Performance of Corn Hybrid Parental Lines in Different Environments and its Implications on F_1 Seeds Production

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ABSTRACT - Three corn hybrid parental lines were evaluated in four trials, located at Rolândia-PR and Barretos-SP, Brazil, during two sowing dates in the 2007-08 cropping season. Trials were random block design with four replications. The traits evaluated were: flowering (FLO, both male and female), plant and ear height (PH and EH) and F1 seeds yield (SY). Data were performed by ANOVA and LSD test. Differences were significant ($p < 0.05$) to genotype effect in respect to PH, EH and FLO; but not to SY. Genotype-location and genotype-times interactions were significant and indicated genotype-environment interaction might be considered on F_1 seeds production. Based on trait means and significant sources of variation, it is feasible to conclude: (i) seeds from female 1 × male and from female 2-male sterile × male might be obtained in Barretos–SP at first sowing date; and (ii) seeds from female 2-male sterile × male can be obtained in Rolândia–PR both dates, using split on the first date.

Key words: *Zea mays* L.**,** grain yield, hybrid seeds, genotypes × enviroment interaction.

Desempenho de Linhagens Parentais de Milho Híbrido em Diferentes Ambientes e Suas Implicações na Produção de Sementes Híbridas

RESUMO - Três linhagens parentais de milho híbrido foram avaliadas em quatro ensaios, em Rolândia-PR e Barretos-SP, em duas épocas de semeadura da safra 2007/08. Os ensaios foram delineados em blocos completos com tratamento ao acaso com quatro repetições. Os caracteres avaliados foram: florescimento (FLO, feminino e masculino), alturas de planta (AP) e espiga (AE) e rendimento de sementes (REND). Os dados foram submetidos à análise de variância e teste de LSD. Foram verificadas diferenças significativas ($p < 0,05$) para o efeito de genótipos para AE, AP e FLO; mas não para REND. Interações significativas de genótipos × locais e genótipos × locais para as características avaliadas indicam que os efeitos da interação genótipos-ambiente devem ser considerados na produção de sementes híbridas. Com base nas médias das características e na significância das fontes de variação, pode-se concluir que: (i) as sementes híbridas fêmea 1 × macho e fêmea 1-macho-estéril × macho podem ser obtidas em Barretos–SP na primeira época; e, (ii) as sementes híbridas fêmea 1-macho-estéril × macho podem ser também obtidas em Rolândia–PR em ambas as épocas estudadas, usando *split* na primeira época.

Palavras-chave: *Zea mays* L., rendimento de grãos, sementes híbridas, interação genótipos × ambiente.

Introduction

Corn grows in several locations in Brazil, including different ecological regions with its peculiarities and cropping systems. Faced on this, a strong genotype-by-environment interaction is expected on performance of hybrids and open-pollinated varieties (RIBEIRO et al., 2000; HAMAWAKI and SANTOS, 2003).

Genotype-by-environment interaction (G × E) is an important phenomenon and a challenge for breeders and agronomists involved on development of new cultivars and its recommendation. The importance of G × E are supposed to be as large as the diversity among genotypes and environmental conditions are, including expected causes, such as duration in photoperiod, soil types and its fertility and aluminum toxicity, sowing dates, and cropping systems; and unexpected causes, such as rainfall frequency and amount, humidity of air, temperature and its range in air and soil, pest and diseases infestation levels (HALLAUER and MIRANDA FILHO, 1988).

To the commercial production of corn, high-yielding hybrids with stability over different environments are crucial (LOCATELLI et al., 2002). In fact, such G × E effects also influence the obtaining of hybrids seed. In this sense, the knowledge on most suitable environments and measuring the G × E effects on major traits of parental lines is critical to finish years of lines breeding and trial tests. Although such studies are relevant, they are rare on literature (ANDRADE SOBRINHO and SMITH, 1952).

In the context of breeding and seeds production, two reasons for evaluating parental lines and its interactions with environments are: (i) to investigate the possibility of reducing number of male parental lines on the area of seeds production; and (ii) to identify the most favorable regions for seeds production. Both reasons are focused on increasing seeds production per area, and reduction of costs per bag of hybrid seed. Once the detasseling of male parental lines spends money, the use of cytoplasmtic male sterility (cms) line also may be employed to reduce costs.

In the present study, the objectives were (i) evaluate the effects of different environment on agronomic traits of hybrid corn elite parental lines and its male sterile version; and, (ii) to determine the best strategy for obtaining hybrid seeds between the combination of these parental lines.

Materials and Methods

Three hybrid corn parental lines (female 1: normal female parental line; male: male parental line; and female 1-cms: male sterile near-isogenic line of the normal female parental line) were evaluated in four trials, located in two distinct locations (Rolândia–PR in South Brazil, and Barreto–SP in Southeast Brazil), and two sowing dates in each location (Rolândia-PR: 1st date - 25/09/2007 and 2nd - 25/10/2007; and Barretos-SP, 1st date - 25/09/2007 and 2nd date - 30/10/2007). All trials were implemented on no-tillage system installed at least four years ago, in succession to black oat wielded with knife-roller at 30 days before planting.

Trials had randomized random block design with four replications. Experimental plots consisted of four 5–m long rows, 0.80 m apart and density of five plants per m. Evaluations were carried out in two central rows. Plots were fertilized with 50 Kg ha^{-1} N, 100 Kg ha^{-1} P_2O_5 and 50 Kg ha^{-1} K_2O at sowing; and 150 Kg ha^{-1} N and 50 Kg ha^{-1} K_2O sidedressing, when the plants had reached development stage V_4 . The recommended cultural treatments, including irrigation, were performed according to crop requirements.

The follow traits were evaluated: (i) FLO-female flowering (in the female lines) and male flowering (in the male flowering): by noting flowering dates when at least 50% plants of male lines shedding pollen or 50% plants of female lines with 2cm silks; (ii) PH-plant height and PE-ear height: measuring from soil to the flag leaf for PH, and from soil to ear insertion to PE, on six plants per plot. (iii) Seeds yield (SY): consists on grain yield on whole plot, threshed and dried until reached 13% moisture, and converted to Kg ha^{-1}.

Levene's and Shapiro-Wilks tests were performed to investigate ANOVA presuppositions. Data transformations were not necessary. Joint ANOVA was carried out using the follow model: $Y_{ijas} = g_i + r_j(l_a/e_s) + l_a + e_s + ge_{is} + gl_{ia} + gle_{ias} + \bullet_{ijas}$, which, Y_{ijas}: observation for i^{th} parental line, at j^{th} replication, a^{th} location, and e^{th} sowing date. g_i: effect of parental line i; $r_j(l_a/e_s)$: effect of replication j^{th} into a^{th} location and e^{th} sowing data; l_a: effect of a^{th} location; e_s: effect of e^{th} sowing data; ge_{is}: effect of interaction between i^{th} parental line and e^{th} sowing data; gl_{ia}: effect of interaction between i^{th} parental line and a^{th} location; gle_{ias}: effect of triple interaction among i^{th} parental line, e^{th} sowing data, and a^{th} location. $\bullet_{ijas}$: experimental error to Y_{ijas}. Additionally, the least square difference test (LSD) at 5% probability was carried out for all interest sources of variations. Statistical analyses were performed using SAS (SAS Institute, Cary, NC).

Results and Discussion

It were verified significant differences ($p < 0.05$) to parental lines effect for plant height (PH), ear height (EH), and flowering (FLO), indicating that one or more lines had a differential behavior (Table 1).

Considering the classification of coefficientes of variation (CV) propoused by Scapim et al., (1995), low CVs were found for EH and PH, and medium CV to SY (Table 1). In this sense, the experiments were considered as precise and able to make reliable inferences in respect to parental lines and its performance over different locations and sowing dates (environments).

It were not verified significant differences ($p > 0.05$) to parental lines effects for seeds yield (SY). However, the interactions parental lines × locations indicated that lines might display variation on SY when sowed at Rolândia or Barretos. The female-1 parental line (normal cytoplasm) was more high-yielding in Barretos than Rolândia during the first sowing date, and did not differed between locations at second sowing date. Female-1cms (sterile cytoplasmatic pollen producer) were high-yielding on first than second sowing date in Barretos, and did not differed between dates in Rolândia. In general, the first sowing date in Barretos might be the most appropriate environment for producing hybrids seeds from this set of parental lines. In addition, female-1cms produced more seeds than female 1 on both sowing dates in Rolândia, and are supposed to be more suitable for this environment. On contrary, these female parental lines did not differed during first sowing date in Barretos, and female 1 overcame female-1cms in SY on Barretos second sowing date. It suggested a complex interaction for SY involving such parental lines, and reinforces the importance of genotypes-by-environment interactions and the need of studies similar to this. In fact, Hallauer and Miranda Filho (1988) pointed out that external environmental factors such as weather, soil, and pests probably have a greater effect on single crosses than other types of hybrids. As Troyer (1996) and Pinto et al. (2007), single hybrids usually also interact more with the environment than double-cross hybrids.

In respect to the flowering (male flowering for male parental line, and female flowering for female 1-normal female parental line and female 1-cms: male sterile near-isogenic line of the normal female parental line), it were verified significant differences ($p < 0.05$) to all sources of variations (Table 2). As according as Paterniani and Viégas (1987), synchronism on flowering dates is crucial for efficient pollinating corn genotypes. In fact, interactions parental lines × sowing dates and parental lines × locations suggested an additional care for coincides male and female flowering of lines. However, although parental lines means were different, they are less divergent in days, indicating that it is not a large difficult in this set of genotypes (Table 3). It might be found all combinations of locations and sowing dates, except for first sowing date in Rolândia, demonstrating that it is not a totally favorable environment for obtaining hybrid seeds.

For the two sowing dates in Barretos, and for the second date in Rolândia, the means for flowering are less divergent, and indicated that there is no need of splits (sowing male lines on several date, spaced in short periods of time, e.g. at 3, 5, and 8 days after sowing female line). Splits are useful to coincide female and male flowering dates. However, for the first sowing date in Rolândia, we suggested a positive split, sowing male line at 5 to 7 days sowing female lines (female-1 or female-1cms).

Significant parental lines × locations and parental lines × sowing dates interactions ($p < 0.05$) were detected for ear height (EH) and plant height (PE) (Table 2). As according Larchner (2004) and Terasawa Júnior (2006), such variations are associated to different crop conditions, e.g. temperature, luminosity, and water disponibility. Plant and ear heights are important for optimizing pollinations because male lines (tallest in general) might shed pollen to silks in ear of female lines. By the results displayed at Tables 4 and 5, such condition has occurred, and provides an easy combination of the lines evaluated. In short, when it occurs, tallest male plants may shed its pollen to plant that are distant, and it is favorable to pollinations since avoid poor fill ears, and then a lower number of male parental lines is needed per area.

Differences in plant height were more pronounced in second sowing date in Barretos, in which the three parental were different each other, and male parental was the tallest. In short, female-1 and female1-cms only differed in this environment, which is consonant and expected once they are near-isogenic lines, and indicates that some physiologic factors influenced EH and PH of such lines in this environment. A eminent preoccupation for EH and PH indexes is the loading of plants, when ears inserted in high position of the plants lead to greater leverage to promote loading.

In respect to the environments (combinations of locations and dates), for all traits we had significance at 5%. It ratified that environmental conditions are critical for F_1 seeds production. In conclusion, a sowing date and a location might be considered outstanding. In short, comparing Barretos to Rolândia into sowing date we had: (i) higher plants and ear insertion; (ii) earlier flowering.

In fact, based on means of traits and significances of sources of variations, it was feasible to: (i) hybrid seeds from combination female-1 × male and female1cms × male may be obtained in Barretos in first sowing date; and (ii) hybrid seeds from female1cms × male also may be obtained in Rolândia both dates, however using split on first sowing date.

Conclusions

Genotype-location and genotype-times interactions were significant and indicated genotype-environment interaction might be considered on F_1 seeds production. Based on trait means and significant sources of variation, it is feasible to conclude: (i) seeds from female 1 × male and from female 2-male sterile × male might be obtained in Barretos–SP at first sowing date; and (ii) seeds from female 2-male sterile × male can be obtained in Rolândia–PR both dates, using split on the first date.

TABLE 1. Joint ANOVA for ear height (EH), plant height (PH), flowering (FLO), and seeds yield (SY). Rolândia-PR, Barretos-SP. Cropping season 2007/2008.

Sources of variation	degrees of freedom	Mean square			
		EH	PH	FLO	SY
Parenal lines (Pl)	2	420.17*	1154.82*	26.27*	472407^{ns}
Replications (Locations/Sowing dates)	12	10.35^{ns}	22.14^{ns}	0.11*	383748^{ns}
Locations (L)	1	7098.04*	4714.39*	1825.33*	4144225*
Sowing dates (Sd)	1	930.16*	5.49*	243.00*	11271408*
Pl × Sd	2	185.15*	494.25*	13.94*	596773^{ns}
Pl × L	2	108.35*	144.73*	22.77*	7812282*
L × Sd	1	137.70*	0.59^{ns}	75.00*	7314846*
Pl × Sd × L	2	14.64^{ns}	29.46^{ns}	2.44*	1298876*
Error	24	17.34	33.58	0.05	421917
Overall mean		107.38	179.16	63.67	5504
Coefficient of variation (%)		3.88	3.23	0.35	11.80

* $p < 0.05$ by F-test. ^{ns} Not significant by F-test ($p > 0.05$).

TABLE 2. Scott-Knott test for seeds yield (in Kg ha^{-1}) over locations and sowing dates.

Parental lines	Rolândia-PR		Barretos-SP	
	Sowing date 1	Sowing date 2	Sowing date 1	Sowing date 2
female-1	5098^{a} Ca	4696^{a} Ba	6598^{b} Ab	5008^{a} Aa
female-1cms	5839^{a} Ba	5918^{a} Aa	6453^{a} Aa	3691^{b} Bb
male	6742^{a} Aa	6500^{a} Aa	5207^{b} Ba	4308^{b} Ba

TABLE 3. Scott-Knott test for flowering (in days) over locations and sowing dates.

Parental lines	Rolândia-PR		Barretos-SP	
	Sowing date 1	Sowing date 2	Sowing date 1	Sowing date 2
female-1	76^{a} Cb	67^{a} Ba	$58,8^{b}$ Ab	56^{b} Aa
female-1cms	75^{a} Bb	67^{a} Ba	59^{b} Aa	$56,5^{b}$ Bb
male	69^{a} Aa	65^{a} Ab	$57,8^{b}$ Bb	57^{b} Ca

TABLE 4. Scott-Knott test for ear height (m) over locations and sowing dates.

Parental lines	Rolândia-PR		Barretos-SP	
	Sowing date 1	Sowing date 2	Sowing date 1	Sowing date 2
female-1	$102,38^{a}$ Bb	$83,00^{a}$ Aa	$116,38^{b}$ Ab	$105,63^{b}$ Aa
female-1cms	$105,58^{a}$ Bb	$91,13^{a}$ Ba	$128,13^{b}$ Ca	$123,00^{b}$ Ba
male	$96,00^{a}$ Aa	$93,25^{a}$ Ba	$122,25^{b}$ Ba	$121,88^{b}$ Ba

TABLE 5. Scott-Knott test for plant height (m) over locations and sowing dates.

Parental lines	Rolândia-PR		Barretos-SP	
	Sowing date 1	Sowing date 2	Sowing date 1	Sowing date 2
female-1	$171,13^{a}$ Ab	$158,88^{a}$ Aa	$187,58^{b}$ Ab	$170,25^{b}$ Aa

female-1cms	172,65^{a} Ab	161,75^{a} Aa	189,38^{b} Aa	184,25^{b} Ba
male	172,25^{a} Aa	178,88^{a} Ba	197,88^{b} Ba	205,13^{b} Ca

Means followed by different capital letters in the rows did not differed by Scott-Knott test at 5% probability (SK0.05). Means followed by different tiny letters in the lines did not differed by SK0.05 between sowing dates in the same location. Means followed by different exponent letters in the lines did not differed by SK0.05 between locations in the same sowing date.

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