Effects of hybrid and row spacing on maize forage yield and quality

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ABSTRACT

This study was conducted to determine the effect of row spacing (40, 60 and 80 cm) on forage dry matter (DM) yield and quality of four hybrids grown in the years 2001 and 2002. The highest DM yield was obtained from the Arifiye (24.1 and 22.4 t/ha) while the lowest DM yield was obtained from Pioneer 3163 (19.9 and 19.8 t/ha) in the years 2001 and 2002, respectively. As row spacing increased, DM yield as an average of two years decreased from 27.2 to 16.6 t/ha. No differences were found among row spacing for DM content, harvest index (HI) and ear content. As row spacing increased, whole-plant acid detergent fiber (ADF) and neutral detergent fiber (NDF) content increased from 214 to 227 g/kg and from 420 to 451 g/kg during the year 2001, respectively. However, ADF content decreased from 281 to 267 g/kg and NDF contents decreased from 530 to 515 g/kg with increasing row spacing during the year 2002. In this study, hybrids showed distinct differences for crude protein, ADF and NDF contents in both years. Forage quality parameter including ADF and NDF of Pioneer 3163, TTM 8119 and Karadeniz Yildizi were higher than Arifiye hybrid.

Keywords: silage maize; row spacing; dry matter yield; harvest index; crude protein; acid detergent fiber; neutral detergent fiber

Forage maize (*Zea mays* L.) is a silage crop widely grown in the world, but has a very limited acreage in Turkey. However, in the last decade, growth of the silage maize has increased rapidly after harvesting of winter cereals in the regions where the season is too short for grain production. In Turkey, most of the information available concerning the effect of row spacing and variety on maize is related to grain rather than forage production. Agronomic practices used to produce maize forage are not the same as those used for grain production in Turkey. Many producers adopted narrow rows under high plant densities and late hybrids in maize silage production for more dry matter per hectare.

Several researchers reported that the effects of row spacing and hybrids on maize DM yield and quality characteristics are variable (Pinter et al. 1994, Widdicombe and Thelen 2002). Maize DM yield and its nutritive value are influenced by numerous interactions including environment (temperature, photoperiod and light intensity), agronomic management (row spacing or plant density, sowing date, fertilizer and harvest stage), and genetic factors (Graybill et al. 1991). Hybrid selection is a key to improve forage quality for optimum animal output (Widdicombe and Thelen 2002).

Roth (1996) concluded a 9% DM yield increase for forage maize grown at 38-cm rows compared with 76-cm rows. Similarly, Cox et al. (1998) found that maize DM yield increased by 4% as row width lowered. In the same study, row spacing had no effect on the forage quality. Graybill et al. (1991) reported that some forage quality traits, including acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents, were not affected by increases in plant density. However, Cusicanqui and Lauer (1999) indicated that plant density had an effect on forage quality. Hence NDF content increased from 20 to 35 g/kg, and ADF content increased from 19 to 29 g/kg with increasing plant densities.

The objective of this study was to determine the effects of row spacing on maize forage DM yield and quality for selected maize hybrids.

MATERIAL AND METHODS

This study was conducted in the experimental area of the Field Crop Department, Faculty of Agriculture, University of Gaziosmanpasa, Tokat, Turkey (40°13'–40°22'N, 36°1'–36°40'E, altitude 623 m above sea level) during the years 2001 and 2002. Temperature and rainfall during the two growing seasons are given in Table 1. Total rainfall of 120.4, 134.6 and 135.0 mm and average monthly temperature of 20.2, 19.6 and 19.4°C were recorded in 2001, 2002 and long-term period, respectively. Soil samples from both locations were collected from a depth of 0–20 cm. Organic matter was determined by the modified Walkey-Black method as suggested by Nelson and Sommers (1982). Phosphorus (P) was determined by the method of Olsen and Sommers (1982) and potassium (K) by Knudsen et al. (1982). The experimental soils were slightly alkaline (pH 7.80), medium in calcium carbonate (10.0%), medium in P content (3.5 mg/100 g soil P), high in K content (41.2 mg/100 g soil K) and organic C 0.756%.

The experimental design was a randomized complete block with split plot design and with four replications. Main plots consisted of hybrids (Arifiye-FAO 700, Pioneer 3163-FAO 600, TTM 8119 and Karadeniz Yildizi-FAO 500), and subplots were focused on row spacing (40, 60 and 80 cm). Each of subplots was 6 m long. Seeds were planted at a density of 125 000, 83 300 and 62 500 plants/ha, respectively. The seeding dates were May 21, 2001 and May 15, 2002. Before planting, 90 kg/ha N (ammonium nitrate) and 44 kg/ha P as Triple super phosphate were applied for the normal growth of the crop. An additional 90 kg/ha N was applied when the plant heights were about 45 cm.

Before harvesting, two border rows from each side and 0.5 m from each end of the plot were removed in order to eliminate border effects. In all experiments weeds were controlled by hand as needed. The three centre rows of each plot were harvested when kernel milk-line was between 50 and 75%. Eight plants were harvested from each sub plot for whole-plant analysis and plants were split into stover and ear fractions. These samples were dried at 60°C for 7 days. Ears were then shelled and grain weights were recorded to determine the harvest index (HI); HI was defined as the ratio between ear DM and fodder DM. Dried samples were ground using a hammer mill to pass a 1-mm screen. Whole-plants samples were analyzed for NDF, ADF and CP content. A 0.5 g sample was used for sequential detergent analysis to determine NDF and ADF contents (Soest et al. 1991). Total N was determined by the Kjeldahl procedure and CP content was calculated by multiplying total N by 6.25. All compositional data were calculated on a dry matter basis.

All data were analyzed with the General Linear Model (GLM) procedure using the SAS package (SAS Institute 1990). Results for each year were analysed separately for a randomized complete block design with split-plot arrangement. Treatment means were compared by using Fisher's Least Significant Difference (LSD) test at the 0.05 and 0.01 probability level. Also, GLM procedure of SAS was used to determine simple correlation coefficient among all measured variables.

RESULTS AND DISCUSSION

Differences among hybrids were observed for plant height, leaf number and stem diameter in 2001 and 2002 (Table 2). In both years, Arifiye had the largest plant height (278 and 322 cm), leaf number (12.0 and 14.2 per plant), and stem diameter (26.5 and 25.7 mm). Row spacing had no

Table 1. Climatic data for the experimental years and long term average

Months	Rainfall (mm)			Mean temperature (°C)		
	2001	2002	long term	2001	2002	long term
May	92.2	16.8	60.3	14.4	15.6	16.3
June	5.6	57.6	39.4	20.2	18.8	19.5
July	1.0	37.6	11.2	23.5	23.2	21.9
August	1.2	11.2	6.6	23.3	21.4	21.7
September	20.4	11.4	17.5	19.6	18.8	17.8
Total/mean	120.4	134.6	135.0	20.2	19.6	19.4

Table 2. Effect of row spacing on the plant height, leaf number, stem diameter and proportion of fraction in whole-plant in four maize hybrids

Hybrids (H)	Row spacing (cm)	Plant height (cm)		Leaf number (per plant)		Stem diameter (mm)		Proportion of fraction in whole-plant (g/kg)					
								leaf		stalk		ear	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Arifiye	40	272	313	12.3	14.4	25.5	24.8	182	226	365	437	455	336
	60	281	328	11.8	14.0	26.0	25.7	177	218	351	444	467	336
	80	280	325	12.0	14.0	28.1	26.6	177	216	356	457	468	351
Pioneer 3163	40	260	289	11.8	13.0	22.0	21.3	173	195	278	343	548	460
	60	266	309	11.6	13.4	22.1	22.5	174	179	293	327	532	493
	80	252	295	11.3	13.1	22.1	23.8	164	188	301	323	548	488
TTM 8119	40	260	286	11.6	11.8	24.6	22.9	157	174	286	389	556	439
	60	265	284	10.8	12.1	25.7	24.6	157	162	297	393	545	462
	80	270	272	11.4	11.5	27.3	25.3	147	172	300	365	553	431
Karadeniz Yildizi	40	–	283	–	12.4	–	22.2	–	202	–	376	–	431
	60	–	286	–	12.3	–	24.9	–	167	–	357	–	440
	80	–	297	–	12.2	–	25.2	–	188	–	342	–	490
Hybrid average	Arifiye	278	322	12.0	14.2	26.5	25.7	178	220	357	446	463	341
	P3163	259	298	11.5	13.2	22.0	22.5	171	187	290	331	542	480
	TTM8119	265	281	11.2	11.8	25.8	24.3	154	169	294	382	551	444
	K. Yildizi	–	288	–	12.3	–	24.1	–	188	–	358	–	453
LSD		17*	18**	0.6*	0.4*	1.8**	1.3**	5.6**	22**	38**	38**	38**	52**
Row spacing average	40	264	293	11.9	12.9	24.0	22.8	171	197	310	386	519	417
	60	271	302	11.4	13.0	24.6	24.4	169	190	314	380	514	433
	80	268	297	11.5	12.7	25.8	25.2	163	185	319	372	523	440
LSD		NS	NS	0.4*	NS	1.1**	0.9**	NS	NS	NS	NS	NS	NS
H × R int. LSD		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*, **significant at 0.05 and 0.01 probability level; ns = not significant

effect on plant height in 2001 and 2002. Although row spacing had a significant effect on the number of leaves in 2001, there was no significant difference between row spacing in 2002.

Effects of hybrid and row spacing on the plant components are shown in Table 2. A difference among hybrids was observed for leaf content. Percentages of leaves for late hybrid (Arifiye) and medium-late hybrid (Pioneer 3163) were considerably higher than those of mid-early hybrids (TTM8119 and Karadeniz Yildizi). In both years, the highest leaf content (178 and 220 g/kg) was obtained from Arifiye while the lowest (154 and 169 g/kg) was obtained from TTM 8119. Barriere and Traineau (1986) reported that the number of leaves and leaf area index were higher in the late-maturing than the early-maturing hybrids. Row spacing did not have any influence on the leaf content in both years. Average leaf content in the forage was higher in 2001 (190 g/kg) than in 2002 (167 g/kg). Hybrids differed significantly in stalk contents in both years (Table 2). The highest stalk content was obtained from Arifiye (357 and 446 g/kg), while the lowest stalk content was obtained from Pioneer 3163 (290 and 331 g/kg) in the year 2001 and 2002, respectively. The stalk content ranged from 294 to 357 g/kg and from 331 to 446 g/kg in 2001 and 2002, respectively. In this study, during the growing season (July, August and September) mean air temperature in 2001

Table 3. Effect of row spacing on the dry matter (DM) yield and content, harvest index (HI), crude protein (CP) content, acid detergent fiber (ADF) concentration and neutral detergent fiber (NDF) concentration in four maize hybrids

Hybrids (H)	Row spacing (cm)	DM yield (t/ha)		DM content (g/kg)		HI (%)		CP (g/kg)		ADF (g/kg)		NDF (g/kg)	
		2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
Arifiye	40	30.8	29.6	278	244	28.9	16.3	80	81	231	314	427	574
	60	23.3	21.3	286	212	31.5	13.4	88	84	217	319	476	600
	80	18.1	16.3	289	197	29.9	15.1	84	86	270	285	538	522
Pioneer 3163	40	26.5	23.7	338	240	40.7	24.9	65	86	223	256	412	492
	60	19.2	19.2	339	247	39.5	30.2	68	80	218	254	437	478
	80	13.8	16.4	347	254	40.7	27.2	75	79	230	257	404	489
TTM 8119	40	28.8	25.0	310	233	42.1	27.5	70	80	189	274	423	518
	60	20.9	19.5	301	235	40.5	26.6	66	79	207	256	408	493
	80	18.2	15.4	306	235	41.3	27.0	73	85	181	269	410	532
Karadeniz Yildizi	40	–	20.7	–	219	–	22.5	–	84	–	280	–	535
	60	–	17.5	–	249	–	24.0	–	83	–	279	–	512
	80	–	20.9	–	232	–	25.8	–	89	–	257	–	518
Hybrid average	Arifiye	24.1	22.4	284	218	30.1	14.9	84	84	239	306	480	565
	P3163	19.9	19.8	341	247	40.3	27.4	70	82	223	255	417	486
	TTM8119	22.6	20.0	306	234	41.3	27.0	70	81	192	266	414	514
	K. Yildizi	–	20.9	–	233	–	24.1	–	86	–	272	–	522
LSD		2.5*	NS	24**	14**	2.3**	3.7**	4*	NS	19**	37*	16**	41**
Row spacing average	40	28.7	25.7	308	234	37.2	22.8	72	83	214	281	420	530
	60	21.1	20.2	308	236	37.2	23.5	74	81	214	277	440	521
	80	16.7	16.4	314	229	37.3	23.7	78	85	227	267	451	515
LSD		1.7**	1.8**	NS	NS	NS	NS	4*	NS	NS	NS	15**	NS
H × R int. LSD		2.9*	3.6*	NS	NS	NS	NS	6*	NS	21**	NS	27**	44*

*, **significant at 0.05 and 0.01 probability level; ns – not significant

was higher than in 2002 (Table 1). Growing maize under unfavourable conditions such as poor light and dense planting, often leads to a poor grain-set and more leaves and stalks (Struik 1982).

There was a significant difference between the hybrids for ear content. Ear content of Arifiye was lower than of the other hybrids in both years; and there was no significant difference among TTM 8119, P3163 and Karadeniz Yildizi cultivars in terms of ear content. Ear contents for hybrids were significantly higher in 2001 than in 2002, probably due to lower mean air temperature during the month of July as compared to September (Table 1). Row spacing did not affect the ear content of corn forage and there was no significant difference between 40, 60 and 80 cm row spacing in both years (Table 2).

Mean harvest index of the hybrids varied from 30.1 to 41.3% and from 14.9 to 27.4% in 2001 and 2002, respectively (Table 3). Harvest index of the late-maturing hybrid cv. Arifiye was lower than the mid-early maturing cv. 8119 and Karadeniz Yildizi, and mid-late maturing hybrid cv. 3163. Maize silage produced from plants containing a low proportion of grain had greater concentrations of ADF and NDF as reported by Vattikonda and Hunter (1983). Whereas Graybill et al. (1991) reported that there was a considerable variation among hybrids for harvest index. In this study row spacing had no effect on the HI in both years.

These results agree with the findings of Graybill et al. (1991) and Widdicombe and Thelen (2002) who found that plant density did not have a significant effect on HI. However, Pinter et al. (1994) reported that corn hybrids responded differently to high plant density.

The effect of hybrid, row spacing and hybrid × row spacing interaction on the DM yield is shown in Table 3. In this study, hybrids had a significant effect on the DM yield in 2001, but there was no significant difference among the hybrids in 2002. The highest DM yield was obtained from Arifiye (24.1 and 22.4 t/ha), while the lowest DM yield was obtained from Pioneer 3163 (19.9 and 19.8 t/ha) in the year 2001 and 2002, respectively. Hybrid differences in DM yield have been documented in many research works (Vattikonda and Hunter 1983, Graybill et al. 1991, Cox et al. 1994). As row spacing narrowed from 80 to 40 cm, the DM yield of the forage increased by 71% and 56% in 2001 and 2002, respectively; maximum DM yields were observed at 40 cm (28.7 and 25.7 t/ha) compared to 80 cm (16.7 and t/ha). There was a significant hybrid × row spacing interaction for DM yield in 2001 and 2002. Forage quality decreased as plant densities increased (Graybill et al. 1991, Cusicanqui and Lauer 1999, Widdicombe and Thelen 2002). Such differences in the results might be attributable to environmental, cultural and genetic factors.

Differences among hybrids were observed for DM content. The highest DM content was obtained from Pioneer 3163 (341 and 253 g/kg), followed by TTM 8119 (306 and 233 g/kg), Karadeniz Yildizi (239 g/kg) and Arifiye (284 and 209 g/kg) in years 2001 and 2002, respectively (Table 3). When averaged, DM content of hybrids was higher in 2001 (an average of 310 g/kg) than in 2002 (234 g/kg). DM content of the early hybrids was nearly as high as that of the late ones. Whole-plant DM content at harvest is important because of its effect on ensiling and animal DM intake as reported by Vattikonda and Hunter (1983). Hunter (1986) reported that DM contents with a range of 280 and 300 g/kg might be considered a reasonable maturity target in the short-season areas of Europe. There were some differences in reported DM content based on hybrids, harvest stage and agronomic factors (Russell et al. 1992). As row spacing narrowed from 80 to 40 cm, DM content varied from 314 to 308 g/kg and from 232 to 238 g/kg in 2001 and 2002, respectively. However, there was no significant difference among 40, 60 and 80 row spacing.

Hybrid variations were observed for CP content in 2001 and the highest CP content was obtained from Arifiye (84 g/kg), followed by Pioneer 3163 (70 g/kg) and TTM 8119 (70 g/kg); there was no significant effect on CP content in 2002. The CP content of hybrids varied from 81 to 86 g/kg. Lewis et al. (2004) reported a similar range in CP for hybrids. Row spacing also affected forage CP evels. The highest CP content was obtained from 80 cm row spacing. As reported by Cusicanqui and Lauer (1999), CP content showed a significant decline for the higher plant densities. There were differences in CP yield among the hybrids as evaluated in 2001. The highest CP yield was obtained from Arifiye (20.2 kg/ha), followed by TTM 8119 (15.8 kg/ha) and Pioneer 3163 (13.5 kg/ha). However, there was no significant effect on CP yield in 2002 and CP yield of hybrids varied from 16.1 to 18.5 kg/ha. As row spacing narrowed from 80 to 40 cm, CP yield increased from 13.0 to 20.6 kg/ha and from 13.8 to 21.0 kg/ha in the years 2001 and 2002, respectively (Table 3).

Hybrids showed a significant variation in ADF and NDF concentrations, which is consistent with the findings of other researchers (Graybill et al. 1991, Cox et al. 1994, Cusicangui and Lauer 1999). Hybrid selection might be an important management input because it influences the nutritive value of maize forage. The late-maturing hybrid cv. Arifiye produced a significantly higher DM yield, ADF and NDF than the other hybrids. Averaged over two years, TTM8119 and Karadeniz Yildizi produced close DM yields (21.3 and 20.9 t/ha in 2001 and 2002, respectively), but showed significant differences in ADF (229 and 272 g/kg for the year 2001 and 2002, respectively) and NDF (464 and 522 g/kg for the year 2001 and 2002, respectively) (Table 3). Hunt et al. (1992) found out that NDF of hybrids varied from 417 to 490 g/kg and ADF from to 239 to 283 g/kg. The silage maize producer may wish to consider hybrid quality characteristics in addition to DM yields before selecting a hybrid (Graybill et al. 1991).

Row spacing did not affect the ADF concentration of forage corn. When averaged across row spacing, ADF concentration varied from 214 to 227 g/kg in 2001 and from 281 to 267 g/kg in 2002. ADF content of maize hybrids in 2002 was 57 g/kg, which was higher than that of 2001. This variation may be attributed to climatic differences, particularly lower air temperature during the month of July as compared to September in 2002. There was a significant difference between the row spacing for NDF concentration in 2001. NDF increased linearly by 31 g/kg as row spacing decreased from highest to lowest. As row spacing narrowed from

Table 4. Correlation coefficient (r) between whole-plant composition and forage quality traits in four maize hybrids (n = 36 for 2001 and n = 48 for 2002)

	DMY	LC	SC	EC	DMC	HI	CP	ADF
2001								
LC	0.17							
SC	0.11	0.42**						
EC	–0.14	–0.63**	–0.97**					
DMC	–0.30	–0.10	–0.26	0.24				
HI	–0.14	–0.68**	–0.86**	0.92**	0.45*			
CP	–0.07	0.34	0.64	–0.64**	–0.44*	–0.70**		
ADF	0.13	0.05	0.34	–0.30	–0.51**	–0.38	0.25	
NDF	–0.11	0.33	0.44	0.45*	–0.46*	–0.57**	0.63**	0.51**
2002								
LC	0.11							
SC	0.14	0.45**						
EC	–0.15	–0.73**	–0.84**					
DMC	0.17	–0.53**	–0.74**	0.75**				
HI	–0.19	–0.68**	–0.85**	0.86**	0.70**			
CP	–0.11	0.13	–0.13	0.01	0.02	0.02		
ADF	0.14	0.43**	0.54**	–0.59**	–0.37**	–0.47**	–0.04	
NDF	0.13	0.42**	0.54**	–0.59**	–0.42**	–0.53**	0.07	0.85**

DMY – dry matter yield, LC – leaf content, SC – stalk content, EC – ear content, DMC – dry matter content, CP – crude protein, HI – harvest index, ADF – acid detergent fiber, NDF – neutral detergent fiber; *, **significant at P = 0.05 and 0.01, respectively

80 to 40 cm, the NDF increased by 15 g/kg in 2002, but there was no significant difference between the row spacing in 2001. The difference in ADF and NDF contents between the two years was due to hybrid × environmental (year) interaction. Likewise, Graybill et al. (1991) reported that little difference was noted among plant density for ADF and NDF content. In contrast to these studies, Cox and Cherney (2001) observed that NDF and CP content of hybrids were not affected with increased row spacing. These differences in ADF and NDF contents may be also attributed to hybrid × environmental (year) interaction.

Relationship between whole-plant composition and forage quality traits

The correlation among all pairs of variables in 2001 and 2002 are given in Table 4. The simple coefficient calculated from the data of 2001 and 2002 indicated that none of the traits had a significant effect on the DM yield. The DM content showed a weak correlation with leaf content (r = –0.10), stalk content (r = 0.25) and ear content (r = 0.24) of the hybrids examined in 2001. However, in 2002, the DM content was closely negatively correlated with leaf content (r = –0.53**), stalk content (r = –0.74**) and positively correlated with ear content (r = 0.75**). Whole-plant DM content at harvest is important because of its effect on ensiling and animal intake (Vattikonda and Hunter 1983). Harvest index was negatively correlated with ADF (r = –0.38 and r = –0.47**) and NDF (r = –0.57** and r = –0.53**) in 2001 and 2002, respectively. These results are in agreement with the results of Cox et al. (1994). Increased HI was generally associated with increased ear content and DM content in all trials. Whole-plant ADF content was negatively correlated with (r = –051**

for 2001 and $r = -0.37^{**}$ for 2002) DM content. On the other hand, as DM content increased, ADF decreased in both years. This relationship was also obtained for NDF and DM content. Whole-plant ADF and NDF contents were found to be an important factor influencing whole-plant nutritional quality (Soest 1994). Whole-plant ADF content was most highly related to NDF content ($r = 0.51^{**}$ for 2001 and $r = 0.85^{**}$ for 2002). Other studies also concluded that whole-plant ADF content had a strong positive relationship with whole-plant NDF content (Cox et al. 1994).

Hybrids showed distinct differences in their morphological characteristics and forage quality. Row spacing had no affect on plant height, number of leaves per plant, stem diameter, plant components and harvest index. Forage DM yields decrease by 12.0 t/ha and 9.3 t/ha as row spacing was narrowed from 80 to 40 cm.

The significant hybrid × row spacing interaction for ADF, NDF and CP content indicates that some of the hybrids examined in this study responded differently to changes in row spacing in both years. The negative relationship between row spacing and forage quality makes it difficult to recommend row spacing for optimum animal performance based on yield. In this study, forage quality parameter including ADF and NDF of Pioneer 3163, TTM 8119 and Karadeniz Yildizi were higher than Arifiye cultivar and these hybrids may be recommended for dairy producers. However, more researches in animal digestions are needed in order to decide about the selection of hybrid and row spacing.

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