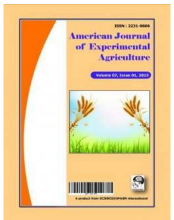

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Effect of Planting Date and Plant Densities on Yield and Yield Components of Sweet Corn (*Zea mays* L. var saccharata)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out to investigate the effect of planting date and plant densities on yield and yield components of sweet corn at agricultural and resources research center of Razavi Khorasan, Iran during 2009 growing season. A split plot experiment, based on randomized complete block design with four replications performed using SC 403 cultivar. The main plots belonged to three planting dates (D1: May 15, D2: July 4, D3: July 25) while subplots belonged to different plant densities (P1: 66600, P2: 83300 and P3: 111000 plants ha^{-1}). There was significant different between planting dates in respect of plant height, ear height, leaves number, leaves number above ear, stalk diameter, de-husked ear yield, conservable grain yield, ear number per plant, grain rows per ear, ear length and diameter, grain depth, 1000- grains weight and harvest index. The highest (18.27 t ha^{-1}) and lowest (0.93 t ha^{-1}) conservable grain yield produced at D1 and D3 respectively. Delay cropping resulted in lower grain yield due to lower growth duration, lower temperatures and solar radiation at late season. There was significant difference between

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different plant densities in respect of ear yield, de-husked ear yield and fresh forage yield. The highest (8.86 t ha^{-1}) and lowest (7.69 t ha^{-1}) grain yield observed for P3 and P1 respectively. Harvests invest affected by interaction between planting date and plat density. The highest conservable grain yield produced at May 15 at the highest plant density level (111000 plants ha^{-1}).

Keywords: Plant density; maize; planting; conservable grain yield; sweet corn.

1. INTRODUCTION

Sweet corn (*Zea mays* L. var saccharata) is a popular vegetable in USA and its popularity has increased in Asia and Europe too. Sweet corn is the product of mutation in genes which control the starch synthesis at kernel endosperm [1]. Sweet corn harvested areas enhanced in Iran due to increasing demand for it during recent years. Sweet corn is a short season vegetable which is suitable for crop rotation in order to planting between two winter crops. It will results in economic use of land and time. Planting date is one of the most important factors in agricultural systems. Maize yield will maximized by selecting the proper planting date. Grain biomass is affected by environmental situations in all growing stages. Temperature and day length are two important factors in planting maize [2]. Sweet corn germination rate and phonology affected by planting date. The minimum soil temperature for maize germination is 13℃ while the optimum soil temperature ranged between 21 to 27℃. At 10℃ maize percentage decreases and germination last for 20 days [3]. An investigation performed about the effect of planting date on maize production at Arlington-USA during 1983-85. The results showed that the yield decreased by delay cropping [4]. Hashemi Dezfoli et al. [5] investigated the effect of four planting dates (August 25, September 1, September 12, September 21) on yield of two sweet corn cultivars (HMX-8394 and HMX-esteem) at Ahvaz-Iran. The results showed that grain yield and kernel per row was significantly affected by planting date. Tamadon Rastegari [6] examined the effect of four planting dates (April 25, May 10, May 25, June 9) on yield and yield components of sweet corn cultivar KSC 403. The results showed that kernel per row, kernel per ear, ear length, 1000-grains weight and stalk diameter affected by planting dates. There was significant difference between planting dates in respect of grain yield too. The highest grain yield obtained at April 25 with 65000 plants ha^{-1} population. The effect of two summer planting dates (June 10 and June 25) on yield and agronomic characteristics of p sweet corn cultivars studied by Khavari Khorasani et al [7] at Mashhad-Iran. The highest grain yield (11.64 t ha^{-1}) produced at June 25, but there was no significant difference studied planting dates in respect of grain yield. The highest grain yield (16.65 t ha^{-1}) observed for Chase (the short season cultivar) at both planting dates. Oktem [8] studied the effect of eight planting dates (April 26, May 9, May 26, June 11, June 26, July 26 and August 11) on yield and yield components of sweet corn at Turkey. There were significant differences between May 26 to July 26 in respect of ear yield, ear diameter, kernel number per ear and ear weight. Noldin and Mundstock [9] declared that ear yield decreased about 9% at November 1 compared with October 11 but kernel per ear did not affected by planting date. Plant density is an important factor in obtaining the highest yield. Yield components affect by plant density and make changes in yield [10, 11]. Increasing plant density is associated with an increase in crop yield to a threshold, thus increasing plant density does not make changes is crop yield and finally crop yield decreases by higher plant densities [12]. Morris et al [13] studied the effect of different plant densities on sweet corn yield at North-East of USA. They declared that plant density is depended on ear length. The proper density for cultivars with 17.78 cm ear length, evaluated between 35500 to 59300 plants ha^{-1}. Peet [14] proposed that a row space between 76.2 to 106.6 cm with 15.2 to 30.4 cm plant distance on rows, results in final 44477 to 54631 plant ha^{-1} density and is proper for sweet corn at the south areas of USA. Tian et al [15] investigated the effect of plant densities on yield and yield components of two sweet corn cultivars at China. The highest yield obtained at 52500 plants ha^{-1} density. Ear weight affects by plant density too. Duncan [16] declared that ear weight decreased at high plant densities due to shading. Ear length affect by plant density too [17,18]. Plant height enhances by plant density but by higher plant densities plant height will decrease. Light interception decreases at high plant densities and result in internodes' elongation due to lower auxin decomposition [19]. Atrashi [20] reported that plant height, unfertilized ears and 1000- grains weight significantly affected by planting date. Danai et al. [21] studied the effect of planting date on sweet corn yield and stated that both SC 402 and SC 403 produced higher yield and yield components at February 9 in Bahaman-Iran condition. The highest 1000-grains weight, grain row and grain per row produced by SC 402 and SC 403 at early February planting date. Darby and Lauer [22] stated that the highest forage yield produced at early May and early June planting dates. They also declared that forage yield of sweet corn increased by high plant densities. Forage yield enhanced 15 percent in high plant density compare with lower plant density. The aim of the present study was to determine the best planting date and plant density of sweet corn in respect of yield and morphological characteristics at Mashhad environmental conditions.

2. MATERIALS AND METHODS

The experiment was carried out at agricultural and resources research center of Razavi Khorasan, Iran during 2009 growing season. The site is located at south east of Mashhad with 36° 13' N latitude and 59°40' E longitude, 985 m altitude above the sea level and mean 202 mm annual precipitation. Soil analysis resulted in a loam-silt texture with 30 cm depth. Electrical conductivity of soil was 1-1.67 ds/m and the pH ranged 7.8 to 8. A split plot experiment, based on randomized complete block design with four replications performed using SC 403 cultivar. The main plots belonged to three planting dates (D1: May 15, D2: July 4, D3: July 25) while subplots belonged to different plant densities (P1: 66600, P2: 83300 and P3: 111000 plants ha^{-1}). Plant density adjusted by differing plant distance on the rows. Plant distances were 20, 16 and 12 cm for P1, P2 and P3 respectively. There were 36 experimental plots with 4 plant rows and 75 cm row space. Three seeds put in each hole by hand. Thinning performed at 4 to 6 leaves stage. Irrigation carried out each 4 days until plant emergence. After plant stability, irrigation performed based on plant water requirement. Fertilizers applied based on soil analysis using the instruction of Iran Soil and Water Research Center. The amount of applied fertilizers were 200 and 300 kg ha^{-1} ammonium phosphate, potassium sulfate and urea respectively. Delayed urea application was managed in order to reducing nitrogen leaching. Urea applied at 6-8 and 10-12 leaves stages. Soil crust was controlled in order to better root growth. Weeding performed using 5 lit ha^{-1} Eradicane®. Morphological characteristics (plant height, ear height, stalk diameter, leaves number and leaves number above ear) measured on 10 random plants in each plot during growing season. Stalk diameter measured at 2 internode. Plots harvested at early dough stage when grains had 65-70 percent humidity. In each plot two marginal rows eliminated. Plants and ears number in each plot counted before harvest. Then ears picked by hands and weighted. Ear yield, de-husked ear yield and ear per plant was determined. Ear length, ear diameter, grain per row, row per ear, grain depth measured on 10 samples of each plot. Kernels cut and then, 1000- grains weight and conservable grain yield determined at 70 percent humidity. The whole plot harvested in order to determine forage yield. Plant harvest index determined as the weight of conservable grains to the percentage of forage yield. Ear harvest index evaluated by dividing the weight of conservable grains on ear yield. The recorded date analyzed using MSTAT-C statistical software. Significance of differences between means was conducted using Duncan's multiple range test.

3. RESULTS AND DISCUSSION

3.1 Plant and Ear Height

The results of analysis of variances showed that both plant and ear height affected by planting date ($p<0.01$) but did not affect by plant density (Table 1). The highest (183.6 cm) and lowest (143.1 cm) plant height produced at D2 and D1 respectively. The same results observed for ear height and the highest (79.64 cm) and lowest (55.01 cm) ear height belonged to D2 and D1 respectively (Table 3). Light intensity reduces by delay cropping due to higher plant competition which results in plant height enhancement. Benoit et al. [23] reported that the most important factor in crop growth is temperature. They declared that temperature is a determining factor in light absorbance and dry material production. Crop resources use efficiency enhances by selecting the proper planting date. Hashemi Dezfoli et al. [5] investigated the effect of planting date on yield and yield components of sweet corn at Khuzestan-Iran. Results showed that ear height significantly affected by planting date. Ear height enhanced by planting dates August 25 to September 12. But at September 21 ear height decreased significantly. Thus ear height changes in response to environmental condition.

3.2 Number of Leaves per Plant and above Ear

Results showed that leaves number and leaves number above the ear affected by planting date ($p<0.01$). There was no significant difference between plant densities in respect of these two characteristics (Table 1). The highest (11.41) and lowest (9.99) leaves number produced at D3 and D1 respectively. The highest (6.45) and lowest (5.67) leaves number above the ear produced at D2 and D1 respectively (Table 3). The results were in agreement with Faravani [4] who reported that leaves number, plant height and ear height enhanced by planting maize at mid-June.

3.3 Stalk Diameter

Stalk diameter affected by planting date ($p<0.01$), but there was no significant difference between plant densities in respect of stalk diameter (Table 1). The thickest (22.82 mm) and thinnest (20.06 mm) stalks produced at D3 and D1 respectively (Table 3). Stalk diameter increased by delay cropping. High temperatures and higher light intensity results in producing more photosynthetic assimilates and higher crop growth and make the stalks thick [24].

3.4 Conservable Grain Yield

Grain yield affected by planting date ($p<0.01$). There was no significant different between plant densities in respect of conservable grain yield (Table 2). The highest (18.27 t ha^{-1}) and lowest (0.93 t ha^{-1}) grain yield produced at D1 and D3 respectively (Table 4). Late season low temperatures occurred during grain filling and resulted in low grain yield. Sweet corn grain yield decreases by delay cropping due to chilling stress during grain filling. Thus the best planting date in respect of grain production is late June. Plants have not enough time to growth by planting dates after June and thus the grain yield decreases.

3.5 Husked and De-husked Ear Yield

Husked Ear yield did not affect by planting date ($p<0.05$). There was significant difference between plant densities in respect of ear yield (Table 2). Ear yield enhanced by high plant densities. The highest ear yield (34.43 t ha^{-1}) produced at P3. De-husked ear yield affected by both planting date ($p<0.05$) and plant density ($p<0.01$) (Table 2). The highest de-husked ear yield (22.9 t ha^{-1}) produced at P3. The highest (23.69 t ha-1) and lowest (12.79 t ha^{-1}) de-husked ear yield produced at D1 and D3 respectively (Table 4). Tian et al. [18] investigated the effect of plant density on sweet corn yield and reported that the highest yield produced by 52500 plants ha^{-1}.

3.6 Number of Ear per Plant

Ear number per plant did not affect by planting date, but there was significant difference between planting densities in respect of ear per plant ($p<0.01$) (Table 1). The highest ear per plant (2.41) produced at P2. Ear per plant decreased by higher plant densities. Ear number per plant decreased to 1.89 at P3. Less ears produce at high plant densities due to higher competition rates.

3.7 Row per Ear and Grain Row per Ear

Grain per ear affected by planting date ($p<0.01$) (Table 2). Grain row per ear did not affect by planting date nor by plant density (Table 1). The highest (38.82) and lowest (27.18) grain per ear produced at D1 and D3 respectively (Table 4). At late planting dates, low temperatures during pollination may results in pollen sterility. Thus lower fertility occurs and less grains were produced. Results showed that the best environmental conditions (such as humidity and temperature) were prepared at mid May planting date. Danai et al. [21] studied the effect of different planting dates on yield and yield components of different sweet corn cultivars at Behbahan-Iran. Results showed that the highest yield components produced by SC 402 and SC 403 at February 9. The highest 1000- grains weight, grain row and grain per row produced by SC 402 and SC 403.

3.8 Ear Diameter, Grain Depth

Grain depth and ear diameter ($p<0.01$) was affected by planting date. There was no significant difference between plant densities in respect of grain depth and ear diameter (Table 1). The highest (34.26 mm) and lowest (17.28 mm) grain depth observed for D2 and D3 respectively (Table 4). The amount of assimilates which consume in producing grains determine by grain depth. The highest (50.8 mm) and lowest (31.6 mm) produced at D2 and D3 respectively (Table 4). Higher soil temperature and decreasing air temperatures during pollination resulted in pollen degradation and low grain depth and slender ears. At late planting dates,

Table 1. Analysis of variance for sweet corn morphological characteristics on different planting date and plant density

S. O. V	Df	Mean of squares									
		1	2	3	4	5	6	7	8	9	10
Rep (R)	3	20.78 n.s	66.71 n.s	0.865 n.s	0.043 n.s	0.213n.s	1.728**	9.940 n.s	0.246 n.s	13.77 n.s	0.316 n.s
D	2	4957.85**	1872.48**	6.74**	1.84 **	23.68*	134.85**	1308.70 **	1.903 n.s	1096.81**	0.231n.s
Error (a)	6	92.64	51.617	0.262	0.080	2.708 n.s	0.126	15.07	2.230	26.34	0.765
P	2	9.54 n.s	31.20 n.s	0.333 n.s	0.021 n.s	2.415 n.s	1.774 n.s	0.477 n.s	0.826**	3.054 n.s	0.320n.s
P×D	4	53.60 n.s	12.97 n.s	0.131 n.s	0.158 n.s	0.400 n.s	0.534 n.s	16.11 n.s	0.110n.s	24.227 n.s	0.709n.s
Error (b)	18	63.57	28.99	0.130	0.061	1.616	1.253	11.77	0.110	20.618	0.944
C.V %		4.92	7.86	3.33	4.07	5.88	6.55	7.86	15.46	16.04	5.71

(1): Plant height, (2): Ear height, (3): Number of leaves plant^{-1}, (4): Number of leaves above ear, (5): Stalk diameter, (6): Ear length, (7): Ear diameter, (8): Number of ear plant^{-1}, (9): Grain depth (mm), (10): No. of grain Row per ear. D: Planting date, P: Plant density also D × P: Interaction between planting date and plant density. CV: Coefficient of variance. Ns, and **: Non-significant and significant at 5% and 1% levels of probability, respectively.*

Table 2. Analysis of variance for sweet corn morphological characteristics on different planting date and plant density

S. O. V	Df	Mean of squares							
		1	2	4	5	6	7	8	9
Rep (R)	3	15.37*	844.53 n.s	12.59 n.s	103.95 n.s	35.07 n.s	19.04 n.s	18.83 n.s	30.94 n.s
D	2	502.69 **	298551.8**	951.64**	419.93 n.s	447.57*	224.04 n.s	765.36 **	1180.02**
Error (a)	6	3.512	1932.97	16.94	121.33	52.99	190.88	17.25	14.34
P	2	1.997 n.s	667.19n.s	4.91 n.s	230.81*	118.83**	609.38**	0.787 n.s	62.71 n.s
P×D	4	1.362 n.s	1415.82n.s	9.19 n.s	51.26 n.s	35.04 n.s	89.72 n.s	25.62**	13.84 n.s
Error (b)	18	3.252	1437.31	10.83	46.38	16.99	54.12	11.63	24.02
CV %		5.21	21	39.05	22.04	20.78	20.84	11.56	7.84

(1): No. of grain Per Row, (2): 1000-grain weight, (3): Conservable Grain Yield, (4): Husked ear yield, (5): Dehusked ear yield,(6): Fresh forage yield, (7): Ear Harvest Index, (8): Plant harvest index. D: Planting date, P: Plant density also D × P: Interaction between planting date and plant density. Also CV: Coefficient of variance. Ns, and **: Non – significant and significant at 5% and 1% levels of probability, respectively*

Table 3. Means comparison for standard ear yield and some agronomic characteristics of baby corn on different planting date

Planting date	Treatment						
	1	2	3	4	5	6	7
14 June	143.1 c	55.01 c	9.992 b	5.675 c	20.06 b	70.20 a	36.68 a
3 July	183.6 a	79.64 a	11.13 a	6.458 a	21.92 a	66.02 b	30.90 b
24 July	159.7 b	70.93 b	11.41 a	6.108 b	22.82 a	51.32 c	20.90 c

(1): Stalk Diameter (mm), (2): Number of leaves plant^{-1}, (3): Number of leaves above ear, (4): Ear height (cm), (5): Plant height, (6): Ear Harvest Index, (7): Plant harvest index. Mean followed by similar letters are not significantly different at 5% probability level.

Table 4. Means comparison for standard ear yield and some agronomic characteristics of baby corn on different planting date

Planting date	Treatment						
	1	2	3	4	5	6	7
14 June	19.63 a	48.91 a	38.82 a	355.94a	33.40 a	23.69 a	18.27 a
3 July	18.35 b	50.38 a	37.92 a	135.17b	34.26 a	23.01 a	6.082 b
24 July	13.29 c	31.60 b	27.18 b	50.14c	17.28 b	12.79 b	0.930 c

(1): Conservable Grain Yield, (2): Dehusked ear yield (kg ha^{-1}), (3): Grain depth (mm), (4): Dehusked ear yield (kg ha^{-1}), (5): Dehusked standard ear yield (kg ha^{-1}), (6): Ear diameter, (7): Ear length. Mean followed by similar letters are not significantly different at 5% probability level.

chilling stress occurs during grain filling which results in lower grain yield too. Tamadon Rastegari declared that grain per row, total grain per ear, ear length, 1000- grain weight, cob weight and stalk diameter of sweet corn significantly affect by planting date. Row per ear, plant height and cob diameter did not affect by planting date [6].

3.9 Ear Length

Ear diameter affected by planting date ($p<0.01$) but there was no significant difference between plant densities in respect of ear diameter (Table 1). The longest (19.63 cm) and shortest (13.29 cm) ears produced at D1 and D3 respectively (Table 4). Suitable environmental conditions resulted in better ear formation at D1 compared with D2 and D3. Ear length is an important qualitative characteristic in sweet corn. Ears shorter than 15 cm are not suitable for processing [17]. Mokhtarpour et al. [17] investigated the effect of planting date and plant density on the ear length of sweet corn. They stated that the longest ears with 23.59 cm length produced at May 9. Between different plant densities the longest ears with 24.13 cm length produced at 45000 plants ha^{-1}. Producing short ears at late planting dates reported by [25,17].

3.10 1000-Grains Weight

1000-grains weight (TGW) is a determining characteristic in final yield. TGW significantly affected by planting date ($p<0.05$). There was no significant difference between plant densities in respect of TGW (Table 2). The highest (355.9 g) and lowest (50.14 g) TGW produced at D1 and D3 respectively (Table 4). Late planting dates resulted in lower yield and TGW due to late season chilling stress and insufficient time for grain filling. Delay cropping resulted in low dry matter accumulation in grains due to lower assimilate amassing and remobilization to the grains.

3.11 Fresh Forage Yield

There was no significant difference between planting dates in respect of fresh forage yield. Forage yield affected by plant densities ($p<0.01$) (Table 2). The highest (42.51 t ha^{-1}) and lowest (28.26 t ha^{-1}) fresh forage yield produced at P3 and P1 respectively (Table 5). Ear production negatively affect by delay cropping due to late season chilling temperatures. But a relative high forage yield produces in such situation. According to the results of this experiment the best planting date in respect of both ear and forage yield was May 15. The results were in agreement with [26] and [22] who declared that the highest forage yield produced from early May to early June planting dates.

3.12 Ear and Plant Harvest Index

Both ear and plant harvest index affected by planting date ($p<0.01$) (Table 2). Plant harvest

Table 5. Means Comparison for standard ear yield and some agronomic characteristics of baby corn on different plant density

Plant density (plant ha^{-1})	Treatment				
	1	2	3	4	5
65000	140.5 a	22.19 a	2.50 a	20.42 b	1879c
85000	140.9 a	21.13 b	2. 11 b	20.01 b	2084 b
105000	140.8 a	21.27 c	1.65 c	22.62 a	2683 a

(1): Plant harvest index, (2): Number of ear plant^{-1}, (3): Number of ear plant^{-1}, (4): Dehusked ear yield, (5): Husked ear yield, Mean followed by similar letters are not significantly different at 5% probability level

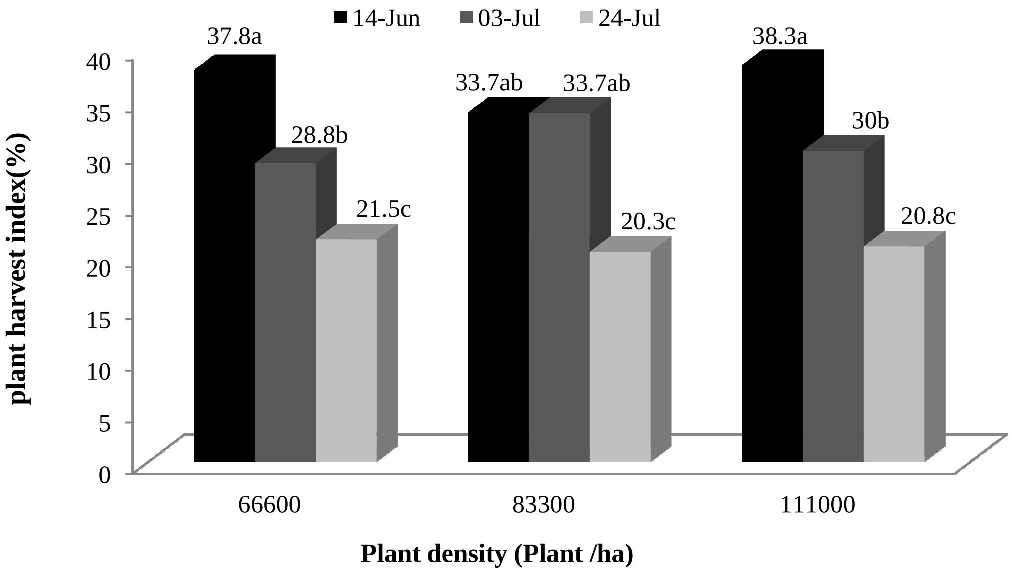

Fig. 1. The interaction effects of planting date and plant density on plant harvest index
Mean followed by similar letters are not significantly different at 5% probability level

Index affected by interaction between planting date and plant density ($p<0.01$). The highest plant harvest index (70.2%) and ear harvest index (36.68%) produced at D1 planting date (Table4).Harvest index (HI) is the weight of economic product of a crop as a percentage of the biological crop weight. Harvest index is affected by plant density, water and resources ability and air temperature during growing season [27,8]. This parameter is the index of grain production or remobilization coefficient of assimilates between economical organs and other parts of crop [28].

4. CONCLUSION

The results showed that dehusked ear yield increased on August 3. However baby corn planting on July 24 due to early cold autumn and reduced marketability is not recommended. In this research according to the international codex to produce and supply products with high quality planting date of 14 June and density of 105,000 plants ha^{-1} recommended for producing the highest and the best standard ear. The results showed that planting date of 14 June and planting density of 105,000 plants ha^{-1} with the highest standard ear Percentage (31/49) has produced. In these circumstances, processing factories, a longer period of time worked the benefits of cultivating this plant weather in Mashhad.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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