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Scientific paper

Effects of nitrogen levels and seed density in maize in Central-South of Paraná

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Abstract

This study aimed to evaluate the influences of two levels of nitrogen fertilization in coverage, associated in two densities of seeding rate, on the agronomic characteristics of four commercial hybrids of maize recommended for the for the Central-Southern Parana. The experiment was conducted at the experimental farm of the Department of agronomy at the Universidade Estadual do Centro-Oeste (State University of the Midwest) in Guarapuava PR. The experimental design used was randomized blocks with three replications in factorial design 4x2x2, corresponding to four hybrids of maize (P30P34, P30R50, FORMULA and NK7G27), and two levels of nitrogen fertilization in coverage (90 kg N ha^{-1} and 120 kg N ha^{-1}), and two densities of seeding rate (65.000 and 75.000 plants per hectare), in a total of sixteen treatments. The largest productivity was obtained in the density 65.000 plants ha^{-1}.The nitrogen fertilization provided highest weight of grains for hybrid P30R50 with 120 kg N ha^{-1}. The hybrid P30R50 when grown in density of 75 000 plants ha^{-1}, it was obtained lower area under the disease progress curve (AUDPC) of *Puccinia sorghi*.

Keywords: *Zea mays*, nitrogen, plant population, leaf diseases.

Introduction

Technological advances in the cultivation of maize, as the use of hybrids with better performance, changes in seed spacing and density, allied to improvements in soil fertility and practices of fertilization, have provided significant increases in productivity (VON PINHO et al., 2009).

Several factors may influence the maize crop yield as the productive potential of the hybrid, the climate conditions, the plant population, and nutritional and phytosanitary conditions in one agro system (DOURADO NETO, et al., 2003).

Among the factors which may be changes aiming to increase the maize productivity, it stands out the population density, which may provide better use of the environment by the current genotypes (DOURADO NETO, et al., 2003). For ARGENTA et al. (2001), it is justified to reevaluate the recommendations of spacing between lines and maize seed density due to the modifications introduced in the most recent genotypes, as: lower plant stature and height of ear insertion, lower plant sterility, lower length of the sub period. However, the plant densification is only possible due to genetic breeding, which has made available hybrids with agronomic characteristics which respond positively to population densification.

In the same way, the soil fertility and the practices of fertilization deserve attention in the

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choice of the plant density to be used in the maize crop, which is very demanding in nutritional terms. According to COELHO (2004), with appropriated content of the other nutrients which are essential in soil, nitrogen is the nutrient which provides the higher increases in grain productivity in the maize crop.

However, the use of very high densities may reduce the photosynthetic activity of the crop, and the efficiency of the conversion of photoassimilates in grain production. As a consequence of this, there is an increase of female sterility and reduction of the number of grains per ear and grain yield (MARCHÃO et al., 2006). Considering this, the great population density, for a determined hybrid, corresponds to the lower number of plants per area unit, which induced greater productivity.

Currently in the programs of maize breeding, it is aimed at genotypes with high productive response in high population densities, from 80 thousand to 100 thousand plants ha^{-1}, and under more reduced spacing between lines (DOURADO NETO et al., 2003).

The Center South region of Paraná is characterized for being a great maize producer, well represented by the municipality of Guarapuava, with an ideal climate for the production of this cereal, with the second largest index of productivity in the world. Thus, it is important to study alternatives of management which may contribute for the maize yield in one region with diversified characteristics.

Thus, the objective of this work was to evaluate the influence of two levels of cover nitrogen fertilization, associated to two seed densities, over agronomic characteristics and the severity of leaf diseases in commercial hybrids of maize recommended for the region of Center South of Paraná.

Material and Methods

The experiment was conducted in the experimental field of the Department of Agronomy of the Universidade Estadual do Centro-Oeste (State University of Mid West), in the campus CEDETG, in Guarapuava (PR), with latitude 25º 23′ 36′′ S, longitude 51º 27′ 19′′ W and altitude of 1120m, in soil classified as Latossolo bruno distroférrico típico[1], very clayey texture (EMBRAPA, 2006).

The design used was randomized block, with three replications, in factorial scheme 4x2x2, corresponding to 4 maize hybrids (P 30P34, P 30R50, FORMULA and NK 7G27), 2 levels of cover nitrogen fertilization (90 kg ha^{-1} e 120 kg ha^{-1}) and two plant densities (65000 and 75000 plants ha^{-1}), with a total of 16 treatments.

It was adopted the spacing 0.8 between lines, being each plot constituted by two lines of 5 m of length. Seeding was performed with plot seeder, in the second half of October, in area with stable no-tillage area, with dissected vegetal cover. The base fertilization was with 330 kg ha^{-1} of the formula NPK 08-20-15. The stand was adjusted for two distinct plant densities, which were 65 thousand plants ha^{-1} (5 plants/linear meter) and 75 thousand plants ha^{-1} (6 plants/linear meter). The cover nitrogen fertilization was divided in two applications, being the first one of 60 kg ha^{-1} in the stage of four leaves (V4) for all treatments, and the second in the stage of seven leaves (V7) with 30 kg ha^{-1} and 60 kg ha^{-1} de N in the form of urea, according to the level of nitrogen cover.

The control of weeds, in post-seeding, was performed with the herbicide Atrazina, 2.5 L ha^{-1}, plus Soberan® (Benzoylciclohexanodiona) 240 ml ha^{-1} and 1 L ha^{-1} of mineral oil. For the control of fall armyworm it was performed two applications of Certero® (triflumuron) in the dosage of 30 ml ha^{-1}.

The evaluated characteristics were: grain productivity corrected for 13% of humidity, stem diameter, weight of 1000 seeds, plant height and height of first pod insertion. It was performed four evaluations of severity of common rust (*Puccinia sorghi*), cercospora leaf spot (*C. zeae-mayds*), dipodia leaf spot (*S. macrospora*), from the symptoms which occurred naturally, from the beginning of the plant tasseling with aid of the diagrammatic scale proposed by AGROCERES (1996).

The averages of the severity grades were used for the calculation of the area under the disease progress curve (AUDPC), according to CAMPBELL and MADDEN (1990). Data was submitted to the individual and joint analysis of

[1] Brazilian Soil Classification

variance and the averages were compared by the Scott-Knott test at the level of 5% of probability, with aid of the statistical software Sisvar 5.0 (FERREIRA, 2000).

Results and discussion

The results of the analysis of variance accused significant difference for the triple interaction 'hybrid x density x fertilization' for grain productivity (Table 1), indicating that the studied genotypes presented diversified levels of grain productivity when submitted to different levels of plant density and nitrogen fertilization.

Table 1. Summary of the analysis of variance of the characters grain production (PROD, kg ha^{-1}), weight of 1000 grains (W1000, g), stem diameter (SD, mm), AUDPC of the leaf diseases cercospora leaf spot (CERC) (*C. zeae-mayds*), dipodia leaf spot (DIP) (*S. macrospora*), and common rust (RUS) (*P. sorghi*), plant height (PH, m) and ear insertion (EI, m), of four hybrids of maize evaluated in two population densities with two levels of nitrogen fertilization.

FV	Means squares								
	GL	PROD	W1000	SD	RUS	DIP	CERC	PH	EI
Hybrid (H)	3	23340359.8*	40230.9*	0.39	3051.1*	530.9*	2314042.32*	0.0800*	0.337*
Fertilization (N)	1	2663797.2*	1008.0	2.56	48.1	12.0	21962.39	0.0005	0.002
Density (D)	1	10450.6	156.5	2.47	102.4	16.6	10966.83	0.0096	0.007
HxN	3	602752.3*	1277.6*	2.07	941.8	27.1	17466.29	0.0031	0.002
HxD	3	754872.1	573.6	10.10*	1969.6*	14.2	24314.63	0.0213*	0.014*
DxN	1	515509.5	45.2	0.06	643.2	5.9	5645.03	0.00003	0.002
HxDxN	3	2393938.4*	630.6	1.31	208.2	1.4	2894.38	0.0036	0.005
CV%		6.13	5.76	7.69	33.46	58.10	31.02	2.74	4.44

*Significant at 5% of probability of error by F test.

There were significant differences between hybrids in the two levels of cover nitrogen fertilization, in both plant densities (Table 2). In the density of 65000 plants ha^{-1} with 90 kg ha^{-1} of N, hybrids P30P34, NK7G27, P30R50 were the most productive and did not differ from each other. Hybrid FORMULA had the worst performance in productivity in the two levels of fertilization for both plant densities. In all the situations, hybrid P30P34 was in the group of the most productive.

Table 2. Grain productivity (kg ha^{-1}) of four commercial hybrids of maize, in two population densities, in two levels of nitrogen fertilization.

HyBRID	Grain productivity							
	65.000 plants ha^{-1}				75.000 plants ha^{-1}			
	90 kg N ha^{-1}		120 kg N ha^{-1}		90 kg N ha^{-1}		120 kg N ha^{-1}	
P30P34	11.050,0	aB	12.637,3	aA	11.949,5	aA	10.546,5	aB
FORMULA	8.113,3	bA	8.182.0	cA	8.441,6	dA	8.544,2	bA
NK7G27	10.589.6	aA	10.707.3	bA	10.517.1	bB	11.775.5	aA
P30R50	10.125.0	aA	11.065.0	bA	9.916.7	cA	10.974.3	aA
MEAN	**9.969.5 A**		**10.647.9 A**		**10.206.3 A**		**10470.2 A**	

CV% General = 6.13. Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05);averages followed by uppercase letter distinct in line (in each density) differ by F test (P≤0.05).

The interaction 'hybrids x fertilizations' was also significant (Table 1) for PROD, considering that the hybrid P30P34 responded positively to the increase of the nitrogen fertilization in cover in the density of 65 000 plants ha^{-1}, presenting increase of grain productivity above 1 500 kg ha^{-1} (Table 2).

For the density of 75 000 plants ha^{-1}, in the level of fertilization of 120 kg ha^{-1} of N, there was positive response of the hybrid NK7G27 over the grain productivity, presenting increase of 1 258 kg ha^{-1}. This result is in accordance with those found by VON PINHO et al. (2009), who used increase in the cover fertilization of the maize obtaining significant increase for grain productivity.

In the contrary, the hybrid P30P34 showed significant reduction in productivity with the increase in the dose of N in cover in the density of 75 000 plants ha^{-1} (Table 2), evidencing the sensibility of this genotype when working with higher population associated to lower levels of N.

It is worth to emphasize that the rate of response of the levels of investment in crop may be variable per genotype, considering that the averages of productivity of cultivars destined to areas of high investment are clearly superior to the averages of the cultivar destined to cultivation with low investment (BACKES et al., 2004; MENDES et al., 2004).

For weight of 1000 grains it was only verified significant effect of the interaction 'hybrids x fertilization' (Table 1), considering that hybrid P30R50 responded positively to the increase in the dose of N in cover, presenting increase of 31.67g under dosage of 120 kg ha^{-1} of N (Table 3).

These results are according with ZANATTA et al. (2007) that verified a linear increase of the weight of 1000 grains with the increase of the doses of nitrogen for maize cultivars.

According Table 3 there was significant different of the weight of 1000 seeds between hybrids in both levels of nitrogen fertilization, considering that P30P34, NK7G27, P30R50 presented the highest averages, did not differed from each other and were superior to the hybrid FORMULA.

Table 3. Values of the weight of 1000 grains (grams) of four commercial hybrids in two levels of nitrogen fertilization.

HYBRID	Weight of 1000 grains (g)	
	90 kg ha^{-1} N	**120 kg ha^{-1} N**
P30P34	372.22 a A	355.55 a A
FORMULA	246.66 b A	251.11 b A
NK7G27	358.88 a A	375.55 a A
P30R50	346.66 a B	378.88 a A
MEAN	331.11 A	340.27 A

CV% General = 5.76. Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05); averages followed by uppercase letter distinct in line (in each density) differ by F test (P≤0.05).

For the characteristic stem diameter there were no significant differences between hybrids, independent on the plant density, however the interaction 'stem diameter x density' was significant (Table 1). Hybrid P30R50 had stem diameter reduced then there was an increase of density to 75 000 plants ha^{-1} (Table 4), and may present problems of lodging when conduced in higher densities.

FIGUEIREDO et al. (2008) found reduction in the stem diameter of plants in different maize cultivars when conduced in more dense systems, attributing this fact to the higher competition between plants.

Table 4. Stem diameter values (millimeters) of four commercial hybrids in two population densities.

HYBRID	Stem diameter (mm)	
	65.000 plants ha^{-1}	75.000 plants ha^{-1}
P30P34	22.25 a A	23.86 a A
FORMULA	23.74 a A	22.72 a A
NK7G27	23.34 a A	23.64 a A
P30R50	24.66 a A	21.96 a B
MEAN	**23.50 A**	**23.04 A**

CV% General: 7.69. Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05); averages followed by uppercase letter distinct in line (in each density) differ by F test (P≤0.05).

The generals results showed, specially the productivity tendencies may be caused due to the fact that this genotype had presented high severity of cercospora leaf spot (Table 5), which reduced its photosynthetic area, compromising the grain filling. These results demonstrate the importance of the study of the effect of the nitrogen fertilization in the factors of productivity of maize genotypes. When evaluating different hybrids of maize, BRITO et al. (2007) verified differences in the susceptibility of cercospora leaf spot between genotypes and attributed this disease to the reduction in yield.

There was no significant effect of the interaction 'hybrids x densities x fertilization' neither from the double interactions among these factors for the severity (AUDPC) of cercospora leaf spot and diplodia leaf spot (Table 1), being observed significant difference only between genotypes (Table 5).

Hybrids NK7G27 and P30R50 did not differ, and were the less susceptible to cercospora leaf spot. Hybrid FORMULA presented the worst performance, and was highly susceptible to cercospora leaf spot (Table 5), fact that may justify its performance relatively inferior in the productivity (Table 2). For diplodia leaf spot, genotypes P30P34 and FORMULA, did not differ statistically from each other, with the lower averages of AUDPC, although this disease was not expressive for this crop in the region.

Table 5. Values of the area under the disease progress curve (AUDPC) of cercospora leaf spot (*C. zeae-mayds*), diplodia leaf spot (*S. macrospora*) and common rust (*P. sorghi*), in four hybrids of maize evaluated in two population densities with two levels of cover nitrogen fertilization.

HYBRID	Cercospora leaf spot (AUDPC)	Diplodia leaf spot (AUDPC)
P30P34	235.82 b	9.18 b
FORMULA	989.83 a	4.50 b
NK7G27	52.65 c	14.49 a
P30R50	89.36 c	19.90 a
MEAN	**341.91**	**12.02**
CV%	**47.03**	**58.10**

Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05);averages followed by uppercase letter distinct in line (in each density) differ by F test (P≤0.05).

For severity of common rust (*P. sorghi*) it was observed significant interaction 'hybrids x density' (Table 1). Hybrids P30P34, NK7G27 and FORMULA did not differ from each other, presenting lower values of AUDPC when compared to the hybrid P30R50, the most susceptible (Table 6). In the density 75 000 plants ha^{-1} the hybrids did not differ from each other. Hybrid P 30R50 had a different behavior when it was cultivated in the density of 75.000 plants ha^{-1}, with expressive reduction in the rust severity.

Table 6. Values of area under the disease progress curve (AUDPC) obtained from four evaluations of severity of the common rust (*P. sorghi*) in four genotypes of maize evaluated in two population densities with two levels of cover nitrogen fertilization.

HYBRID	COMMON RUST (AACPD)	
	65.000 plants ha^{-1}	**75.000 plants ha^{-1}**
P30P34	65.31 a A	90.03 a A
FORMULA	51.96 a A	63.63 a A
NK7G27	75.02 a A	58.09 a A
P30R50	110.34 b B	79.20 a A
MEAN	**75.66 A**	**72.74 A**

CV% General = 33.46. Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05); averages followed by uppercase letter distinct in line (in each density) differ by F test

Concerning plant height, it was verified significant effect from the interaction 'hybrids x densities' (Table 1). Hybrids P30P34 and FORMULA presented the lowest averages for plant height in the density of 65 000 plants ha^{-1} (Table 7).

For higher density, hybrid FORMULA differed from the others, presenting lower average of plant height, while genotype NK7G27 obtained higher plant height for both densities.

Hybrids P30P34 and NK7G27 presented higher plant height (PH) when the plant density was increased, which is an undesirable effect, since it increases the index of lodged and broken plants. Studies performed by GROSS et al. (2006), evidenced a linear increase in plant height for some hybrids with the increase of plant density in the area. With this, it can be said that there is a differenced response between genotypes when they are submitted to higher densities.

Table 7. Values of plant height and height of ear insertion of four maize genotypes evaluated in two population densities with two levels of nitrogen fertilization.

HYBRID	Plant height		Ear insertion height	
	65.000 plants ha^{-1}	**75.000 plants ha^{-1}**	**65.000 plants ha^{-1}**	**75.000 plants ha^{-1}**
P30P34	2.41 a A	2.50 b B	1.47 b A	1.56 b B
FORMULA	2.38 a A	2.39 a A	1.27 a A	1.26 a A
NK7G27	2.52 b A	2.62 c B	1.62 c A	1.69 c A
P30R50	2.56 b B	2.48 b A	1.60 c A	1.55 b A
MEAN	**2.47 A**	**2.49 A**	**1.49 A**	**1.51 A**
CV%	**2.74**		**4.44**	

Averages followed by lowercase distinct letters in column differ by the Scott-Knott test (P≤0.05);averages followed by uppercase letter distinct in line (in each density) differ by F test (P≤0.05).

For height of ear insertion (EI), there was significant difference between genotypes in two plant densities (Table 1). Hybrid FORMULA obtained lower EI for both densities, behavior similar to the one presented for plant height. Hybrid NK7G27 obtained higher EI in both densities, in a similar way to plant height.

Hybrid P30P34 presented highest EI, as well as the plant height when submitted to a higher density, evidencing an undesired behavior when in more dense cultivations, which may cause more index of lodged plants. VON PINHO et al. (2009) found that with increases in plant density, for some cultivars, there are increases in PH and EI, which is undesired for the grain production in the maize crop.

These results also corroborate with the data obtained by DEMETRIO et al. (2008), who obtained increase in plant height and first ear insertion with increase in the population density of maize.

Conclusions

There is interaction between nitrogen fertilization and plant density over the agronomic characters of the maize crop, considering that these factors are influenced by the choice of the hybrid.

The reduction of the nitrogen fertilization and the plant density did not influence the reaction of the studied hybrids for the leaf diseases *Cercospora zeae-mayds* and *Stenocarpella macrospora*.

The hybrid P30R50 obtained lower area under the disease progress curve AUDPC for *Puccinia sorghi* when submitted to the density of 75 000 plants ha^{-1}.

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