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Influence of Planting Patterns and Plant Density on the Performance of Maize Hybrids in the Eastern Mediterranean Conditions

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ABSTRACT

There has been an increasing interest in different planting patterns such as twin-row and narrow-row configurations to obtain better grain yield in maize. To observe the effect of different planting patterns (twin-row & narrow-row), a study was conducted at the Research Station of Mustafa Kemal University, Hatay in the Eastern Mediterranean region of Turkey in the years, 2003 and 2004. The experiment was conducted in split-split plot arrangement in the randomized complete block design with three replications. Planting patterns, plant densities and hybrids were placed in main, split and split-split plots, respectively. Planting patterns were conventional row with 75 cm inter-row, twin-row with 55:20 cm alternate row and narrow-row with 50 cm inter-row. Plant densities were 80.000, 100.000 and 120.000 plants ha^{-1} and maize hybrids were Dk-585, Maverik and Pr-1550. A better grain yield was obtained from twin and narrow row systems than the conventional one. However, grain yield and its component traits were strongly affected by environment and hybrid, as well as planting patterns used in the field experiments. The results suggested that Maverik and Dk-585 could be better choices for twin row planting while Pr-1550 was better for narrow-row planting in the double cropping systems.

Key Words: Twin-row; Narrow-row; Grain yield; Maize hybrid; Density

INTRODUCTION

Grain yield increase is a major concern for maize producers. Maize is generally cultivated in wide spaced rows; however, recently there has been an interest in different planting patterns such as twin-row and narrow-row configurations. Current developments in maize genetics have enhanced plant density by narrowing and intensifying the rows (Duvick *et al*.,1999) and the current hybrids were found to have decreased lodging frequencies at the higher plant populations (Nafziger, 1994).

It was determined that optimum plant density depends on the hybrid properties (Farnham, 2001; Widdicombe & Thelen, 2002; Sener *et al*., 2004; Sarlangue *et al*., 2007). Farnham (2001) reported that responses of six corn hybrids to narrowing the row space were different due to strong hybrid × row spacing interaction. Several reports revealed that narrower rows produced higher grain yields than conventional rows (Nielsen, 1988; Porter *et al*., 1997; Andrade *et al*., 2002; Sharratt, B.S., 2005; Yılmaz *et al*., 2008). Cox *et al*. (2006) indicated that narrow rows had greater dry matter yield (17.6 Mg ha^{-1}) than twin (17.2 Mg ha^{-1}) or conventional rows (16.6 Mg ha^{-1}). While narrow rows seem to be desirable, there may be a problem during cultivation practices. Twin row planting can be treated as a single row, allowing some of the advantages of narrow rows without any practical disadvantages (Yılmaz *et al*., 2008). Gozubenli *et al*. (2004) obtained the highest grain yield from 90,000 plant ha^{-1} density with twin-row (60:20 cm) planting, which yielded 4% more than the single row (80 cm) planting. Twin-row (30:76 cm) planted corn yielded 6.5% more than single-row (96 cm) planted corn in the Atlantic Coastal plain in USA (Karlen & Camp, 1985). Yılmaz *et al*. (2008) reported that forage and dry matter yields were significantly affected by planting patterns, plant densities and maize hybrids. Their results revealed the advantage of twin-row planting pattern over conventional and narrow-row plantings at all studied plant densities.

Many field experiments were conducted to determine optimum plant density and row spacing by different researchers in the last decades; however, studies on twin row planting configurations are still new and needs further evaluation.

The objectives of this research were to determine the most suitable planting pattern, plant density, maize hybrid for increased grain yield in maize grown as second crop in Hatay ecological conditions.

MATERIALS AND METHODS

The field experiments of this study were conducted at the Research Station of Mustafa Kemal University, Hatay,

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located at 36º15' N and 36º30' E in the Eastern Mediterranean region of Turkey in the 2003 and 2004 growing seasons. The soil of the experimental site, developed from alluvial deposits of river terraces is typical for the Eastern Mediterranean region of Turkey, having relatively high clay content with the predominant clay minerals smectite and kaolinite. The soil of experimental plots was a clay silt loam with pH of 7.12, having 1.93% organic matter and water holding capacity of 0.51 cm^3.

Weather conditions of the experimental site were hot and dry during growing seasons (Table I). The field experiments were planted on 20 June, 2003 and 22 June, 2004 shortly after wheat harvest. The hybrid corn seeds were over seeded at a double rate and then thinned by hand after emergence to attain the desired target plant densities. Fertilizers were applied using 100 kg ha^{-1} each of N and P_2O_5, before seeding. Nitrogen was also top dressed at the rate of 150 kg ha^{-1}, when the plants reached at knee heigh stage. Six irrigations were applied, when consumed nearly half of the available soil water. In the experiments, weeds were controlled by hand and harrowing.

The experiment was performed using split-split plot arrangement in the randomized complete block design with three replications. Main plots involved planting patterns, split-plots contained plant densities and split-split-plots were hybrids. A split-split-plot size was 3 × 5 m = 15 m^2. Three planting patterns were conventional row with 75 cm inter-row, twin-row with 55:20 cm alternate row and narrow row with 50 cm inter-row (Fig. 1). Three plant densities were 80,000; 100,000 and 120,000 plants ha^{-1} and three maize hybrids were Dk-585 (FAO 520), Maverik (FAO 490) and Pr-1550 (FAO 550), which are cultivated as second crop in Hatay.

Tasseling period (day), defined as 75% of the plants were tasseled in a plot was measured as the number of days after planting. Ten plants were sampled randomly at the center two rows of each plot before harvest and plant height (as cm from the soil surface to the lowest branch of tassel), ear height (as cm from the soil surface to the first ear node) and stem diameter (diameter of the first internode as mm above the soil surface) were measured. The center two rows of each plot were harvested by hand at maturity to determine ear weight and grain yield.

Data were analyzed using standard analysis of variance (ANOVA) technique and means were separated using least significant difference (L.S.D.) comparisons using SAS statistical analysis package (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

Responses to planting patterns: Grain yield, plant height and ear height were significantly affected by planting patterns, however, the other measured plant characteristics of maize were not affected ($p<0.05$; Table II). Higher plant and ear height values were obtained from narrow and twin-row plantings than the conventional row planting. The highest grain yield was obtained from narrow-row planting (9837 kg ha^{-1}) followed by twin-row planting (9704 kg ha^{-1}), which was in the same statistical group, while the lowest grain yield (8815 kg ha^{-1}) was obtained from the conventional planting (Table II). Decreasing row spacing at equal plant densities produces a more equidistant plant distribution. This distribution decreases 'plant to plant' competition for available water, nutrient and light and increases radiation interception and biomass production (Ottman & Welch, 1989; Andrade *et al*., 2002) and provide minimum competition and maximum yield at any given plant density (Olson & Sander, 1988).

Widdicombe and Thelen (2002) reported that maize grain yield increased, when row width was narrowed. Barbieri *et al*. (2000) showed that the average increase in response to narrow rows was 20.5% for grain yield of maize. Decreasing row spacing from 76 cm to 51 cm resulted in 4% more grain yield (Shapiro & Wortmann, 2006). Gozubenli *et al*. (2004) reported that twin row planting resulted in 4% more grain yield than single row planting. Finck (2003) indicated in a 3 year twin-row study that twins out-yielded 30 inch single rows.

Responses to plant densities: Grain yield and yield-related traits of maize except for tasseling period were significantly affected by plant densities (Table III). Plant height and ear height increased as the plant density increased and the tallest plants and the highest ears (208.1 cm & 93.5 cm, respectively) were measured at 120,000 plant ha^{-1} density and the shortest plants and ear heights (199.7 cm & 88.2 cm, respectively) were at 80,000 plant ha^{-1} density. On the other hand, stem diameter decreased as the plant density increased and the highest value (18.3 cm) was obtained at the lowest (80,000 plant ha^{-1}) density, while the lowest value was obtained at the highest density (120,000 plant ha^{-1}) (Table III). Plant height, stem diameter and to some extent, other yield component traits were strongly influenced by environmental conditions during stalk elongation. It has been frequently observed in experiments involving different plant densities that maize plants were taller as mutual shading increased, although there was considerable genotypic variations in this characteristic (Duncan, 1975). Increased population density causes plant stems to become thinner and often taller. Some researchers revealed that thinner stem diameters and taller plants were observed at higher plant densities (Gozubenli *et al*., 2004; Sener *et al*., 2004; Turgut *et al*., 2005).

Ear weight decreased with increasing plant densities and the heaviest ears obtained at 80,000 plant ha^{-1} with 167.6 g ear^{-1} (Table III). The ear weight reduction may be due to the effects of inter-plant competition for light, water, nutrients and other yield limiting environmental factors (Olson & Sander, 1988). Gozubenli *et al*. (2003) and Sener *et al*. (2004) reported that the highest ear weight values obtained from the lowest plant density and the lowest values were obtained at the highest plant density.

Table I: Some climatological data of experimental site during maize growing seasons in 2003 and 2004. (Meteorology Station of Hatay State Farm, Reyhanli, Hatay)

	2003			2004		
Months	**Temp. (ºC)**	**Rainfall (mm)**	**R.H.* (%)**	**Temp. (ºC)**	**Rainfall (mm)**	**R.H. (%)**
June	26.3	_	50.7	25.6	_	52.5
July	28.6	_	54.0	28.8	_	45.0
August	28.9	_	50.8	27.8	_	53.7
September	24.5	20.7	56.0	24.9	_	56.5
October	21.6	11.4	60.1	22.0	3.1	47.2

*Relative humidity

Table II: Tasseling period (day), plant height (cm), ear height (cm), stem diameter (mm), ear weigh (g) and grain yield (kg ha^{-1}) in different planting patterns

Planting patterns	Tasseling period (day)	Plant height (cm)	Ear height (cm)	Stem diameter (mm)	Ear weight (g)	Grain yield (kg ha^{-1})
			2003			
Conventional-row (75 cm)	55.1	210.5 b	94.1 b	17.7	162.6	9556 b
Narrow-row (50 cm)	55	219.5 a	98.8 a	18.1	172.3	11281 a
Twin-row (55:20 cm)	55.5	214.2ab	96.2 ab	18.0	169.3	10632 a
LSD (5%)	N.S.	5.43	3.14	N.S.	N.S.	690
			2004			
Conventional-row (75 cm)	52.7	189.4	82.7	16.8	134.3	8073 c
Narrow-row (50 cm)	52.7	193.5	84.3	17.0	136.8	8393 b
Twin-row (55:20 cm)	52.9	194.9	87.1	17.2	138.7	8775 a
LSD (5%)	N.S.	N.S.	N.S.	N.S.	N.S.	158
			Mean			
Conventional-row (75 cm)	53.9	200 b	88.4 b	17.9	148.5	8815 b
Narrow-row (50 cm)	53.9	206.5 a	91.6 a	17.6	154.6	9837 a
Twin-row (55:20 cm)	54.2	204.6 a	91.7 a	17.6	154.0	9704 a
LSD (5%)	N.S.	4.5	2.12	N.S.	N.S.	294

Means with the same letter are not significantly different ($p>0.05$)

Grain yield decreased at the highest plant density of 120,000 plant ha^{-1}, while higher and similar grain yields (9725 kg ha^{-1} and 9652 kg ha^{-1}, respectively) obtained from 80,000 plant ha^{-1} and 100,000 plant ha^{-1} densities (Table III). Grain yield is the product of crop dry matter accumulation and the proportion of the dry matter allocated to the grain (harvest index) and harvest index in maize declined when plant density increased above the critical plant density (Tollenaar *et al*., 1994). For instance, grain yield increased with increasing plant densities up to 90,000 plant ha^{-1} and decreased at higher densities. However, there were no significant differences among 80,000 plant ha^{-1}, 90,000 plant ha^{-1} and 100,000 plant ha^{-1} densities (Gozubenli *et al*., 2003). Farnham (2001) reported that maize grain yield increased as plant density increased from 59,000 to 89,000 plant ha^{-1}. Gozubenli *et al*. (2004) also found that grain yield increased with increasing densities up to 90,000 plant ha^{-1} and decreased in higher plant densities. Zamir *et al*. (1999) reported that there were highly significant differences among the plant spacings and the maximum grain yield was obtained from 10 cm inter-row spacing that was statistically similar with 15 cm inter-row spacing in 60 cm inter-row spacing.

Table III: Tasseling period (day), plant height (cm), ear height (cm), stem diameter (mm), ear weigh (g) and grain yield (kg ha^{-1}) in different plant densities

Plant densities	Tasseling period (day)	Plant height (cm)	Ear height (cm)	Stem diameter (mm)	Ear weight (g)	Grain yield (kg ha^{-1})
			2003			
80 000 (plant ha^{-1})	55.2	209.9 b	94.0 b	18.7 a	180.5 a	10821 a
100 000 (plant ha^{-1})	55.6	214.7 ab	95.8 b	17.9 b	169.9 b	10667 a
120 000 (plant ha^{-1})	54.8	219.4 a	99.3 a	17.3 c	153.8 c	9983 b
LSD (5%)	N.S.	6.42	3.2	0,54	6.1	284
			2004			
80 000 (plant ha^{-1})	52.5	188.4 b	82.3 b	17.8 a	154.8 a	8628 a
100 000 (plant ha^{-1})	52.7	192.7 ab	84.2 b	17.0 ab	133.7 b	8636 a
120 000 (plant ha^{-1})	53.0	196.7 a	87.6 a	16.2 b	121.3 c	7977 b
LSD (5%)	N.S.	4.99	3.23	0.93	3.41	304
			Mean			
80 000 (plant ha^{-1})	53.9	199.7 c	88.2 b	18.3 a	167.6 a	9725 a
100 000 (plant ha^{-1})	54.2	203.7 b	90.0 b	17.4 b	151.8 b	9652 a
120 000 (plant ha^{-1})	53.9	208.1 a	93.5 a	16.7 c	137.6 c	8980 b
LSD (5%)	N.S.	3.85	2.14	0.51	5.19	197

Means with the same letter are not significantly different (p□0.05)

Table IV: Tasseling period (day), plant height (cm), ear height (cm), stem diameter (mm), ear weigh (g) and grain yield (kg ha^{-1}) of maize hybrids

Hybrids	Tasseling period (day)	Plant height (cm)	Ear height (cm)	Stem diameter (mm)	Ear weight (g)	Grain yield (kg ha^{-1})
			2003			
Dk-585	54.6 c	214.5	93.2 b	18.2	165.1 b	10547
Maverik	55.9 a	212.7	98.9 a	17.9	172.3 a	10625
Pr-1550	55.1 b	216.7	97.0 a	17.7	166.8 b	10298
LSD (5%)	0.53	N.S.	2.59	N.S.	4.35	N.S.
			2004			
Dk-585	52.6	189.8 b	83.3	17.1	134.7 b	8261 b
Maverik	52.7	192.7 ab	85.1	17.1	138.9 a	8596 a
Pr-1550	52.9	195.3 a	85.7	16.8	136.2 ab	8383 ab
LSD (5%)	N.S.	3.25	N.S.	N.S.	3.24	236
			Mean			
Dk-585	53.6 b	202.2 b	88.3 b	17.7	149.9 b	9404 ab
Maverik	54.3 a	202.7 b	92.0 a	17.5	155.6 a	9611 a
Pr-1550	54.0 a	206.0 a	91.4 a	17.3	151.5 b	9341 b
LSD (5%)	0.38	2.6	1.91	N.S.	2.9	216

Means with the same letter are not significantly different ($p>0.05$)

Performance of hybrids: Differences among hybrids for grain yield and the other traits of maize were significant except for stem diameter (Table IV). Tasseling periods among maize hybrids were statistically significant. Maverik and Pr-1550 had similar at tasseling period while Dk-585 had earlier tasseling period. Plant height and ear height differed among hybrids. The tallest plants were measured from Pr-1550 and the highest ears measured from Maverik and Pr-1550 hybrids. Additionally, ear weights of maize hybrids were different and the heaviest ears (155.6 g ear^{-1}) were obtained from Maverik hybrid, while lighter ears were obtained from Pr-1550 (151.5 g ear^{-1}) and Dk-585 (149.9 g ear^{-1}) hybrids (Table IV). Gozubenli *et al*. (2003) indicated that differences in ear characteristics of maize hybrids were significant and ear weight differed from hybrid to hybrid.

Table V: Year × Planting pattern interactions for grain yield (kg ha^{-1})

	Plantıng patterns		
Year	**Conventional-row (75 cm)**	**Narrow-row (50 cm)**	**Twin-row (55:20 cm)**
2003	9556 c	11282 a	10633 b
2004	8073 e	8393 de	8775 d
	LSD (5%) = 416		

Means with the same letter are not significantly different (p□0.05)

Table VI: Planting pattern × hybrid interactions for grain yield (kg ha^{-1})

	Hybrıds		
Plantıng patterns	**Dk-585**	**Maverik**	**Pr-1550**
Conventional-row (75 cm)	8853 d	8864 d	8726 d
Narrow-row (50 cm)	9549 bc	10005 a	9957 a
Twin-row (55:20 cm)	9811 ab	9962 a	9339 c
	LSD (5%) = 360		

Means with the same letter are not significantly different (p□0.05)

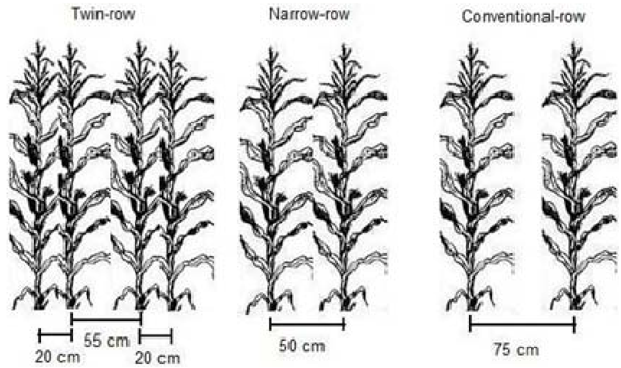
Furthermore, Sener *et al*. (2004) and Turgut *et al*. (2005) reported significant genotypic differences for such characteristics. Those traits were highly affected by different environmental conditions as well.

Grain yield of maize hybrids were significantly different and Maverik had the highest grain yield with 9611 kg ha^{-1} and Pr-1550 had the lowest grain yield with 9341 kg ha^{-1} (Table IV). Our results were in corroboration with the previous studies that grain yield was genetically variable in maize hybrids (Farnham, 2001; Iqbal *et al*., 2001; Gozubenli *et al*., 2004; Sener *et al*., 2004; Abdulai *et al*., 2007).

Interaction effects: Grain yield was significantly affected by the year × planting pattern interaction (Table V) and the planting pattern × hybrid interaction (Table VI). When the year × planting pattern interaction was in consideration, narrow-row plantings had the highest grain yield in 2003, while twin-row plantings had the highest grain yield in 2004 (Table V). These results indicated that grain yield response of maize to planting patterns varied in different years. However, higher grain yield was obtained from narrow and twin row plantings than the conventional planting pattern.

Responses of hybrids to planting patterns were different (Table VI). All the tree hybrids produced higher grain yields in twin and narrow rows than in the conventional-row plantings. Dk-585 had the highest grain yield (9811 kg ha^{-1}) in twin row planting, while Pr-1550 had the highest grain yield (9957 kg ha^{-1}) in narrow-row planting. Maverik had similarly higher grain yield in twin and narrow-rows (10005 & 9962 kg ha^{-1}, respectively). Considering the planting pattern × hybrid interaction table showed that grain yield differences among narrow-row × Maverik (10005 kg ha^{-1}), twin-row × maverik (9962 kg ha^{-1}), narrow-row × Pr-1550 (9957 kg ha^{-1}) and twin-row × Dk-585 (9811 kg ha^{-1}) interactions were statistically insignificant (Table VI). Farnham (2001) reported that certain hybrids responded differently to varying row spacings. Turgut *et al*. (2005) recorded that strong hybrid × row spacing interactions for both forage and dry matter yields, suggesting that certain hybrids may perform better at prescribed row spacings.

Fig. 1: Planting patterns of maize



CONCLUSION

Twin and narrow row spacing had superiority over the conventional planting systems. However, grain yield and planting patterns were strongly influenced by environment and hybrids. Therefore, producers should be careful to choose, which planting patterns and hybrids under certain ecological conditions in order to obtain better grain yield. Maverik and Dk-585 could be better choices for twin-row planting, while Pr-1550 for narrow-row planting as a double cropping in the Eastern Mediterranean region of Turkey.

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