.1 ab	22.33 a	35.25 a	16.5 a
SU1 × W2 × D1	5.9 b	21.94 a	36.25 a	16.5 a
SU1 × W2 × D2	5.7 b	19.9 a	35 a	15 a
SU1 × W2 × D3	7.6 ab	20.58 a	32 a	16 a
SU2 × W1 × D1	7.2 b	25.21 a	38.75 a	17 a
SU2 × W1 × D2	9.5 a	25.04 a	35 a	17 a
SU2 × W1 × D3	9.7 a	24.56 a	35.25 a	15 a
SU2 × W2 × D1	7.4 ab	25.86 a	42.25 a	16.5 a
SU2 × W2 × D2	6.7 ab	23.29 a	32.5 a	16 a
SU2 × W2 × D3	9.2 a	23.57 a	34.75 a	16 a

The same letter(s) in each column shows significant difference on the basis of Duncan Test at the level of 5%.

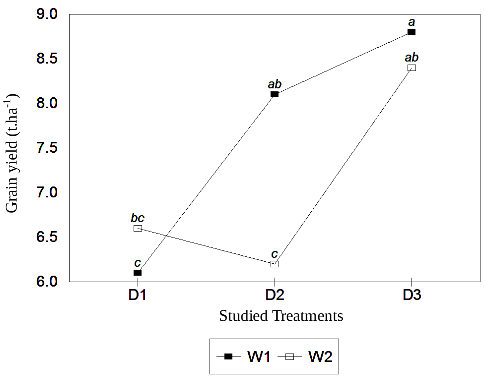

Fig. 1. The effect of the interaction between plant density and weeds control on grain yield. Diagrams D1, D2, D3 and D4 show the densities of 53000, 67000 and 89000 plants/ha, respectively and W1 and W2 show weeds full control and not control treatments, respectively.

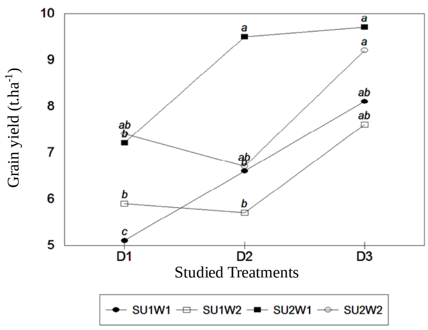

Fig. 2. The effect of hybrid (SU1 and SU2) × weeds control × plant density (D1, D2 and D3) interaction on grain yield.

reported that plant density significantly affected yield and the lowest plant density had the lowest yield.

Regarding the interaction between treatments, it can be said that the interaction between hybrid and weeds control was insignificant for all the studied traits. Nonetheless, in all treatments included Shimmer, yield and all the other studied traits showed more desirable conditions (Table 2). On the other hand, the interactions between hybrids and different plant densities showed significant differences for grain yield and weight (Table 1).

Means comparison of the studied traits showed that Shimmer and KSC403 had the highest yields at the density of 89000 plants/ha (9.4 and 7.8 t/ha, respectively). In this study, the interactions between weeds control and plant density only affected the grain yield at probability level of 95%. Means comparison of grain yield for weeds full control at the density of 89000 plants/ha gained the highest rank with an average of 8.8 t/ha.

Figure 1 shows the interactions between plant density and weeds controlling and their effect on grain yield. It should be noted that both hybrids were less affected at higher plant densities and that with the increase in plant density from 67000 plants/ha, grain yield was significantly increased as compared with the weed not-control treatment. The interactions among all three hybrid, weed and plant density treatments affected grain yield at probability level of 99%. Grain yield means comparison put the effects of hybrids, weeds and plant densities on treatment combinations of SU2×W1×D3, SU2×W1×D2 and SU2×W2×D3 in the same group, so that in all these grain yield was greater than 9.2 t/ha. It is important that sweet corn had the highest grain yield at approximate densities of 67000-89000 plants/ha. On the other hand, by controlling the weeds the grain yield of both hybrids could be increased by about 6%. However, the grain yield, especially of Shimmer was more strongly affected by weeds at the density of 67000 plants/ha and weeds controlling at this density increased grain yield from 6.7 to 9.5 t/ha.

Figure 2 shows the variations in grain yield under various treatment combinations. As can be seen, Shimmer had a relatively higher yield at all treatments. In addition, the grain yield was higher in weeds full control treatment than that in not-control treatment. On the other hand, the grain yield was higher in higher plant densities at all treatments. But as the main result of the study, it can be said that the interaction between hybrids especially Shimmer had its main effect on tillering potential of this hybrid. Indeed, the plant itself can mitigate the competition of surrounding weeds. For example, the decrease in density from 98000 to 67000 plants/ha under weeds full control conditions did not decrease its yield. But under weeds not-control conditions, the best practice for controlling the competition and avoiding grain yield decline in the studied area and similar areas is to increase the plant density.

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