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An Approach on Yielding Performance in Maize under Varying Plant Densities

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Abstract: The purpose of this study was to evaluate the yielding performance of F1 single maize hybrids and their mechanical mixture in three plant densities and in two different years. Experiments were conducted in the farm of TEI of Larissa in 2000 and 2001. The genetic material used was consisted of commercial and experimental F1 single-cross maize hybrids and their balanced mechanical mixture for each year. It was found that there was a tension for increasing field yields of almost all hybrids when the plant density was increasing. This was very clear for year 2000, but in 2001 this was found only for the middle density in comparison to the low density because of the presence of common smut. Only hybrid Dias was the exception, with decreasing field yield when the plant density was increasing. The increasing plant density resulted in increasing CV values and number of barren plants. The performance of the mechanical mixture of all hybrids was similar to the mean performance of the hybrids when grown separately. This kind of performance was rendered to the genetic background of modern hybrids, in a way that under stress conditions (allocompetition, density effects) they express stable performance. In general, modern commercial maize hybrids increase field yields under increasing plant density and they can be used as a mixture without decreasing yielding performance. It is possible that allocompetition is not a stronger stress factor than isocompetition in modern maize hybrids.

Key words: Plant density, maize, competition, yield

INTRODUCTION

High yielding performance of modern maize hybrids is considered as the result of indirect selection based in adoption of tolerance to various biotic and abiotic factors (Russell, 1991; Tollenaar and Wu, 1999). Various stress conditions affect yielding performance in relation to the genotype involved and modern maize hybrids are affected in a different way in relation to older hybrids, especially when competition between plants is present (Bonan, 1991; Tollenaar, 1992; Vafias *et al*., 2000a). Plant density in farmer's field is considered an important stress factor since, in such conditions, competition between different plant species or between different maize hybrids (different genotypes) is very strong (Fasoulas, 1981, 1988, 1993; Daynard and Muldoon, 1983; Tetio-Kagho and Gardner, 1988; Bonan, 1991; Thomas *et al*., 1994; Vafias *et al*., 2000b). Larson and Hanway (1977) reported different plant densities in order to achieve maximum yields in maize, including field yield, LAI index and dry matter percentage. They also reported that, combining data from other researchers, lead to an increased plant density up to 70,000 or even 100,000 plants per hectare for optimum performance. Older data showed decreased yielding performance under competition (Fehr, 1987; Fasoulas, 1988), but these references are referred to older maize hybrids (Duvick, 1984; 1992). Data reported by Duvick (1992), Tollenaar and Wu (1999) and Vafias *et al.* (2000b) showed a considerable tolerance of modern maize hybrids under stress conditions, involving performance under higher plant densities. Optimum plant density for some maize hybrids was found at 90,000 plants per hectare (Vafias *et al*., 2000b). These data indicate that most of the commercial maize hybrids are density-dependent and their performance is related to optimum plant density in farmer's field (Tokatlidis, 2001; Tokatlidis *et al*., 2001). On the other hand, genetic purity is considered a greater stress condition than density effects (Ipsilandis *et al.,* 2005). In general, both stresses are considered of great importance (Fasoulas, 1981, 1988, 1993; Fehr, 1987; Vafias *et al*., 2000a;

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Ipsilandis *et al*., 2005). Mixtures of genotypes are not preferred for farmer's field because of lower yields due to competition effects (Fehr, 1987; Fasoulas, 1988); the only known advantages for using mixtures are summarized in controlling diseases or for adaptation in extreme environments. Newer reports refer that, problems caused by genetic impurity may be overcome by increasing plant density (Vafias *et al*., 2000a).

The purpose of this study was to evaluate the yielding performance of maize hybrids and their mechanical mixture, under three plant densities, in different years.

MATERIALS AND METHODS

The experiments were conducted in the farm of Technological Education Institute of Larissa, Greece, during years 2000 and 2001. In year 2000, 8 maize commercial hybrids were used: Dias, Rio Grande, Prisma, Dracma, Aligreen, Volusia, Costanza and CS1251. In year 2001, 7 maize commercial hybrids were used: Aris, Dias, Aligreen, Volusia, Costanza, Dracma, Damao and the 3 experimental hybrids A, B and C. Three plant densities were used: 66,600, 88,800 and 133,300 plants per hectare (6660, 8880 and 13330 plants/10 ares). Plant to plant spacing was 20, 15 and 10 cm respectively and between rows 75 cm. The split-plot design was used and the three densities formed the main plots, while hybrids formed the subplots. Double rows 5 m long were used for each plot, with four replications. Factorial analysis was based on Snedecor and Cochran (1980). Additional evaluation (in both years) was performed for balanced mechanical mixtures formed by mixing hybrid seed for all hybrids used in each year. Yield estimation was based on individual plant yield in grammars (g) and field yield in kg per stremma (1 Stremma = 10 ares or 0.1 hectare, according to European Community standards). Humidity was found below 15%. Additionally, Coefficient of Variation (CV%), barren plants (%) and maize plants (%) infested by common smut (*Ustillago maydis*) were calculated.

RESULTS

Table 1 and 2 show the results for both years of experimentation (2000 and 2001, respectively). Yield estimation was the basic trait examined, accompanied by CV(%), barren plants (%) and especially for year 2001, plants that were found infested by common smut (%). In both years of experimentation, there was found statistically significant interaction between the different genetic materials (hybrids) and plant densities, for yield estimations ($p<0.05$). Greater differences were found between hybrids ($p<0.001$), than for density levels. Experimental CV for yield estimations was near 7%, for both years. From Table 1 and Fig. 1, there was found an increase in field yield from low to high density for year 2000. Almost the same was found for year 2001 (Table 2 and Fig. 1), except for high density in presence of

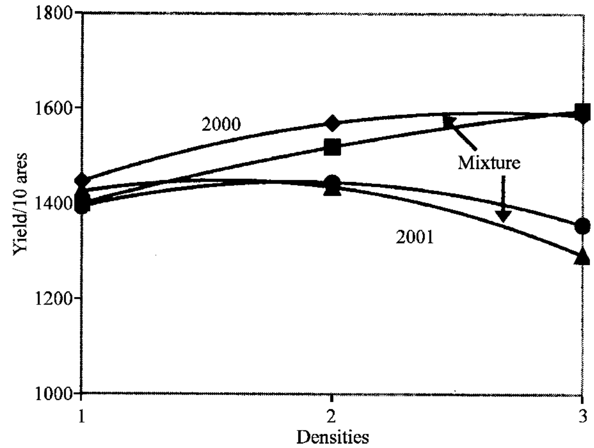

Fig. 1: Yield in kg per 10 ares of total mean of hybrids and of their mixture across densities (1, 2, 3) for years 2000 and 2001. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

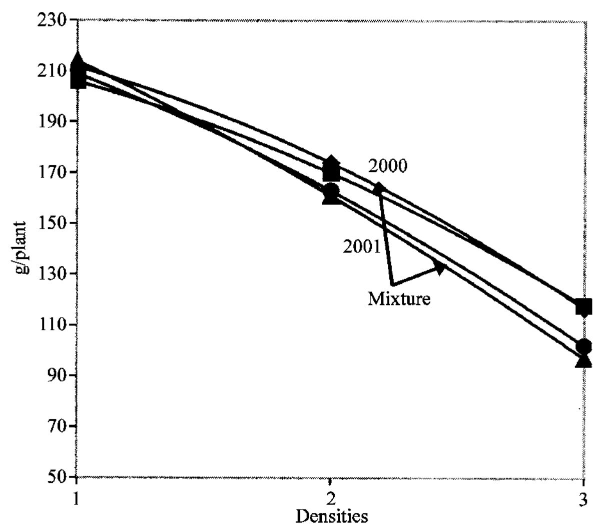

Fig. 2: Yield in g per plant of total mean of hybrids and of their mixture across densities (1, 2, 3) for years 2000 and 2001. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

Table 1: Yield in kg per 10 ares, in g per plant, Coefficient of variation (CV%) and barren plants (%) of 8 F1 maize hybrids their mean and their mixture, across three plant densities for year 2000

Plant density	Trait	Rio Grande	Prisma	Dracma	Aligreen	Volusia	Costanza	CS1251	Dias	Mixture	Mean
20×75 cm	kg 10 ares	1541	1397	1391	1457	1385	1401	1222	1406	1447	1400
6660	g/plant	225	207.5	204	215	203	207.7	178.5	207.8	211.7	206
plants	CV (%)	29.4	28.5	25.2	30.6	24.7	29.7	28	32.5	32.2	28.6
per 10 ares	Barren (%)	1.2	2.4	1	4	2.4	1.2	2.5	3	3.2	2.2
15×75 cm	kg 10 ares	1595	1573	1551	1494	1574	1518	1455	1393	1570	1520
8880	g/plant	178	176	172.5	165	176	171.7	162.8	156.6	174	170
plants	CV (%)	32.7	32.5	26.2	39	31	34.6	28.4	49	34	34.2
per 10 ares	Barren (%)	3.5	2.7	2.3	2.3	2.3	2.3	1.8	10	3.7	3.4
10×75 cm	kg 10 ares	1654	1628	1733	1553	1689	1584	1593	1340	1586	1597
13330	g/plant	121.5	120.7	127.5	114.6	126.2	117	117.7	97.5	116.9	117.8
plants	CV (%)	53.8	51.3	41.4	53.7	40.7	52.7	44.5	75.6	50	51.7
per 10 ares	Barren (%)	8.8	11	5.5	8	4.7	6.9	5.8	20	6.1	8.8

Table 2: Yield in kg per 10 ares, in g per plant, Coefficient of variation (CV%), barren plants (%) and plants infested by common smut (%) of 10 F1 maize hybrids their mean and their mixture, across three plant densities (1,2,3) for year 2001

Plant density	Trait	Aris	Dias	A	B	C	Aligreen	Volusia	Costanza	Dracma	Damao	Mixture	Mean
20×75 cm	kg 10 ares	1425	1297	1271	1424	1272	1477	1445	1448	1399	1479	1425	1394
6660	g/plant	214	195	191	214	191	222	217	217	210	222	214	209
plants	CV (%)	25.6	29.4	26	25	25	24.3	20	26.9	20	20.5	26.5	24.3
per 10 ares	Barren (%)	1.5	2.5	1.5	0.5	1	2.5	1	2	2.5	1	2	1.6
1	Com Smut (%)	1	2	0.5	0.5	1	1	0.5	2	0	1	1.5	1
15×75 cm	kg 10 ares	1453	1327	1291	1473	1285	1539	1400	1497	1562	1624	1435	1445
8880	g/plant	163	149	145	166	145	173	158	168	176	183	161	163
plants	CV (%)	38.7	46.8	40.6	31	38.3	33.4	34.3	34.3	28.2	29.1	39	35.5
per 10 ares	Barren (%)	6.5	9.5	2.5	1.5	5	3	5	2.5	3	2.5	4.5	4.1
2	Com Smut (%)	3	2.5	4	1.5	2	2	0.5	4.5	3.5	0	1	2.3
10×75 cm	kg 10 ares	1320	959	1390	1400	1200	1345	1466	1468	1467	1546	1293	1356
13330	g/plant	99	73	104	105	90	101	110	110	110	116	97	102
plants	CV (%)	61	87	53.3	58.8	61.7	59	49	47.7	47.7	45.4	59.6	57.1
per 10 ares	Barren (%)	14	26	10	12	13	11	9	7	8	7	11.9	11.7
3	Com Smut (%)	7	10	4	4	7	8	3	7	7	2	5	6

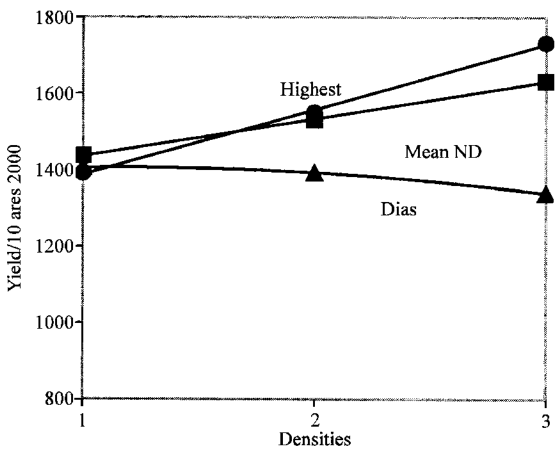

Fig. 3: Yield in kg per 10 ares of the mean of hybrids, not including hybrid Dias (Mean ND), of hybrid Dias and of highest-yielding hybrid across densities (1, 2, 3) for year 2000. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

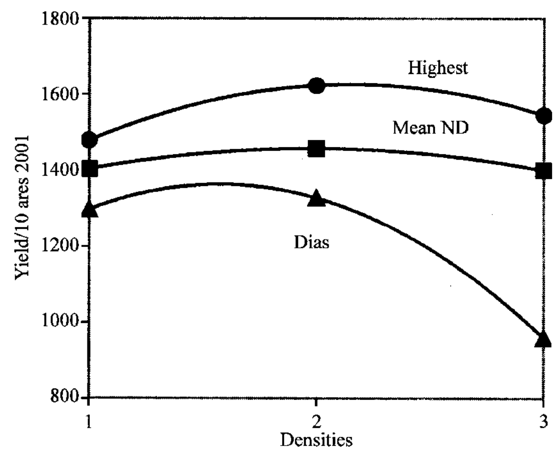

Fig. 4: Yield in kg per 10 ares of the mean of hybrids, not including hybrid Dias (Mean ND), of hybrid Dias and of highest-yielding hybrid across densities (1, 2, 3) for year 2001. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

common smut. Yield of individual plants (Table 1, 2 and Fig. 2) declined as the plant density increased. Only hybrid Dias showed a different behavior, especially in year 2001 (Table 1, 2 and Fig. 3, 4).

In Fig. 3, it is clear an almost linear increase of the mean of all hybrids (Dias not included) and the increase in yield of the highest yielding hybrid, when plant density was increased. In Fig. 4, the mean of all hybrids

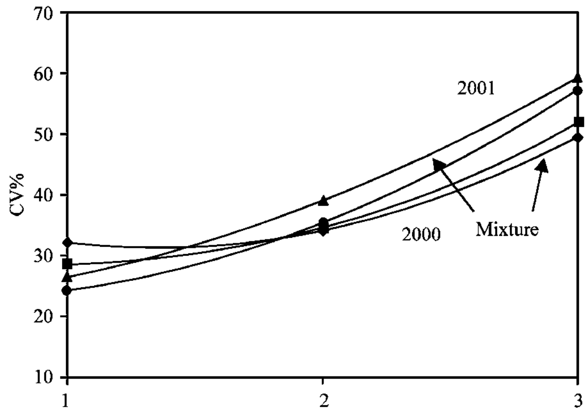

Fig. 5: Coefficient of variation (CV%) of total mean of hybrids and of their mixture across densities (1, 2, 3) for years 2000 and 2001. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

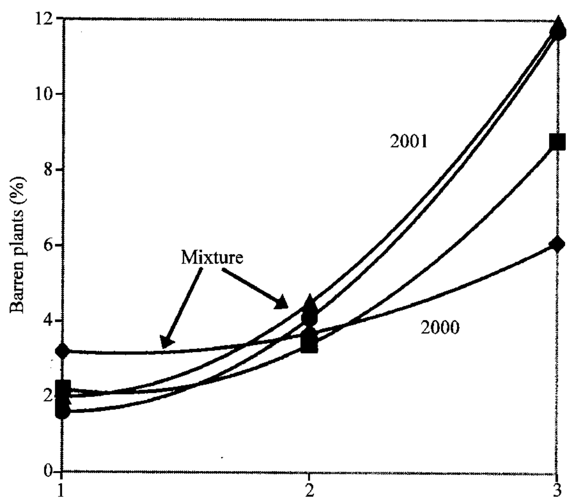

Fig. 6: Barren plants (%), of total mean of hybrids and of their mixture across densities (1, 2, 3) for years 2000 and 2001. Density 1: 6660 plants/10 ares (low); Density 2: 8880 plants/10 ares (medium); Density 3: 13330 plants/10 ares (high)

(Dias not included) was almost stable, but hybrid Dias showed decreased yields, when plant density was increased. CV(%) and barren plants (%) were increased when plant density was increased (Fig. 5 and 6).

The mechanical mixture (Table 1, 2; Fig. 1, 2, 5 and 6) showed the same performance as the mean of hybrids (sown in separate plots). Only in year 2000, the number of the barren plants of the mixture was reduced compared to the mean of hybrids. The same was found for CV(%), but in year 2001 these traits found almost the same for the mixture and the mean of hybrids. In year 2001, there were found many plants with common smut (Table 1 and 2) and hybrid Dias found to be the most susceptible.

Hybrid Damao was the best yielding for year 2001, while for 2000, hybrids Dracma and Volusia overyielded all the rest hybrids. Hybrid CS1251 showed the higher increase of yielding performance, as the plant density increased and Rio Grande showed stable and high yields. Differentiation between the yielding performance of hybrids was found only in higher plant densities (Table 1, 2; Fig. 1, 2, 5 and 6).

DISCUSSION

In year 2000 there was found a considerable increase of yielding performance as the plant density increased. This indicated that modern maize hybrids incorporate the proper genes to overcome density stress and additionally, they are able to increase field yielding performance, since they tolerate greater plant populations (Duvick, 1992; Tollenaar and Wu, 1999; Vafias *et al.*, 2000a). In year 2001, this tension was not so apparent due to the presence of common smut. Only hybrid Dias showed decreasing yield as the plant density increased. Optimum plant density was found near 90,000 per hectare, in agreement with the findings of Vafias *et al.* (2000b) and Larson and Hanway (1977). Tokatlidis *et al.* (2001) showed that the limits for optimum field yields of maize hybrids are very narrow in relation to plant population, but in the present study there were found a few hybrids with stable and high yields, while most of them increased yield from low to high plant density.

The decreasing yield per plant under high plant densities was expected, but the rate of decrease allowed higher field yields in high plant densities. CV(%) and barren plants (%) increased under high plant densities because of competition effects (Vafias *et al.*, 2000a, b). Additionally, the percentage of barren plants may be an indirect estimation of original hybrid seed low purity (Vafias *et al.*, 2000a) and reveals the absence of genes controlling tolerance to density effects. Under these assumptions, Dias exhibited many disadvantages in relation to newer hybrids.

The mechanical mixture showed the same performance in both years in comparison to the mean performance of all hybrids, for all traits studied. This kind of performance was rendered to the genetic background of modern hybrids, in a way that under stress conditions (allocompetition, density effects) they express stable performance. It is possible that, these genes controlling tolerance to density stress, to be alike in many modern hybrids. In years 2000 and 2001, the mixture showed similar field performance to the mean of hybrids, but in year 2000, exhibited higher yield under low plant density (with low allocompetition). This finding together with the low number of barren plants and lower CVs of mixture in year 2000, lead to the conclusion that mixtures exhibit stability of performance (buffering). It is possible that allocompetition is not a stronger stress factor than isocompetition (Fasoulas, 1988) in modern maize hybrids. Furthermore, mixing of two commercial F1 single-cross maize hybrids may not lead to decreasing yielding performance. In general, modern commercial maize hybrids increase field yields under increasing plant density and they can be used as a mixture without decreasing yielding performance. In some cases, for high yielding hybrids (over the mean of all hybrids) this mixing may prove a disadvantage. In such cases the hybrids exhibit positive isocompetition under high plant density conditions and as a result they improve field yielding performance and exhibit low numbers of barren plants.

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