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FRESH EAR YIELD AND GROWING DEGREE-DAYS OF SWEET CORN IN DIFFERENT SOWING DATES IN SOUTHWESTERN ANATOLIA REGION

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ABSTRACT

The study was carried out with the aim to determine optimum sowing date and growing degree-days (GDD) of sweet corn using different sowing dates from April to June during the 2009 and 2010 growing seasons under semi-arid ecological conditions of the Southwestern Anatolia Region. The research included five sowing dates 1st April, 15th April, 1st May, 15th May and 1st June. The experiment was set up as Randomized Complete Block Design with three replications. Lumina F_1 hybrid sweet corn cultivar was used as an experimental materials. Sowing dates had a significant effect on harvest period, emergence rate, fresh ear yield and yield characteristics. Compared with the corn, sowing dates from April to June the corn sowed in the earlier had longer total growth period. The maximum fresh ear yields (14648.3 and 14568.3 kg ha^{-1}, respectively) were obtained from May l and the highest fresh ear number (64976.7 and 64915.7 number ha^{-1}, respectively) recorded from May l5 sowing date in 2009 and 2010 years. The highest emergence rate (93.3 and 91.7 %, respectively) was determined from June 1 in both years. The highest ear diameter (44.8 and 44.9 mm), ear length (18.7 and 18.3 cm, respectively), number of kernels per ear (566.4 and 551.7 grain, respectively) and ear weight (225.2 and 224.7 g, respectively) were observed from May 1 sowing date in 2009 and 2010 years. Total GDD accumulated as milk stage period of sweet corn in different sowing dates occurred between 578.9-938.8 ^{0}C in 2009 and 646.7-1025.5 ^{0}C in 2010.

Key words: Sweet corn, ear yield, growing degree-day, sowing date

INTRODUCTION

In selecting the correct sowing date for maize, various factors should be considered, including the temperature during the growing season, soil texture, geographical location, weed cover, soil infection by pests and pathogens, seed quality, heat requirements during sprouting and development, the hybrid maturity group, the aim of production and the sowing technology. In order for crops to best utilize moisture, nutrients and solar radiation, they must been grown on an optimum sowing date. Sowing date had a significant effect on maize grain yield. The grain yields of hybrids with longer growing periods were significantly higher than those with shorter growing periods (Nagy 2009).

In agriculture, heat units are often expressed as growing degree days (GDD). Sometimes growing degree days are called growing degree units (GDU), but the two terms are identical. Calculating GDD for a specific day uses a simple formula that involves subtracting a base or threshold temperature from the average temperature for the day. The base temperature is the threshold temperature for which plant growth begins. Plant species differ for base temperature. The base temperature for corn is 10 ^{0}C (McMaster and Wilhelm 1997; Berti and Johnson 2008). Maize is a plant summer annuals. Summer annuals produce flowers, fill seeds, mature, and die within a single growing season. Grain crop plants respond to environmental signals that regulate the timing of stages of development (Russelle et al. 1984). Two common environmental signals that affect plant growth and development are photoperiod and temperature. Modern corn hybrids respond little to photoperiod, but are affected by temperature. The responses to temperature for corn growth rate and the amount of time to progress from one stage of development to the next stage are nearly linear from about 10°C to 30°C. Understanding the accumulation of heat units and the relationship of heat units to corn development allows us to predict when important stages will occur. Heat units can also be used to compare hybrids for adaptation. Growth and development of corn are strongly dependent on temperature. Corn develops faster when temperatures are warmer and more slowly when temperatures are cooler. Elkarouri and Mansi (1980) reported that the mean daily temperature is the major enviromental factor that influences the crop development and yield. Numerous studies have demonstrated the usefulness of temperature indices, like growing degree days or heat units, for predicting crop growth and development, classifying crop species, hybrids and varieties, or evaluating climates for specific crop-management combinations (Neild and Seeley 1977; Fairey 1983).

Isparta Province has 37° 45' N latitude, 30° 33' E longitude and 1050 m altitude. Isparta has feature semi-arid climatic characteristics with total annual precipitation 524.4 mm. Sweet corn does have some specific environmental and cultural needs such as a planting time that must be met for the plant to produce high, marketable yields (Öktem et al. 2004). De et al. (1983) found that yield increased considerably by adjusting the sowing date to the best atmospheric temperature. Growth, productivity and quality parameters can be affected by planting maize crop earlier or later than the optimum date. The increase in yield of sown crops in optimal sowing date could be due to length growing period and depending on absorbing maximum nutrients from the soil and light for the sun resulting in maximum photosynthesis. Therefore, the objective of the research were to determine 1- the most suitable sowing date of sweet corn in Isparta ecological conditions, 2- the effect of different sowing dates on fresh ear yield, ear yield components of sweet corn, 3- growing degree-days of sweet corn using different sowing dates under Isparta ecological conditions.

MATERIALS AND METHODS

Experimental conditions

This experiment was carried out at the Experimental Farm of the Faculty of Agriculture, Suleyman Demirel University, Isparta during the growing seasons 2009 and 2010. In the study, Lumina F_1 hybrid variety was used as maize cultivar.

The experiment included five sowing dates: 1st April, 15th April, 1st May, 15th May and 1st June. These five sowing dates treatments were arranged in a randomized complete block design with three replications. Land was plowed and cultivated then prepared for planting with a single pass of a disk-harrow. Distance between rows was 70 cm and intra row spaces were 20 cm. Each plot area was 22.4 m^{-2} (8 m x 2.8 m) and consisted of 4 rows. Seeds were sown at 5-6 cm depth using a dibbler. Nitrogen, phosphorus and potasium fertilizers were applied to the rows at a rate of 250 kg ha^{-1}, 120 kg ha^{-1} and 100 kg ha^{-1} in the form of ammonium sulphate, P_2O_4 and KCl, respectively (Kara and Kırtot, 2006). The whole quantity of phosphorus and potasium fertilizers were applied at the time of sowing. Total nitrogen fertilization was applied in two equal doses, before the first and third irrigations. In both years, irrigation water was first applied to all treatments using a sprinkler irrigation system. After the emergence of plants, plots were irrigated equally by the dripping irrigation system. Irrigation water was applied as required to prevent the occurrence of moisture stress in the crop.

Climatic data of the experimental area

Meteorological data for growing seasons are shown in Table 1. Isparta Province has 37° 45' N latitude, 30° 33' E longitude and 1050 m altitude. The long-term annual mean temperature, relative humidity, total annual precipitation, wind speed and sunshine duration per day in the area are 12.4°C, 55%, 524.4 mm, 2.4 m s^{-1} and 7.6 h, respectively (Anonymous 2009 and 2010). With these climate characteristics, Isparta has features semi-arid climatic characteristics in the Southwestern Anatolia region. The vegetative periods (from April to August) in 2009 and 2010 had average temperatures of 18.6 and 19.6 °C, total precipitation of 152.0 and 173.1 mm and average humidity of 51.7 and 55.2 % respectively (Table 1). Meteorological data of maize growing seasons were nearly similar compared to long-term meteorological data.

Table 1. Meteorological data of the experimental field

Climatic factors	Years	Months					Total or Average
		April	May	June	July	August	
Precipitation (mm)	2009	40.4	66.6	26.8	18.0	0.2	152.0
	2010	47.0	32.4	53.7	39.7	0.3	173.1
	Long Years	56.6	50.8	28.4	18.4	0.8	155.0
Average temperature (^{0}C)	2009	11.3	14.7	20.6	23.5	22.8	18.6
	2010	11.7	16.6	19.0	24.3	26.4	19.6
	Long Years	10.8	15.6	20.1	22.3	23.9	18.5
Relative humudity (%)	2009	62.5	61.4	47.5	46.8	40.1	51.7
	2010	62.2	57.4	64.5	51.5	40.6	55.2
	Long Years	64.2	50.3	53.0	45.8	44.5	51.5

Regional Meteorology Station, Isparta

Soil structure

Soil in a depth of 60 cm was sampled before the setting the experiment and subjected to physicochemical analysis. The soil was medium in nitrogen (19.8 kg NH_4^+ ha^{-1}), alkaline (pH 7.9), limy (1.3 $CaCO_3$ %), medium P (22 kg ha^{-1} P_2O_5) and high K_2O (850 kg ha^{-1}) contents.

Measurements

Yield and its components

Emergence rate of seeds in different sowing date were tested in field conditions, and emergenced seeds were counted and were expressed in per cent. When plants reached to milk stage period, 0.5 m was removed from each ends and one row from each side as border effects of plots. Ears from 2 rows in the center of each plot were harvested manually. Fresh ear yield and its components including fresh ear number, ear diameter, ear length, number of kernels per ear and ear weight were determined as describe by Gökmen et al. (2001).

Growing-degree days (GDD)

Growing-degree days (GDD) or heat units has been developed to more accurately rate corn maturity. The study, it is based on the number of growing degree days between emergence date and milk stage period of sweet corn. GDD for corn (*Zea mays* L.); base temperature of 10 ^{0}C was used (Wiebold 2002). Growing degree days were calculated from the Formula (Berti and Johnson 2008):

$$GDD = \sum [[(Tmax + Tmin) / 2] - T_{base}]$$

where Tmax and Tmin are the maximum and minimum daily temperature, respectively, and Tbase is the base temperature at which the crop grows. Maize's optimum growth and photosynthesis temperature is 21-27 ^{0}C (Martin et al. 1976), maximum temperature is 30 ^{0}C (Angel 1997). Temperature data were collected daily from the meteorological station located within experimental period (Anonymous 2009 and 2010).

All the data were analyzed with analysis of variance (ANOVA) using SAS Statistical Package Program, means were compared using the LSD (Least Significant Difference) test according to the method given by Steel and Torrie (1985).

RESULTS

According to results of variance analysis; effects of the different sowing date on the emergence rate, fresh ear yield and its components were statistically significant found for both years (Table 2 and 3).

The emergence rate of sweet corn in different sowing date significant variations observed in both years. The highest emergence rate was determined from the June 1 sowing date (93.3 and 91.7 %, respectively), the lowest emergence rate was obtained from the April 1 sowing date (81.0 and 77.3 %, respectively) in the both years (Table 2).

Ear diameter and ear length influences fresh ear yield directly. The highest ear diameter (44.8 and 44.9 mm, respectively) and ear length (18.7 and 18.3 cm, respectively) were observed from the May 1 sowing date, the lowest ear diameter (40.0 and 38.7 mm, respectively) and ear length (17.3 and 17.0 cm, respectively) were obtained from the June 1 sowing date in the 2009 and 2010 years (Table 2).

Significant differences in number of kernels per ear of sweet corn were observed. The highest number of kernels per ear was determined from the May 1 sowing date (566.4 and 551.7 grain, respectively), the lowest number of kernels per ear was obtained from the June 1 sowing date (438.0 and 459.7 grain, respectively) in the both years (Table 2).

Table 2. Effects of different sowing dates on emergence rate, ear diameter, ear length, number of kernels per ear in sweet corn

Sowing dates/Years	Emergence rate (%)		Ear diameter (mm)		Ear length (cm)		Number of kernels per ear (grain)	
	2009	2010	2009	2010	2009	2010	2009	2010
1st April	81.0 c**	77.3 c**	44.5 a**	43.9ab**	18.3 ab*	17.7bc*	538.6a**	514.0ab**
15th April	86.6 b	83.7 b	44.0 a	44.1 a	18.4 ab	18.0 ab	556.2 a	522.3 ab
1st May	92.0 a	90.3 a	44.8 a	44.9 a	18.7 a	18.3 a	566.4 a	551.7 a
15th May	93.0 a	91.3 a	43.2 a	42.0 b	18.2 ab	17.7 bc	468.0 b	487.3 bc
1st June	93.3 a	91.7 a	40.0 b	38.7 c	17.3 b	17.0 c	438.0 b	459.7 c
Mean	89.2 A	86.8 B	43.3 A	42.7 B	18.4 A	17.7 B	513.4	507.0
CV (%)	6.42	5.02	8.69	6.66	7.44	8.71	9.15	11.84
LSD	3.48	2.45	2.00	1.94	1.22	1.80	44.37	53.43

*, **: significant at P<0.05 and P<0.01 probability levels, respectively

Means in the same columns followed by the same letters are not significantly different as statistically

Ear weight is important because it affects seed size, hence it influences fresh ear yield directly. The highest ear weight was observed from the May 1 sowing date (225.2 and 224.7 g, respectively), the lowest ear weight was obtained from the June 1 sowing date (208.4 and 204.3 g, respectively) in the both years (Table 3).

Table 3. Effects of different sowing dates on ear weight, fresh ear number, fresh ear yield in sweet corn

Sowing dates/ Years	Ear weight (g)		Fresh ear number (ha^{-1})		Fresh ear yield (kg ha^{-1})	
	2009	2010	2009	2010	2009	2010
1st April	223.9 a*	220.8 a*	56380.0 c**	55190.0 c**	12756.3 c**	12188.3 c**
15th April	222.8 a	220.7 a	60233.3 b	60428.0 b	13560.0 b	13334.0 b
1st May	225.2 a	224.7 a	64376.7 a	64835.7 a	14648.3 a	14568.3 a
15th May	219.6ab	218.0ab	64976.7 a	64915.7 a	14424.0 a	14223.7ab
1st June	208.4 b	204.3 b	64800.0 a	65489.3 a	13732.3 b	13379.3 b
Mean	220.0	217.7	62153.3	62171.7	13824.0A	13538.7B
CV (%)	5.07	6.69	7.32	5.89	8.67	9.79
LSD	12.50	16.08	2248.20	1523.80	633.96	1035.70

*, **: significant at P<0.05 and P<0.01 probability levels, respectively

Means in the same columns followed by the same letters are not significantly different as statistically

Fresh ear number is one of the most important yield component in sweet corn that are fresh consumed. While the highest fresh ear number was obtained from the June 1 sowing date 64976.7 number ha^{-1} during 2009 and 65489.3 number ha^{-1} during 2010, whereas the lowest fresh ear number was observed from the April 1 sowing date (56380.0 and 55190.0 number ha^{-1}) in both years (Table 3).

Significant differences in fresh ear yield of sweet corn were observed and were statistically significant found for both years. While the highest fresh ear yield was obtained from the May 1 sowing date (14648.3 and 14568.3 kg ha^{-1}), the lowest fresh ear yield was observed from the April 1 sowing date(12756.3 and 12188.3 kg ha^{-1}) in both years (Table 3).

Emergence period of sweet corn were remarkably and highly significant affected by sowing dates (Table 4). While emergence period extended in early sowing (in April) due to low soil temperature, it was shortening when sowing time was delayed to the June. Similarity, there were significant variations among the fresh ear harvest period of sweet corn (Table 4).

Table 4. Fresh ear harvest period of sweet corn in different sowing dates

Sowing dates/ Years	Soil temperature in sowing dates (^{0}C)		Emergence period		Fresh ear harvest period		Degree-Days (^{0}C)	
	2009	2010	2009	2010	2009	2010	2009	2010
1st April	11.7	14.1	April 19	April 15	8 July	10 July	578.9	646.7
15th April	13.4	14.3	April 30	April 26	20 July	21 July	722,2	766,5
1st May	15.5	18.5	May 12	May 10	26 July	24 July	802,9	771,6
15th May	18.7	23.2	May 25	May 20	11 August	9 August	938,8	935,6
1st June	23.4	26.2	June 9	June 8	23 August	19 August	810.8	1025.5

There were significant variations among the different sowing dates for degree-day (GDD) of sweet corn. Total GDD as milk stage period of sweet corn varied between 578.9-938.8 ^{0}C during 2009 and 646.7-1025.5 ^{0}C during 2010 (Table 4).

Soil temperatures on 10 cm-deep were determined 11.7-14.1 ^{0}C in April 1, 13.4-14.3 ^{0}C in April 15, 15.5-18.5 ^{0}C in May 1, 18.7-23.2 ^{0}C in May 15, 23.4-26.2 ^{0}C in June 1 during 2009 and 2010 (Table 4), respectively. The soil temperatures were at the level of minimum germination temperature of sweet corn in early sowing in both years. However, delaying sowing date from May 15 up to June 1 increased the soil temperature.

DISCUSSION

Effect of the different sowing date on the emergence rate of sweet corn was significant found and emergence rate was reduced in the early sowing (Figure 1). In the study, emergence period delayed because of cold soil in early sowing. Decreases in the germination rate and emergence period of sweet corn resulted from the soil cold. Minimum germination temperature of sweet corn is 10-12.7 ^{0}C (Aldrich et al. 1986).

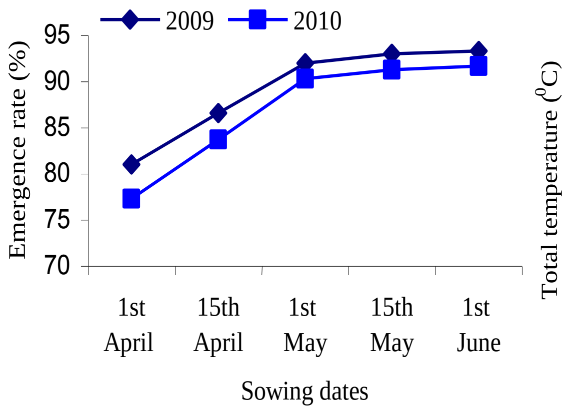

Figure 1. Emergence rate of sweet corn

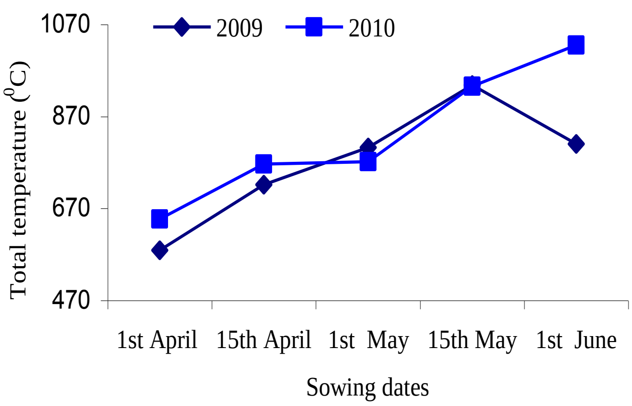

Figure 2. Growing degree-days of sweet corn

The study showed that the effects of sowing date on the yield and its components of sweet corn were significant found in both each years. The highest fresh ear yield was obtained when sweet corn was sown on May 1. Between May 1 and May 15 sowing dates were not statistically significantly different from the at the 1% level on the basis of LSD's test. In the study, fresh ear yield was decreased when early or delayed sowing for both years. The fresh ear number of late sown sweet corn was significantly higher than that of early sown maize because of the higher number of plant m^{-2}. Among the May 1, May 15 and June 1 sowing dates were not significantly different at the 1% level on the basis of LSD's test. Drying the ends of sheets of seedling due to low night temperature occurred the early sowing time. Day and night temperature differences could be taken in consideration in this respect. In the Isparta, low April temperature is one of the most important abiotic factors restricting early sowing of maize. Cold conditions during sprouting and seedling development result in the plants becoming yellow, retarded development, and later flowering, yield formation and ear ripening. Marton (1991) considered a temperature range of 9-18 ^{0}C to be adequate for evaluating and comparing the cold resistance. The average temperature on the sowing date was reported to affect the duration of sprouting (Gyorffy et al. 1965). Nagy (2009) stated that selecting the correct sowing date for maize, various factors should be considered, including the temperature during the growing season, soil texture, geographical location. Therefore, the negative effects of the climate and cold soil hinder the earlier sowing of corn and this restricts corn planting at April in the region. The negative effects of late sowing of corn are high temperature and hot dry winds due to cause fertilization problems in corn (Öktem et al. 2004). Martin et al. (1976) stated that the production of corn requires a mean summer temperature of 21 to 27 ^{0}C, and a mean night temperature exceeding 13 ^{0}C. Corn is grown extensively in hot climates, but yields are reduced where the mean summer temperatures are above about 27 ^{0}C. Cold weather retards the shedding of pollen, while hot dry conditions tend to hasten it. Stress can reduce maize grain yield and quality and any further rise in temperature reduces the pollen viability and silk receptivity, resulting in poor seed set and reduced grain yield (Aldrich et al. 1986; Samuel et al, 1986; Johnson 2000). Some researchers stated that delaying the sowing date resulted in decreased yields (Mc Cormick, 1974; Ishimura et al. 1984; Tomorga et al. 1985; Imholte and Carter 1987), whereas Herbek et al. (1986) reported that yields increased with a delayed sowing date.

Data collected on fresh yield components as affected by the different sowing dates are listed in Table 2 and Table 3. Fresh yield components including ear diameter, ear length, number of kernels per ear and ear weigh were decreased when sweet corn was sown early or delayed. This result agree with finding by Otegui et al. (1995) that optimum planting date resulted in higher grain yield than early and late planting dates because of higher ear numbers, ear diameter, ear length, ear weight and number of kernels per ear. The results of a sowing date experiment carried out in Hungary showed that the yield of maize sown in mid-April was 7% higher than after sowing in mid-May, averaged over several years. Sowing one month later also delayed ripening by 11–16 days (14 on average) (Berzsenyi et al. 1998). Another study has showed that the highest ear yield and its components were obtained when maize was sown on mid of May, early or delayed planting significantly decreased the traits (Turgut and Balcı 2002).

GDD of sweet corn were accumulated from seedling emergence until milk stage period. Total GDD accumulated as milk stage period of sweet corn in different sowing dates occurred between 578.9-1025.5 ^{0}C (Table 4). GDD accumulated of sweet corn increased when sowing time was delayed to the June in 2010 (Figure 2). On May 1 and May 15 that the highest fresh ear yield was obtained, total GDD of sweet corn occurred 802.9-938.8 ^{0}C during 2009 and 771.6-935.6 ^{0}C during 2010, respectively (Table 4). Total GDD of sweet corn increased in June 1 during 2010 growing season, but its fresh ear yield not increased. The total growth period, fresh ear yield and yield characteristics of corn were affected mainly by temperature. Heat units be used to compare hybrids for adaptation. The growth and development stages of plants are mainly affected by enviromental factors such as light, photoperiods and temperatures as much as genetic factors. The enviromental factors are also a strong determinant of the dates of flowering and harvest which are often crucial to yield in the diverse climates and agricultural systems. Therefore, genetic and enviromental control of the plant phenological development should be predicted accurately in order to stabilize crop yields in a wide range of temperature and photoperiods (Baydar 1997). Baker et al. (1986) found a positive correlation between the rate of leaf appearance expressed on the basis of thermal time and the rate of change of daylength around the time of plant emergence. De et al. (1983) found that wheat yield production increased considerably by adjusting the sowing date to the best atmospheric temperature. Serter et al. (2005) determined that the total heat sum in the growing period was 982.68-1064.26 °C for physiological and harvest maturity.

CONCLUSION

Determination of optimum sowing date for sweet corn is very crucial for better crop yields. The study revealed that sowing dates had significant effect on fresh ear yield and its components. The highest fresh ear yield was obtained from the May 1 to May 15 sowing period in semi-arid field conditions in the Southwestern Anatolia region. Our results suggest that optimum sowing dates for sweet corn could be from May 1 to May 15 in Isparta ecological condition and similar ecological regions. The average daily low temperature and low soil temperature in April restricts the earlier sowing of sweet corn in the region. GDD of sweet corn were accumulated from seedling emergence until milk stage period, and total GDD accumulated in different sowing dates occurred between 578.9-1025.5 ^{0}C.

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