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Effects of mulch practices on fresh ear yield and yield components of sweet corn

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Abstract: The experiment was carried out in the vegetation seasons of 2010 and 2011. The main purpose of the study was to determine the effects of mulch practices (a control–unmulched treatment, a plastic mulch treatment, and a straw mulch treatment) on fresh ear yield and some yield-related traits of sweet corn according to 3 sowing dates: 1 April, 15 April, and 1 May, respectively. The main effects of sowing dates were significant for the harvest period, the emerging rate from soil, the fresh ear yield per hectare, and the yield components of the sweet corn. The emergence rate of sweet corn was decreased on 1 April and 15 April due to the low soil temperature on these sowing dates. Of the mulch practices, the plastic mulch practice resulted in the highest emergence rate, the highest ear length, the highest ear diameter, the highest ear weight, the highest number of kernels per ear, the highest fresh ear yield, and the highest fresh ear number in both 2010 and 2011. The fresh ear yield and yield components were decreased by the straw mulch practice in both 2010 and 2011. The effects of the sowing date × mulch practice interactions on emergence rate, fresh ear yield, and some yield-related traits of sweet corn were statistically ($P < 0.05$ and $P < 0.01$) significant in both years. Of the interactions between the sowing dates and the mulch practices, the highest emergence rate (91.2% in 2010 and 93.7% in 2011), highest ear length (18.4 cm in 2010 and 18.5 cm in 2011), highest ear diameter (45.2 mm in 2010 and 46.5 mm in 2011), highest ear weight (229.1 g in 2010 and 227.1 g in 2011), highest number of kernels per ear (562.1 grains in 2010 and 552.3 grains in 2011), highest fresh ear yield (14,952.6 kg ha^{-1} in 2010 and 14,805.2 kg ha^{-1} in 2011), and highest fresh ear numbers (65,781.8 cobs ha^{-1} in 2010 and 65,789.6 cobs ha^{-1} in 2011) were determined from the plastic mulch practices on 1 May, the latest sowing date. The lowest emergence rate, the lowest fresh ear yield, and the lowest yield components were obtained from the straw mulch practice on 1 April, the earliest sowing date, in both 2010 and 2011.

Key words: Sweet corn, ear yield, mulch methods, sowing date

1. Introduction

Various factors such as 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 should be considered in the determination of the proper sowing date for maize. It is well known that sowing date has a significant effect on maize grain yield. The grain yields of hybrids were significantly higher with longer growing periods than shorter growing periods (Nagy 2009). Early sowing of maize crop can increase the grain yield, but the crop must be able to tolerate the cold temperature due to the fact that the crops are very sensitive to the low temperature at early growth stages (Ahmad et al. 2012). Poor germination and slow growth in cool spring weather were reported to be the major limiting factors in the case of early production with the intention of high market prices (Kwabiah 2004). Maize seeds are to be sowed when the soil temperatures are around 10 °C (Cohn and Obendorf 1978). De et al. (1983) stated that the yield increased considerably when the sowing date was adjusted to the best atmospheric temperature (10–12 °C). The development of corn becomes faster at temperatures above 25–32 °C, whereas temperatures below 18 °C slow down corn growth.

Isparta Province is located at 37°45′N, 30°33′E, and at 1050 m altitude with semiarid climatic characteristics. The total annual precipitation is around 524.4 mm. Sweet corn requires some specific environmental and cultural conditions, such as an optimum planting time, which must be respected for high productive and marketable yields (Öktem et al. 2004). Mulching is an important agricultural practice, which is used for the spring sowings. The use of plastic mulch in field crops such as corn, cotton, sugarcane, and rice is successfully used in many countries (Kasirajan and Ngouajio 2012). Mulching may influence the temperature and moisture content of the soil (Acharya et al. 2005) and directly improves the grain yield of crops (Ramalan and Nwokeocha 2000). Straw mulching systems

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may conserve soil water and reduce the temperature due to the reduced soil disturbance and increased residue accumulation at the soil surface (Zhang et al. 2009). Soil mulching with plastic film, leading to reduced water loss and more even regulation of soil temperature, has been widely used in many agricultural practices (Zhang et al. 2005). Plants growing under plastic mulch are seen to be uniform, since they are protected against cold temperatures and damage caused by insects and birds. Many sweet corn producers use clear plastic mulch successfully to warm up the soil and enhance harvest maturity. The use of clear plastic mulch may also improve seed germination, increase plant tolerance under cool soil conditions, and improve the yield and quality of sweet corn (Warner and Zandstra 2004). Swiader et al. (1992) reported that mulching practice reduces water evaporation by 10% to 50%. Low temperatures during the first growth have profound effects on the maize yield in the cold areas (McCormick 1979). The effect on soil temperature in the early season by mulching improved the yield and quality of sweet corn (Felcyzynski 1994). The objective of this study was, therefore, to test the influence of various mulch practices on the fresh ear yield and yield-related traits of sweet corn at different sowing dates.

2. Materials and methods

2.1. Experimental site

The experiment was conducted during the growing seasons of 2010 and 2011 at the Experimental Station of the Faculty of Agriculture in Süleyman Demirel University, Isparta, Turkey. In the study, the Lumina F_1 hybrid variety was used as the sweet corn cultivar. The experiment land was plowed, cultivated, and then prepared for planting with a single pass of a disk-harrow. The distance between rows was 70 cm and distances within the rows were 20 cm. Each plot was 44.8 m^2 (8 m × 5.6 m) and consisted of 8 rows. Seeds were sowed at 5–6 cm depths using a dibbler. Nitrogen, phosphorus, and potassium fertilizers were applied to the rows at a rate of 200 kg ha^{-1}, 100 kg ha^{-1}, and 100 kg ha^{-1} in the form of ammonium sulfate, P_2O_4, and KCl, respectively (Kara and Kırtok 2006). The total quantity of phosphorus and potassium fertilizers was applied at the time of sowing. Total nitrogen fertilization was applied in 2 equal doses, before the first and third irrigations. In both years, the irrigation water was applied to all the treatments using a sprinkler irrigation system. After the emergence of plants, the plots were then irrigated equally by the dripping irrigation system. Irrigation water was applied as required to prevent the occurrence of moisture stress in the crop.

The experiment was repeated on 3 sowing dates (1 April, 15 April, and 1 May) using 3 different mulch practices (control–bare soil, plastic mulch, and straw mulch). Sowing dates and mulch practices were arranged according to a randomized complete block design by a split-plot arrangement with 3 replicates. Sowing dates were in the main plots, and the mulch practices were in subplots split within the main blocks. Kara (2011) determined that the optimum sowing date for sweet corn is 1 May in Isparta's ecological conditions. Therefore, in this research, "1 May" and "earlier sowing dates" were tested. A clear white plastic film was used as plastic mulch (Mp) and wheat straw was used as straw mulch (Ms). Mulching was applied just after the tested maize sowing dates. The plastic films were removed from the field on 15 May as the soil temperature increased to its optimum level.

2.2. Climatic data of the experimental area

Meteorological data for the growing seasons are shown in Table 1. The long-term annual mean temperature, relative humidity, total annual precipitation, wind speed, and sunshine duration per day in the area were 12.4 °C, 55%, 524.4 mm, 2.4 m s^{-1} and 7.6 h, respectively (data of the Isparta Meteorological Station). During the vegetative periods (from April to the end of August) in 2010 and in 2011, an average temperature of 19.6 and 18.5 °C, total precipitation of 173.1 and 162.4 mm, and an average humidity of 55.2% and 56.2% were recorded, respectively (Table 1). Meteorological data of maize growing seasons were nearly similar compared to long-term meteorological data.

2.3. Soil structure

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

2.4. Experimental parameters

2.4.1. Yield and its components

The emerging rate of seeds was tested in the field conditions. The emerged seeds were counted and expressed as percentages. When the kernel moisture was about 72% (Olsen et al. 1990; Öktem et al. 2004), ears from 6 rows in the center of each plot were harvested manually. Fresh ear yield and yield components, including fresh ear number, ear diameter, ear length, number of kernels per ear, and ear weight, were determined as described by Gökmen et al. (2001).

All the data were analyzed according to analysis of variance (ANOVA) using SAS. The significant differences between the group means were separated using the Duncan test.

Table 1. Meteorological data of the experimental field.

Climatic factors	Years	Months					Total or average
		April	May	June	July	August	
Precipitation (mm)	2010	47.0	32.4	53.7	39.7	0.3	173.1
	2011	54.7	43.1	62.2	1.8	0.6	162.4
	Long-term	56.6	50.8	28.4	18.4	0.8	155.0
Average temperature (°C)	2010	11.7	16.6	19.0	24.3	26.4	19.6
	2011	10.2	14.1	19.5	24.7	24.0	18.5
	Long-term	10.8	15.6	20.1	22.3	23.9	18.5
Relative humidity (%)	2010	62.2	57.4	64.5	51.5	40.6	55.2
	2011	70.0	68.0	59.0	44.0	40.0	56.2
	Long-term	64.2	50.3	53.0	45.8	44.5	51.5

Regional Meteorology Station, Isparta.

3. Results

The effects of the different sowing dates and mulch practices on the emergence rate, fresh ear yield, and yield components were found to be significant ($P < 0.05$ and $P < 0.01$) for both years. No significant differences between the 2 years in all examined characteristics were found (Tables 2 and 3).

In both years (2010 and 2011), the 1 May sowing date resulted in the highest emergence rate (88.3% and 89.8%), the highest ear length (17.8 and 18.0 cm), the highest ear diameter (44.2 and 45.6 mm), the highest ear weight (225.1 and 220.7 g), the highest number of kernels per ear (544.2 and 531.5 grains), the highest fresh ear yield (13,747.0 and 13,770.3 kg ha^{-1}), and the highest fresh ear numbers (61,941.7 and 61,848.0 cobs ha^{-1}) (Tables 2 and 3). The fresh ear yield and yield components decreased in the earliest sowing dates in both 2010 and 2011; the lowest emergence rate, the lowest ear length, the lowest ear diameter, the lowest ear weight, the lowest number of kernels per ear, the lowest fresh ear yield, and the lowest fresh ear numbers were obtained from the 1 April sowing date (Tables 2 and 3).

Of the mulch practices, the highest emergence rate (89.3% and 90.9%, respectively), ear length (17.9 and 18.1 cm, respectively), ear diameter (43.9 and 46.1 mm, respectively), ear weight (223.3 and 223.7 g, respectively), number of kernels per ear (532.7 and 533.5 grain, respectively), fresh ear yield (11,078.1 and 14,324.7 kg ha^{-1}, respectively), and fresh ear numbers (63,203.9 and 63,418.7 cobs ha^{-1}, respectively) were determined from the plastic mulch in the both years (Tables 2 and 3). The fresh ear yield and yield components decreased with the straw mulch practice in both 2010 and 2011 (Tables 2 and 3).

Of the interactions of sowing dates by mulch practices, the highest emergence rate (91.2% and 93.7%), the highest ear length (18.4 and 18.5 cm), the highest ear diameter (45.2 and 46.5 mm), the highest ear weight (229.1 and 227.1 g), the highest number of kernels per ear (562.1 and 552.3 grain), the highest fresh ear yield (14,952.6 and 14,805.2 kg ha^{-1}), and the highest fresh ear numbers (65,781.8 and 65,789.6 cobs ha^{-1}) were obtained from the Mp practice on the 1 May sowing date in 2010 and 2011, respectively (Tables 2 and 3). The lowest emergence rate, fresh ear yield, and yield components were determined from the Ms practice on the 1 April sowing date in both 2010 and 2011 (Tables 2 and 3).

Significant differences ($P < 0.01$) were observed between the fresh ear harvest periods of sweet corn: the fresh ear harvest period of sweet corn varied from 83 to 96 days during 2010 and from 82 to 97 days during 2011 (Table 4).

Soil temperatures at 10 cm deep were determined as 14.1 and 11.0 °C for 1 April, 14.3 and 13.2 °C for 15 April, and 18.5 and 16.5 °C for 1 May in the years 2010 and 2011, respectively. The soil temperatures were at the level of minimum germination temperature of sweet corn for the 1 April and 15 April sowing dates in both 2010 and 2011.

4. Discussion

The effects of the sowing dates on the emergence rate of sweet corn were significant and the emergence rate was reduced in the early sowing dates. The reduced emergence rate of sweet corn for 1 April and 15 April was due to the low soil temperatures. While the emergence period was extended in early sowing (1 and 15 April) due to low soil temperature, it was shortened when the sowing time was delayed (from 1 April to May). The minimum germination temperature of sweet corn is 10–12.7 °C (Aldrich et al.

Table 2. Effects of sowing dates and mulch practices on emergence rate, ear length, ear diameter, and ear weight in sweet corn.

Sowing dates	Mulch practices / years	Emerging rate (%)		Ear length (cm)		Ear diameter (mm)		Ear weight (g)	
		2010	2011	2010	2011	2010	2011	2010	2011
1 April	Mu	83.3 d**	84.7 d**	17.3 b**	17.7 ab**	43.5 bc*	42.6 d**	217.5 b**	221.0 ab**
	Ms	71.3 e	72.7 g	16.1 c	16.4 c	40.8 d	42.3 d	206.3 c	215.6 bc
	Mp	87.0 c	88.7 c	17.4 b	17.8 ab	42.8 bc	45.5 ab	219.7 ab	221.2 ab
15 April	Mu	89.0 b	90.0 b	17.6 b	18.1 ab	44.2 ab	43.7 cd	220.7 ab	222.7 ab
	Ms	82.3 d	80.3 f	17.4 b	17.4 b	41.8 cd	43.5 cd	207.6 c	213.3 c
	Mp	89.7 b	90.7 b	18.0 ab	18.2 a	43.8 ab	46.3 a	221.0 ab	222.7 ab
1 May	Mu	90.3 a	93.3 a	17.9 ab	18.3 a	45.0 a	46.0 ab	227.3 ab	220.9 ab
	Ms	83.6 d	82.6 e	17.0 b	17.5 b	42.3 bc	44.2 bc	217.9 b	214.0 bc
	Mp	91.2 a	93.7 a	18.4 a	18.5 a	45.2 a	46.5 a	229.1 a	227.1 a
Main effects									
Year		85.3	86.3	17.5	17.8	43.3	44.5	218.6	218.4
Sowing dates	1 April	80.5 c**	82.0 c**	16.9 b*	17.3 b**	42.4 b*	44.1 b*	214.5 c*	218.4 b*
	15 April	87.0 b	87.1 b	17.7 a	17.9 a	43.4 a	44.5 a	216.4 b	219.6 a
	1 May	88.3 a	89.8 a	17.8 a	18.0 a	44.2 a	45.6 a	225.1 a	220.7 a
Mulch practices	Mu	87.5 b**	89.6 b**	17.6 a*	17.8 b*	43.5 a*	44.1 b*	221.8 a*	221.5 b*
	Ms	80.4 c	78.5 c	16.8 b	17.1 c	41.6 b	43.3 b	210.6 b	214.3 c
	Mp	89.3 a	90.9 a	17.9 a	18.1 a	43.9 a	46.1 a	223.3 a	223.7 a
CV (%)		3.38	5.87	6.15	5.98	6.64	7.59	6.87	4.53

Mu: unmulched (bare soil–control), Ms: straw mulch, Mp: plastic mulch.
*, **: 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.

1986). The soil temperatures of the experimental area were at the level of minimum germination temperature of sweet corn for 1 April and 15 April in both years.

This study showed that the effects of sowing dates on the fresh ear yield and yield components of sweet corn were significant in both 2010 and 2011. The highest fresh ear yield was obtained from the 1 May sowing time. Fresh ear yield and yield components including ear diameter, ear length, number of kernels per ear, and ear weight decreased at 1 and 15 April due to low night temperatures for both years. This result was parallel with the finding of Otegui et al. (1995), where an 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. Another study showed that the highest ear yield and yield components were obtained when maize was sowed mid-May, while early or delayed planting significantly decreased the traits (Turgut and Balcı 2002). In Isparta, the low April temperature is one of the most important abiotic factors restricting the early sowing of maize. Cold conditions during sprouting and seedling development result in the plants becoming yellow, having retarded development and late flowering, yield formation, and ear ripening. Cold weather retards the shedding of pollen, while hot, dry conditions tend to hasten it. Nagy (2009) stated that when selecting the correct sowing date for maize, various factors should be considered, including the temperature during the growing season, soil texture, and geographical location. Therefore, the negative effects of the climate and cold soil hinder the earlier sowing of corn, and this restricts corn planting in April in the region. Martin et al. (1976) determined that the production of corn requires a mean summer temperature of 21 to 27 °C and a mean night temperature exceeding 13 °C.

Table 3. Effects of sowing dates and mulch practices on number of kernels per ear, fresh ear yield, and fresh ear number in sweet corn.

Sowing dates	Mulch practices / years	Number of kernels per ear (grains)		Fresh ear yield (kg ha^{-1})		Fresh ear number (ha)	
		2010	2011	2010	2011	2010	2011
1 April	Mu	467.2 c**	476.9 b**	12,351.0 d**	13,389.7 c**	56,516.7 d**	59,193.3 d**
	Ms	387.9 d	399.6 c	9993.0 e	10,626.0 e	48,450.0 e	49,270.0 f
	Mp	482.0 c	497.6 b	13,422.3 c	13,850.3 bc	61,040.0 c	61,313.3 c
15 April	Mu	511.6 b	502.9 b	13,699.7 c	14,144.3 ab	62,000.0 bc	62,130.0 bc
	Ms	481.8 c	491.8 b	11,776.0 d	11,628.7 d	56,716.7 d	54,530.0 e
	Mp	553.9 a	550.5 a	13,859.3 bc	14,318.7 ab	62,790.0 b	63,153.3 b
1 May	Mu	561.9 a	545.3 a	14,468.3 ab	14,699.3 a	63,143.3 b	65,003.3 a
	Ms	508.5 b	496.8 b	11,820.2 c	11,806.5 d	56,900.1 d	54,751.2 e
	Mp	562.1 a	552.3 a	14,952.6 a	14,805.2 a	65,781.8 a	65,789.6 a
Main effects							
Year		501.9	501.5	12,926.9	13,252.1	59,259.8	59,459.3
Sowing dates	1 April	445.7 c**	458.0 c**	11,922.1 c**	12,622.0 c**	55,335.6 c**	56,592.2 c**
	15 April	515.8 b	515.1 b	13,111.7 a	13,363.9 b	60,502.3 b	59,937.8 b
	1 May	544.2 a	531.5 a	13,747.0 a	13,770.3 a	61,941.7 a	61,848.0 a
Mulch practices	Mu	513.5 b*	508.4 b**	13,506.3 b**	14,077.5 a**	60,553.3 b**	62,108.9 b**
	Ms	459.4 c	462.7 c	11,196.4 c	11,353.7 c	54,022.3 c	52,850.4 c
	Mp	532.7 a	533.5 a	14,078.1 a	14,324.7 a	63,203.9 a	63,418.7 a
CV (%)		5.20	7.19	9.19	8.13	11.98	10.53

Mu: unmulched (bare soil–control), Ms: straw mulch, Mp: plastic mulch.
*, **: 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.

Table 4. Effects of sowing dates and mulch practices on fresh ear harvest period in sweet corn.

Sowing dates	Mulch practices / years	Fresh ear harvest period (day)			
		2010		2011	
1 April	Mu	6 July	96 a**	5 July	95 b**
	Ms	5 July	95 a	7 July	97 a
	Mp	2 July	92 b	3 July	93 c
15 April	Mu	13 July	89 c	14 July	90 d
	Ms	14 July	90 c	16 July	91 d
	Mp	11 July	87 d	12 July	88 e
1 May	Mu	24 July	85 e	22 July	83 g
	Ms	25 July	86 d	23 July	85 f
	Mp	22 July	83 f	21 July	82 g
CV (%)			0.59		0.66

Mu: unmulched (bare soil–control), Ms: straw mulch, Mp: plastic mulch.
**: significant at $P < 0.01$ probability level.

The germination ratio in the plastic mulch was higher compared to the straw mulch and bare soil (control). This was due to an increase in soil temperature under the plastic mulch. The germination ratio of seeds in the bare soil (control) was higher than in the straw mulch. The straw mulch had the lowest germination ratio because of the allelopathic effects of wheat straw extracts. Previous researchers have mentioned that wheat straw extract has phenolic compounds that appear to have toxic effects on corn seedlings (Safari et al. 2010). These effects were due to phenolic compounds, like ferulic acid, coumaric acid, vanillic acid, and hydroxyl benzoic acid, which influenced cell division in corn varieties (Dias 1991; Weih et al. 2008). Safari et al. (2010) reported that wheat straw extracts have allelopathic effects on corn seedlings. Rahman et al. (2005) stated that winter wheat has allelopathic effects on the following wheat culture.

The effect of mulch practices on the fresh ear yield and yield components of sweet corn were found to be significant in both years. Fresh ear yield was increased with the Mp practices compared to the Ms practices and bare soil on the 1 April sowing date. Similarly, ear diameter, ear length, number of kernels per ear, and ear weight were increased with the Mp practices on the 1 April sowing date compared to the Ms practice and bare soil. The fresh ear yield and yield components of sweet corn under the bare soil (control) were higher than the straw mulch because of the lower germination ratio. The soil temperature on 1 May was adequate for optimum germination of sweet corn. Guo and Gu (2000) and Ndubuisi (2009) stated that plastic film mulches raise soil temperature, thereby promoting faster crop development and increased yields. Ripening extended in early sowing because of the late germination results due to the low soil temperature in the early growth stage, and it was shortened when the sowing was delayed to 1 May. Generally, ripening periods were shortened with the Mp practices on all sowing dates, compared to the Ms and bare soil. Ripening for 3–4, 2–3, and 2–3 days in 2010 and 2–4, 2–3, and 1–3 days in 2011 with the Mp practices were shortened on 1 April, 15 April, and 1 May, respectively. Kwabiah (2004) stated that poor germination and slow growth in cool spring weather are limiting factors for early production. Berzsenyi et al. (1998) reported that sowing 1 month later also delayed ripening by 11–16 days. Van der Werf (1993) stated that plastic mulching raises soil temperatures by 2–4 °C, and maize grows and reaches maturity more rapidly than an unmulched practice. Adekalu et al. (2008) reported that mulches promote crop development and early harvests and increase yields. The major advantage of mulching was the earlier harvests compared with unmulched sweet corn (Hochmuth et al. 1990).

The results obtained from the present study indicated that mulch practices (plastic mulch and straw mulch) on different sowing dates (1 April, 15 April, and 1 May) had significant effects on fresh ear yield and yield components of sweet corn. Fresh ear yield, ear diameter, ear length, number of kernels per ear, and ear weight were increased with Mp practices on all sowing dates compared to Ms and Mu. The highest fresh ear yield and yield components were obtained from the Ms and Mu practice on the 1 May sowing date. Based on the results of the research: 1) We recommend plastic mulch sowed on 1 April for sweet corn in Isparta's ecological conditions and similar ecological regions because of the higher fresh ear yield than Ms and Mu. 2) Sweet corn should be sowed on 1 May without mulch because the differences between Mp and Mu on a 1 May sowing date were not statistically significant. 3) We would not recommend straw mulch sowed early for sweet corn because of the low germination ratio.

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