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*Full Length Research Paper*

# The effect of water deficit and sowing date on yield components and seed sugar contents of sweet corn (*Zea mays* L.)

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**Considering the little amount of research on this crop in Iran and especially in Kermanshah, this paper was devoted to its study. In order to study the effect of sowing date and water stress on yield and yield components and seed sugar content in sweet corn cv.SC403, an experiment was conducted in the research farm and laboratories of the department of agronomy and plant breeding at Razi University, Kermanshah, in 2008. This investigation was performed as a factorial experiment based on randomized complete block design (RCBD) with four replications. The sowing date factor included four dates (4 May, 24 May, 13 June and 3 July) and three levels of water stress (control, moderate and severe water stress). The accumulated evaporation included: 70 (control), 120 (moderate water stress) and 170 (severe water stress) from evaporation pan class A. With respect to the results of this experiment, if the purpose in sowing of sweet corn is quantitative yield, the 3rd of July under no water stress treatment (control) will be the best date (8547.2 kg ha$^{-1}$). The sowing date of 3rd July and the moderate water stress treatment did not have significant effect on quantitative yield. Thus, in arid and semi arid areas such as Kermanshah where water saving is important, this sowing date maybe very useful for water saving. But if the purpose is to have high qualitative yield in sweet corn (seed sugar), the sowing date of 4 May under severe water stress (1.48% sucrose) maybe the best choice.**

**Key words:** Seed sugar content, sowing date, sweet corn, water stress, yield components.

## INTRODUCTION

Sweet corn has attracted very little attention as a crop in Iran and it has been called a fancy product. So research on this crop is poor and sparse. Sweet corn was obtained with genetic mutation on Su-locus of chromosome number 4 of corn. These features cause sugar and soluble polysaccharides accumulation in seed endosperm (Kaukis and Davis, 1986). Unlike dent corn type, sweet corn is grown primarily for fresh consumption, not feed or flour (Dickerson, 2003). By comparison with other derivatives of corn, fresh consumption of sweet corn is more profitable due to its soft grains, thin shells, high concentration of sugar and tastefulness (Oktem et al., 2003). The kernels of sweet corn at maturity are translucent and more or less creased. Sweet corn has a sweeter taste than other types before it is ripe and dry, because the endosperm contains sugar as well as starch (Oktem et al., 2004). Sweet corn, in principle, is unripe corn, it is also harvested prior than its physiological maturity, and then it can be considered for replace plant (Hashemi et al., 2001).

The aim of investigating the sweet corn sowing date was to discover the time in which the plant can have maximum seed contents while tolerating unfavorable outside conditions. Sowing date of sweet corn while effective on speed of germination affects all plant phonological stages as well. It appears that the reproductive, pollination and zygotic organs for purposes of polarity with stress conditions, especially heat or deficit humidity can influence growth and ultimate yield (Hashemi and Herbert, 1992). Oktem et al. (2004) reported that early sowing dates (from April 25 to June 25) in sweet corn caused decrease in fresh ear yield. They added that the mentioned date could be optimal sowing date for sweet corn. Williams (2008) noted that best

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**Table 1.** Some chemical and physical properties of the soil at the experimental field.

| Soil depth (cm) | EC(dS $m^{-1}$) | pH | Organic carbon (%) | Nutrient elements | | | Soil particles | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | N(%) | P (mg $kg^{-1}$) | K (mg $kg^{-1}$) | Clay(%) | Silt(%) | Sand(%) |
| 0-30 | 0.61 | 7.6 | 1.45 | 0.14 | 9.5 | 390 | 42 | 37 | 21 |
| 30-60 | 0.61 | 7.8 | 1.20 | 0.12 | 7.0 | 350 | 45 | 36 | 19 |

sowing date for sweet corn was early May in the north Central United States. He also emphasized that although numerous factors influence crop yield, yield components of sweet corn consistently decreased in the early July planting date. Kwabiah (2004) pointed out that in Newfoundland (Canada), for sweet corn planting, since soil temperature remains below 12°C until about mid-June when planting can begin, crops are usually not matured for harvesting until late August.

One of the most important factors that can limit crop production is the availability of water. Payero et al. (2006) indicated that moisture tension in the soil during any of the phenological stages of the plant causes reduction in growth, delayed maturity and decreased crop yield. Demand for water increases as the plants grows, maximizing during and after flowering (Brewbaker, 2008). Sweet corn quality may be reduced by temporary water shortages, especially if they occur during kernel fill. Therefore maintaining an adequate level of soil moisture during critical periods of crop development is important to ensuring high sweet corn crop quality in many seasons (Ohio vegetable production guide bulletin, 2008). Stone et al. (2001) reported that water stress reduced yield of sweet corn. Whereas there was no stage of crop development at which yield was particularly sensitive to water deficit, the scale of damage depended on timing and severity of drought. Oktem (2008), indicated that under conditions of water stress, the sweet corn plant decreased its leaf area index (LAI), yield and marketable ear number. Pandey et al. (2000) stated that yield reduction caused by deficit irrigation was associated with reducing kernel weight and number. Rivera-Hernandez et al. (2010) reported that sweet corn is highly sensitive to water shortage because its morphological quality was significantly affected by low values of moisture tension (-55 and -80 Kpa) in the soil.

In sweet corn, sweetness is the major component of taste and is affected by the proportion of sugar and starch in the endosperm (Dickert and Tracy, 2001). Sweet corn accumulated more sugar than normal maize. The primary sugar is sucrose, with lesser amounts of glucose, fructose and maltose. The amount of sucrose at an early time of harvest is about twice as much the amount of sucrose at normal that dwindle at sweet corn and this quality near to normal (Kaukis and Davis, 1986). There has been little information on the effects of irrigation on sugar concentration in sweet corn, but water stress can temporarily increase sugar concentration in sugar beets (Dickert and Tracy, 2001). Massacci et al. (1996) reported that during the panicle maturation of sweet sorghum, sucrose in drought-stressed stems was higher than in control. Also, Kaukis and Davis (1986) reported that a decrease in the amount of sucrose in sweet corn endosperm was caused by heat.

Due to the fact that little information is available about sweet corn as a crop and its physiological status in Iran, the necessity of carrying out this research was concerned. Hence, the main aim of the present study was to determine the influence of variable regimes of water stress and different sowing dates on yield and its component as well as seed sugar content in a semi-arid condition.

## MATERIALS AND METHODS

The current study was conducted at the research field of the Faculty of Agriculture at Razi University in Kermanshah Province, Iran; during early May to late October 2008 (altitude: 1319 m, 47°9′ N and 34° 21′ E). Some of the relevant soil properties of the research field are presented in Table 1. Moreover, some useful climatic data of the experimental site was obtained from the Meteorological Station of Kermanshah City (Table 2). A single cross sweet corn (*Zea mays* L. var. *saccharata* Sturt), SC403, was used. The experiment was performed as a factorial experiment based on randomized complete block design (RCBD) with four replications. The sowing date factor included four dates (May 4, May 24, June 13 and July 3) and three levels of water stress (control, moderate and severe water stress).

The accumulated evaporation included: 70 mm (control), 120 mm (moderate water stress) and 170 mm (severe water stress) (Kalantar-Ahmadi et al., 2006). Daily evaporation values of the class A pan were used to determine the required irrigation water (Oktem, 2008). Total evaporation from the class A pan was measured daily with a manual limnimeter with 0.1 mm accuracy. Different moisture tension treatments were applied from 5 leaves stage. Irrigation was applied to all plots using the same intensity, actually according to various amount of ET, irrigation times were different. The volume of irrigation water for each irrigation time was calculated using the equation:

$$Vw = (Fc - Pwp) \times Bd \times A \times D / e_\alpha$$

Where Vw is the volume of irrigation water ($m^3$), Fc is the soil moisture's weight percent in filed capacity status, Pwp is the soil moisture's weight percent in permanent wilting point status, Bd is bulk density ($gcm^{-3}$), A is plot area ($m^2$), D is root depth and $e_\alpha$ is irrigation water efficiency ≈ 90%.

Each plot consisted of six rows that were 6 m-long. Plots were spaced 1.8 m apart to prevent water movement between plots. The rows were planted 60 cm apart and 20 cm spaced in the rows. For each plot, 150 kg $ha^{-1}$ N was applied as starter at planting time and

**Table 2.** Monthly climatic data during the sweet corn growth in 2008*.

| Month | Mean temperature | | Mean relative | Total | Mean |
|---|---|---|---|---|---|
| | Maximum (℃) | Minimum (℃) | Humidity (%) | Precipitation (mm) | Evaporation (mm/day) |
| May | 33.7 | 4.4 | 34 | 6.6 | 237.5 |
| June | 37.8 | 8.7 | 20 | 0.0 | 346.7 |
| July | 42.8 | 14.4 | 16 | 0.0 | 379.0 |
| August | 42.0 | 16.2 | 17 | 0.8 | 419.5 |
| September | 39.2 | 10.1 | 25 | 9.3 | 308.8 |
| October | 32.5 | 3.8 | 29 | 0.0 | 256.0 |

*Data collected from the Kermanshah Metrological Station.

also at 6 leaves stage. In addition, 200 kg $ha^{-1}$ P and K were added to the soil before sowing. Ears of two rows at the center of each plot (10 plants) were harvested manually when the kernel moisture reached 45 to 50%. At harvest time, green biomass and number of ears in plant and then qualities such as total seed yield, number of seed in row, ear length and ear diameter were measured.

#### Measurement of sugar content of kernel

One of the most important parameter which is used for calculating sugar content in sweet corn seed is the measure of sucrose amount in samples in which this parameter was calculated using Lane and Eynon's (1923) method. For this purpose, five ears in each plot were selected randomly at the end of the milking stage and seeds were harvested. The seeds were immediately frozen by liquid nitrogen to prevent changing sugar to starch and then ground down with porcelain mortar. A proper amount of distilled water was added to the obtained flour and preserved in a refrigerator for 24 h in order for the sugar content of the mixture to reach maximum level and after this time pH of the sample was adjusted to 6.5. Given solutions including Hegzasiano ferrate ($Fe_2(CN)_6$) and Zinc acetate + Acetic acid were added to the sample in the laboratory for sediment of different components such as starch, protein and fat. Then, pH of the solution was adjusted to 8.3 to 8.5 with NaOH 0.1 N. The solutions reached 100 cc volume and filtered. Then for analysis of % sucrose, sugar before hydrolysis (%) and sugar after hydrolysis (%) were calculated. Sucrose amount in samples was calculated as follows (Lane and Eynon, 1923);

Sucrose amount in sample = (sugar after hydrolysis – sugar before hydrolysis) × 95%.

#### Statistical analysis

The data were subjected to ANOVA procedures using the SAS statistical package (Ver 6.12) and significance of differences between means was conducted using Duncan's multiple range test at P=0.01.

## RESULTS AND DISCUSSION

### Grain yield (GY)

Results indicated that the effect of sowing date and water stress and the sowing date × water stress interaction was significant (Tables 3 and 4). The highest grain yield occurred at July 3 (6954.6 kg/ha) and showed significant differences in comparison with other sowing dates (Table 3). It may have resulted from the pollination periods at maturity which did not face the hot months of summer (Table 2). Maddoni et al. (1998) reported that the environmental conditions may affect kernel biomass accumulation. Several studies have shown that critical periods for yield in corn are tassel flowering, ear flowering and milky stage. The hot and dry weather as well as water deficit during this period cause yield reduction (Oktem et al., 2003). Water stress led to a significant decrease of sweet corn yield, so that maximum grain yield would be obtained in the control treatment (5344.2 kg $ha^{-1}$).

Osborne et al. (2002) stated that water stress occurring prior to silking, decreased yield by 22.1 and 15.1% for the dry land (no additional irrigation except that needed to avoid complete crop loss) and 0.5 ET irrigation treatments. Oktem (2008) reported that the relationships between fresh ear yields and the irrigation treatments were statistically significant (P<0.01) and yield decreased with deficit irrigation. Nesmith and Ritchie (1992) reported that decreased yield of deficit plants was attributed to a reduction in the number of well-developed kernels. Cakir (2004) stated that during dry years (for example, 2008 in kermanshah), even a single irrigation emission during one of the sensitive growth stages, caused up to 40% grain yield losses.

The significant sowing date × water stress interaction for grain yield indicated that the influence of the planting dates tested in this experiment depended on the effect of water stress (Table 3). In regard of maximum grain yield, no significant differences were observed between control (8547.2 kg $ha^{-1}$) and moderate (7706.4 kg $ha^{-1}$) levels of water stress at July 3. Shaozhong et al. (2000) stated that the grain yield of moderate soil moisture stress plots was not significantly reduced by control. So water-use efficiency for these plots was substantially improved as a result. Therefore, favorable yields can be obtained with moderate levels of moisture stress, combined with a planting date of 3rd July.

**Table 3.** Main effects of sowing date and water stress on yield and yield components of sweet corn (SC403) and results of the F-tests for the effects of main factors and interactions.

| Treatments | GY (kg ha$^{-1}$) | BIO (kg ha$^{-1}$) | NEP | NRE | EL (cm) | ED (cm) | Sucrose (%) |
|---|---|---|---|---|---|---|---|
| **Sowing date** | | | | | | | |
| 4 May | 2305.4$^{b}$ | 40733$^{ab}$ | 1.10$^{b}$ | 14.65$^{a}$ | 19.55$^{a}$ | 3.48$^{b}$ | 1.04$^{a}$ |
| 24 May | 2599.5$^{b}$ | 43867$^{a}$ | 0.95$^{c}$ | 10.74$^{c}$ | 17.38$^{b}$ | 3.02$^{d}$ | 0.50$^{d}$ |
| 13 June | 2539.7$^{b}$ | 37807$^{b}$ | 1.00$^{bc}$ | 13.57$^{b}$ | 17.71$^{b}$ | 3.23$^{c}$ | 0.90$^{b}$ |
| 3 July | 6954.6$^{a}$ | 40713$^{ab}$ | 1.23$^{a}$ | 15.33$^{a}$ | 18.70$^{ab}$ | 4.01$^{a}$ | 0.70$^{c}$ |
| **Water stress** | | | | | | | |
| Control | 5344.2$^{a}$ | 50270$^{a}$ | 1.28$^{a}$ | 14.75$^{a}$ | 20.56$^{a}$ | 3.74$^{a}$ | 0.50$^{c}$ |
| Moderate | 3560.6$^{b}$ | 38505$^{b}$ | 1.02$^{b}$ | 13.07$^{b}$ | 17.44$^{b}$ | 3.42$^{b}$ | 0.72$^{b}$ |
| Severe | 1894.7$^{c}$ | 33565$^{c}$ | 0.91$^{c}$ | 12.90$^{b}$ | 17.01$^{b}$ | 3.14$^{c}$ | 1.16$^{a}$ |
| **F- tests** | | | | | | | |
| Sowing date (D) | ** | ns | ** | ** | * | ** | ** |
| Water stress (S) | ** | ** | ** | ** | ** | ** | ** |
| Interaction D × S | ** | ns | * | ** | ns | ** | ** |
| CV (%) | 23.23 | 15.94 | 16.47 | 8.10 | 9.16 | 7.41 | 10.97 |

GY=Grain yield, BIO= biomass, NEP= number of ear per plant, NRE= number of rows in ear, EL= ear length, ED= ear diameter; Within each column (between two horizontal lines), the means followed by a different letter are significantly different at 5% level (DMRT); ns, * and ** : Not significant, significant at 5% and 1% probability levels, respectively.

## Biomass (BIO)

Biomass was significantly affected by water stress only (Table 3). The highest and the lowest biomass were observed in control (50270 kg/ha) and severe (33565 kg/ha) stress treatments, respectively (Table 3). Stone et al. (2001), Osborne et al. (2002), and Moser et al. (2006), also reported that biomass was reduced by moisture stress. Stone et al. (2001) stated that yield was related strongly to biomass, especially that accumulated after silking. Biomass also was reduced by water deficit.

## Number of ears per plant (NEP)

Results indicated that effect of sowing date and water stress, also sowing date × water stress interaction effects on NEP was significant (Tables 3 and 4). The highest NEP was from 3 July (1.23) and was significantly different compared with the other three sowing dates (Table 3). Moser et al. (2006) reported that the ear number increases when the growing conditions improve. Water stress caused a significant decrease in NEP as the highest NEP was obtained with the control (1.28) while the lowest was obtained by the severe stress treatment (0.91) (Table 3). Cakir (2004) reported that water shortage caused reduction of ear per plant that was due to omitted irrigation during the sensitive tasselling and cob formation stages. Data in Table 4 shows that number of ears per plant fluctuated between 0.66 to 1.32.

## Number of rows in ear (NRE)

Regarding the number of rows per ear, there were no significant differences between July 3 and May 4 and the lowest rate of this parameter obtained at May 24 (10.74) (Table 3). Water stress caused significant reduction in NRE but this reduction was not significant between moderate and severe water stress (Table 3). Rivera-Hernandez et al. (2010) reported that although significant differences were observed among irrigation treatments for a variable number of rows per ear, this was the least affected by the rise in soil moisture tension. This suggests that the number of rows per ear is more influenced by heredity factors than by crop management. Moser et al. (2006) reported that pre-anthesis drought significantly reduced the number of kernel rows. The effect of sowing date and water stress interaction on NRE was significant (Table 3). The maximum of NRE (15.62) on 3 July × control and the minimum of NRE (8.87) on 24 May × sever (Table 4).

## Ear length (EL)

With respect to significant simple effects in Table 3, it can

**Table 4.** Interaction effects of sowing date and water stress on yield and yield components of sweet corn (SC403).

| Treatments | | GY (kg ha $^{-1}$) | BIO (kg ha $^{-1}$) | NEP | NRE | EL (cm) | ED (cm) | Sucrose (%) |
|---|---|---|---|---|---|---|---|---|
| 4 May | Control | 3917.0$^{b}$ | 53940$^{a}$ | 1.20$^{a}$ | 14.98$^{a}$ | 21.82$^{a}$ | 3.60$^{b}$ | 0.80$^{de}$ |
| | Moderate | 2454.4$^{c}$ | 39220$^{bcd}$ | 1.12$^{ab}$ | 14.08$^{ab}$ | 18.76$^{bcd}$ | 3.42$^{bc}$ | 1.02$^{c}$ |
| | Severe | 544.8$^{d}$ | 29040$^{d}$ | 0.97$^{bc}$ | 14.90$^{a}$ | 18.11$^{bcde}$ | 3.41$^{bc}$ | 1.48$^{a}$ |
| 24 May | Control | 4674.0$^{b}$ | 53600$^{a}$ | 1.30$^{a}$ | 13.79$^{ab}$ | 19.20$^{abc}$ | 3.58$^{b}$ | 0.15$^{h}$ |
| | Moderate | 2450.4$^{c}$ | 39720$^{bcd}$ | 0.90$^{c}$ | 9.58$^{c}$ | 16.10$^{de}$ | 2.87$^{de}$ | 0.18$^{h}$ |
| | Severe | 674.2$^{d}$ | 38280$^{bcd}$ | 0.66$^{d}$ | 8.87$^{c}$ | 16.85$^{cde}$ | 2.60$^{e}$ | 1.27$^{b}$ |
| 13 June | Control | 4238.6$^{b}$ | 47200$^{ab}$ | 1.30$^{a}$ | 15.20$^{a}$ | 20.50$^{ab}$ | 3.67$^{b}$ | 0.45$^{g}$ |
| | Moderate | 1631.0$^{cd}$ | 35460$^{d}$ | 0.85$^{cd}$ | 13.10$^{b}$ | 16.75$^{cde}$ | 3.06$^{cd}$ | 0.78$^{e}$ |
| | Severe | 1749.4$^{cd}$ | 30760$^{d}$ | 0.85$^{cd}$ | 12.43$^{b}$ | 15.90$^{e}$ | 2.97$^{de}$ | 1.31$^{a}$ |
| 3 July | Control | 8547.2$^{a}$ | 46340$^{abc}$ | 1.32$^{a}$ | 15.62$^{a}$ | 20.72$^{ab}$ | 4.42$^{a}$ | 0.59$^{f}$ |
| | Moderate | 7706.4$^{a}$ | 39620$^{bcd}$ | 1.22$^{a}$ | 15.54$^{a}$ | 18.19$^{bcde}$ | 4.33$^{a}$ | 0.92$^{cd}$ |
| | Severe | 4610.2$^{b}$ | 36180$^{cd}$ | 1.15$^{ab}$ | 15.43$^{a}$ | 17.20$^{cde}$ | 3.57$^{b}$ | 0.58$^{f}$ |

GY=Grain Yield, BIO= biomass, NEP= number of ear per plant, NRE= number of rows in ear, EL= ear length, ED= ear diameter; Within each column, the means followed by a different letter are significantly different at 5% level (DMRT).

be said that both sowing date and water stress have separate effect on ear length (Table 3). The maximum ear length on 4 May (19.55 cm) had no significant difference with 3 July (18.70 cm). The minimum values of this characteristic on the second and third sowing dates (24 May and 13 June) are shown in Table 3. Kwabiah (2004) reported that sowing date had no significant effect of ear length. Water stress reduced ear length as the highest EL for control (20.56 cm) that was significantly different from two other levels of stress (Table 3). Rivera-Hernandez et al. (2010) believed that an increase in the other features causes a decrease of ear length in consequence of drought stress, by reason of decrease in the photosynthesis and total biomass accumulation of the plant.

## Ear diameter (ED)

The significant interaction between sowing date and water stress for ED stemmed from the differential response of the water stress at the different planting dates (Table 3). The highest ED value was determined at the 3 July × control (4.42 cm) with a non-significant difference with 3 July × moderate (4.33 cm). The ear diameter value was lowest at 24 May × sever (2.60 cm) (Table 4). Oktem et al. (2004) indicated that ear diameter increased with delayed sowing date because of pollination and fertilization problems observed at the early sowing dates. It was observed that pollination period experienced less heat when seed planting was performed at July 3; since irrigation faced better climate situation and ear diameter had risen, which is in line with the statement of Rivera-Hernandez et al. (2010), that water stress causes reduction of ear diameter.

## Seed sugar content

The sweetness trait in sweet corn mainly depends on its kernel sucrose content (Kaukis and Davis, 1986). The highest sucrose (%) was from the 4 May (1.04%) that was significantly different compared with three other sowing dates (Table 3). Generally, the highest and the lowest percentage of sucrose content occurred in sever (1.16) and control (0.5) treatments of water stress, respectively. Dickert and Tracy (2001), in biennial experiment indicated that reduced irrigation resulted in higher sucrose levels that in one of this years was significant and non significant in another, also irrigation treatment did not affect total sugar levels in either year. Massaci et al. (1996) pointed out more increase in the amount of sucrose in drought-stress than in control stems. Also, the significant interaction between sowing date and water stress for sucrose (%) indicated that the highest sucrose (%) for 4 May × sever (1.48) with non significant difference with 13 June × severe (1.31) and the lowest sucrose for 24 May × control (0.15) with non significant difference with 24 May × moderate (0.18) (Table 4). In this experiment, we were unable to detect any consistent affects of sowing date treatments on sucrose content and also its effect on water stress on interaction between both of them. But we can say that water stress caused an increase in sucrose content in sweet corn.

## Conclusion

In this study, the maximum grain yield (8547.2 kg $ha^{-1}$) was obtained from 3 July × control with no significant difference with 3 July × moderate (7706.4 kg $ha^{-1}$). Seed sucrose content increased as the amount of water deficiency increased. But we did not observe any consistent effects of sowing date treatments on sucrose content. Results from the present study show that it is possible to grow sweet corn with water deficit (moderate level) without significant reduction in the amount of grain yield. Also, this treatment somehow caused an increase in the seed sugar content.

This was due to the dilution effect. Lower moisture content resulted in higher sucrose %. A true indication of the effect on sucrose would be to measure the grams of sucrose produced. A sowing date at July 3 with moderate water deficit can be acceptable for the sweet corn (SC403) in the semi-arid region of Iran. More observations are needed to determine whether the results in this study are site specific or are applicable to other areas or cropping systems. Besides sowing date and water deficit, factors such as density, fertilization, and pesticide application are important for determining sweet corn yields.

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