http://dx.doi.org/10.18512/1980-6477/rbms.v2n2p90-98

YIELD POTENTIAL AND VARIABILITY OF TWO MAIZE COMPOSITES

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Revista Brasileira de Milho e Sorgo, v.2, n.2, p.90-98, 2003

ABSTRACT - In the 1994/95 season, 1272 accesses of the Active Maize Germplasm Bank (CENARGEN-EMBRAPA) were evaluated in several locations previously chosen to assure incidence of leaf diseases caused by *Phaeosphaeria maydis* and *Exserohilum turcicum*. Two composite populations named RPM (Resistant to *P. maydis*) and RET (Resistant to *E. turcicum*) were synthesized after recombination of 46 and 34 accesses, respectively. After two generations of recombination, a sample of 300 open pollinated ears (half-sib families) was chosen from each population. Families were evaluated in Anhembi (SP) in the 1999/00 season in six experiments with 50 families representing each population. The hybrid Master (Novartis Seeds) was used as check. The additive genetic variance ($^{2}_{A}$) and the coefficient of heritability (h^2_F) were estimated for ear yield, plant height and ear height. Mean yield of the RPM composite was 5.707 t ha^{-1} (77% of the hybrid check). Plant and ear height means were 19.4% and 36.3% higher than check. Parameters of variability were high with estimates of $^{2}_{A}$ and h^2_F of 554.73 (g/pl)^2 and 0.58, respectively. Mean yield of the RET composite was 4.393 t ha^{-1} (56.7% of the hybrid check). For plant and ear height, means were slightly lower than check. In the RET composite the variability for yield was less expressive with estimates of 195.58 (g/pl)^2 and 0.40 respectively.

Key words: leaf spots, additive genetic variance, coefficient of heritability

POTENCIAL DE PRODUÇÃO E VARIABILIDADE EM DOIS COMPOSTOS DE MILHO

RESUMO - No ano agrícola de 1994/95, 1.272 acessos do Banco Ativo de Germoplasma de Milho da Embrapa foram avaliados em diversos locais previamente escolhidos, para assegurar a incidência de doenças foliares causadas por *Phaeosphaeria maydis* e *Exserohilum turcicum*. Dois compostos denominados RPM (Resistente a *P. maydis*) e RET (Resistente a *E. turcicum*) foram sintetizados após a recombinação de 46 e 34 acessos, respectivamente. Após duas gerações de recombinação, uma amostra de 300 espigas de polinização livre (famílias de meios-irmãos) foi tomada de cada população. As famílias foram avaliadas em Anhembi (SP), no ano de 1999/00, em seis experimentos, com 50 famílias representando cada população. O híbrido Master (Novartis Seeds) foi utilizado como testemunha. A partir das análises de variância, foram estimados a variância genética aditiva ($^{2}_{A}$) e o coeficiente de herdabilidade (h^2_F), para os caracteres peso de espigas, altura da planta e altura da espiga. A média de produção de espigas do composto RPM foi de 5.707 t ha^{-1} (77% do híbrido testemunha). As médias de altura de planta e da espiga foram 19,4% e 36,3% maiores que as da testemunha. Os parâmetros de variabilidade para produção foram altos, com estimativas de $^{2}_{A}$ e h^2_F de

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554,73 $(g/pl)^2$ e 0,58, respectivamente. A média de produção do composto RET foi de 4.393 t ha^{-1} (56,7% do híbrido testemunha). Para altura de planta e da espiga, as médias foram levemente inferiores às da testemunha. No composto RET, a variabilidade de produção foi menos expressiva, com estimativas de 195,58 $(g/pl)^2$ e 0,40 para variabilidade aditiva e herdabilidade, respectivamente.

Palavras-chave: manchas foliares, variância genética aditiva, coeficiente de herdabilidade.

The maize crop is in general exposed to a great number of adverse biotic and non biotic factors. For the biotic stresses, emphasis is given to leaf diseases, which affect both yield and quality of the crop product. In Brazil, several factors have contributed to the increase of the incidence of leaf diseases. Continuous cropping (two crops in the same year) have contributed to maintain the potential of inoculum at a high level, thus favoring the pathogenecity of leaf diseases (Silva & Menten, 1997). The genetic susceptibility of some cultivars also have contributed to increase the incidence and severity of diseases. In fact, the introduction of exotic germplasm, particularly from temperate zones, led to an increase of leaf diseases as a consequence of the high susceptibility to tropical diseases. Introduction of exotic germplasm with low adaptation to tropical conditions has continuously been done in Brazil.

Among the most important leaf diseases of maize is the phaeosphaeria leaf spot, caused by *Phaeosphaeria maydis*, which, in recent years, has spread out rapidly over corn crops in many regions in Brazil. When first detected, the disease was considered as occurring in the final phase of plant development with little effect in yield; however, recently it has occurred earlier, thus causing expressive losses in yield (Menten *et al.*, 1996). The disease became more important after the decade of 1990 (Pereira, 1995) and losses up to 60% in yield have been reported (Fernandes & Oliveira, 1997). The occurrence of *P. maydis* is restricted to some areas in India and Latin America, including Brazil, Colombia, Ecuador, and Mexico. The most favorable environment for the development of the disease is high moisture and temperature within the range of 24^0 C to 35^0 C. Silva (1997) reported that in regions with altitude above 700m the occurrence of phaeosphaeria leaf spot is attributed to the intense dew formation on the leaf surface. In general the symptoms first appear in the lower leaves, progressing rapidly upward in susceptible germplasm.

Studies on the resistance to *P.maydis* have shown the quantitative nature of the trait variation and that the additive gene action is more important, with low expression of dominance (Carson *et al.*, 1996; Pegoraro *et al.*, 2000; Carson, 2001).

Another important disease of maize in Brazil is the northern leaf blight, caused by *Exserohilum turcicum* (Pass) Leonard & Suggs (Syns *Helmintosporium turcicum* Pass.; *Bipolaris turcica* (Pass.) Shoemarker; and Drecheslera turcica (Pass.) Subramanian & P.C. Jain, perfect state *Trichometasphaeria turcica* (Luttrel) K. J. Leonard & E. G. Suggs (Shurtleff, 1986; Berquist, 2000). This disease has been reported in Central-Western, Southwestern and Southern Brazil (Fernandes & Balmer, 1990; Pereira, 1995). The fungus shows high pathogenic variability (Jenkins & Robert, 1952) and the incidence is higher under conditions of high moisture and temperature within the range of 18^0 C to 27^0 C (Ullstrup, 1970). Low moisture and reduced rainfall affect negatively the disease development (Shurtleff, 1986). Reduction in yield caused by *E. turcicum* depends on the stage of the plant development at the time of infection and on the severity of the disease. Pereira (1995) reported on

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expressive losses in yield in off-season crop (“safrinha”). In addition, plants infected by *E. turcicum* become more sensitive to infection by stalk and root rot pathogens (Raymundo & Hooker, 1981).

Two forms of resistance exist for turcicum leaf blight: one monogenic, which appears as necrotic lesions, surrounded by an yellow ring with few or no sporulation, and the other is polygenic resistance, expressed as small lesions, more frequently in the lower leaves (Balmer & Pereira, 1987; Fernandes & Oliveira, 1997). Monogenic resistance is determined by the genes Ht_1, Ht_2, Ht_3 e Ht_N (Coe Junior *et al.*, 1977; Freymark *et al.*, 1994). Research on polygenic resistance to turcicum leaf blight has shown that additive and dominant genic action are important sources of variation, depending on the set of genotypes under study (Jenkis *et al.*, 1952; Hughes & Hooker, 1971; Regitano Neto, 1993). The quantitative resistance to *E. turcicum* is a trait of high heritability (Hooker, 1982; Ceballos *et* a*l*., 1991) but there are distinct races of the pathogen, which justify the search for different sources of germplasm toward the development of resistant cultivars.

The germplasm banks keep collections of accesses that can contribute to new sources of disease resistance in maize; however, the original accesses do not have acceptable agronomic traits. The pre-breeding strategy can prepare such a non conventional genetic material for use in breeding programs. Pre-breeding has been used in several programs worldwide, such as the LAMP (Latin American Maize Project), and GEM (Germoplasm Enhancement of Maize).The NAP-MILHO (*Núcleo de Apoio a Pesquisa de Milho*) Program has been coordinated by the Genetics Department (ESALQ/USP) and supported by a cooperative agreement involving several public and private institutions for the identification of new sources of resistance to leaf diseases in maize. This project initiated in 1994 with the evaluation of 1272 accesses and 140 populations from Germplasm Banks (CNPMS/EMBRAPA) in 13 locations over five states in Brazil. The evaluation traits included days to flowering, grain yield, resistance to corn stunt and leaf diseases (turcicum leaf blight, phaeosphaeria leaf spot, tropical rost, and polysora rost). This work is the final stage where the selection and recombination of accesses resistant to *Phaeosphaeria maydis* and to *Exserohilum turcicum* led to the formation of two composites (RPM and RET) specifically resistant to those diseases. RPM and RET are the base populations of the present study, that aimed the evaluation of their yield potential and genetic variability.

Material and Methods

The evaluation of 1272 accesses of the Maize Germplasm Bank of Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) was conducted in Guaíra (SP), Ribeirão Preto (SP), Arapongas (PR), Rio Verde (GO), Barretos (SP), Capinópolis (MG), Santa Helena (GO), Rondonópolis (MT), Sete Lagoas (MG), and Jacarezinho (PR) in the year 1995. From the whole set of accesses, 46 were selected for resistance to *Phaeosphaeria maydis* (Miranda Filho *et al.*, 2000). The selected accesses are identified in Table 1. In the same way 34 accesses, out of 1272, were selected for resistance to *Exserohilum turcicum*, based on evaluations conducted in Barretos (SP) and Rondonópolis (MT) and are identified in Table 2 (Miranda Filho *et al*., 2000).

The two sets of 46 and 34 accesses were planted at the Department Genetics Department (ESALQ/USP), Piracicaba, SP, in 1997 in two independent blocks. The two blocks were represented by 46 and 34 rows with 50 plants, where each row represented one access selected for *P. maydis* and *E. turcicum*, respectively. At the

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TABLE 1. Identification of 46 accesses of the Maize Germplasm Bank (BAG-EMBRAPA) used for the synthesis of de RPM composite (resistance to *Phaeosphaeria maydis*).

Access	Access	Access	Access
SE 028	SE 025	VERA CRUZ 150	PROLIFICO JAPONES
BA 094	PA 068	MAYA XV	SAN LUIS POTOSI 128
BA 154	PA 083	CMP JAIBA II	SAN LUIS POTOSI 127
MG 090	MG 099	VERA CRUZ GR 20	PANAMA GR 86
PR 053	BA 125	VERA CRUZ 210	SAN LUIS POTOSI 100
MG 104	RR 064	VERA CRUZ GR 22	SAN LUIS POTOSI 118
I 74-5	MG 089	VERA CRUZ GR 48	SAN LUIS POTOSI 14
PA 049	SE 016	BA 190	IAC MAYA ANAO II
BA 118	CMS 28	BA 160	VERA CRUZ 119
MEB I	RR 192	VERA CRUZ 183	DROUGHT TOLERANT
PA 078	AL 009	I 74-6	31096 G F2834 COMP
PR 050	RR 132	--	--

TABLE 2. Identification of 34 accesses of the Maize Germplasm Bank (BAG-EMBRAPA) used for the synthesis of RET composite (resistance to *Exserohilum turcicum*).

Access	Access	Access
BA 020	CMS 44	EL SALVADOR GR 1^{A}
BA 166	BA 061	CMS 27 III
MATAHAMBRE x GUAPIRA	ZAPALOTE CHICO	CMS 33
TEMPLADO AM. CRISTALINO	SE 030	CMS 49
AMAR.BAJIO x INDON 027171	CNPH 1	BR 427 III
HONDURAS GR 13 A	CMS 465 Pool 33 QPM	WP 33
CMS 467	BA 046	PIPOCA TIMOTEO
BOLIVIA I	BA 048	COMP CRUZ CUZCO
BA 018	BA 035	PIPOCA MIUDO
CMS 40	RN 003	MG 060
CMS 35	CMS 47	
SE 004	BA 032	

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pollination, tassels were collected in each row and a sample of pollen was used to pollinate receptive shoots in the whole block, for each set. At harvest, samples of seeds were collected in each row and mixed to represent the first generation of recombination of the composites named as RPM (resistance to *P. maydis*) and RET (resistance to *E. turcicum*). For the second generation of recombination, samples of the composite RPM and RET were planted in 1998 in a large isolated block with about 16,000 plants, in Anhembi (SP) and Ribeirão Preto (SP) respectively. From each composite, phenotypic selection resulted in 300 open-pollinated ears (half-sib families), which represented the experimental material in this study. The families were evaluated for their yield potential and variability in six experiments conducted in Anhembi (SP) as completely randomized blocks with three replications. Plots were 4 m long spaced 0.90 m apart with 20 plants per plot (planted in 09/11/1999). The following traits were analyzed: EY- total ear yield, PH- plant height (cm) and EH- ear height (cm). Estimated parameters were (Vencovsky & Barriga, 1992): additive genetic variance ($^{2}_{A}$), coefficient of heritability (h^{2}_{F} , family mean basis), and index of variation (Iv).

Results and Discussion

Mean yield of the RPM Composite, represented by 300 half-sib families, was 5.707 t ha^{-1}, representing 76.7% of the hybrid check (Table 3). The environment conditions in Anhembi (SP) are appropriate for the development of phaeosphaeria leaf spot as high temperature and high moisture predominate during the summer season (Mesquita Neto, 2000). The station borders the Tietê River, which assures a good condition for the development of tropical diseases. Mesquita Neto (2000) detected high incidence of *P. maydis* in Anhembi in normal season crop, when studying other selected accesses from the Maize Germplasm Bank. However, the yield level of accesses *per se* and in crosses did not reach 5 t ha^{-1} in both normal and off-season crops. For plant and ear height, observed means for RPM Composites were higher (19.4% and 36.3%, respectively) than the hybrid check, on average,

TABLE 3. Observed means of half-sib families (m_F) of the RPM composite (resistance to *Phaeosphaeria maydis*) and hybrid check (m_C) for three traits in six experiments. Anhembi, SP, 2000.

Experiments	Ear yield (t ha^{-1})			Plant height (cm)			Ear height (cm)		
	m_F	m_C	m_F%	m_F	m_C	m_F%	m_F	m_C	m_F%
Exp. 01	5.660	7.314	77.4	288	245	117,2	191	144	132,8
Exp. 02	5.516	7.139	77.3	290	236	123,0	192	134	143,2
Exp. 03	5.940	7.855	75.6	294	247	119,1	192	147	131,0
Exp. 04	5.655	7.499	75.4	294	245	119,8	197	141	139,5
Exp. 05	5.706	7.641	74.7	290	249	116,7	195	149	131,5
Exp. 06	5.763	7.217	79.9	294	243	121,2	193	137	140,6
Grouped	5.707	7.444	76.7	292	244	119,5	194	142	136,3

Check: Master- Novartis Seeds; m_F%: in percent of check mean.

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indicating that attention must be given to those traits in recurrent selection programs toward the development of cultivars with appropriate plant architecture. Paterniani (1990) emphasized that tropical maize germplasm is generally characterized by tall plants and high ear placement in the stalk, which may cause problems in mechanical harvesting.

In the RET Composite, ear yield, represented by 300 half-sib families, averaged 4393 t ha^{-1}, representing 56.7% of the hybrid check (Table 4). Some factors might have influenced the apparently low level of productivity observed in this composite: first, selection of the 34 accessions focused only resistance to *Exserohilum turcicum* (Miranda Filho *et al.*, 2000); second, the environment in Anhembi (SP) is characterized by acid soil and low fertility, where a broad base population formed by several sources of germplasm, including exotics, may present problems with adaptation (Morello *et al.*, 2001); finally, the control check is an outstanding hybrid well adapted to the local conditions. In Anhembi there is a high probability for the expression of leaf diseases, particularly the corn stunt complex (Basso, 1999). For plant and ear height, observed means were smaller than the hybrid check in most experiments and on the average of all experiments.

Coefficients of variation (CV) for yield of RPM Composite varied from 15.0% to 20.4%, averaging 16.8%; Mesquita Neto (2000) reported on CV's varying from 14.0% to 20.4% in four off-season experiments and from 13.1% to 14.0% in four normal season experiments in the same location. In the experiments representing RET Composite, CV's varied from 16.4% to 21.9%, averaging 18.5%.

Estimates of the additive genetic variance in RPM Composite were obtained from the analysis of variance (Table 5) and were considered of high magnitude for EY and EH and intermediate for PH. Hallauer & Miranda Filho (1988) showed average estimates of 469.1 (g/pl)^2, 213.9 cm^2 and 152.7 cm^2 for EY, PH and EH, respectively. The coefficient of heritability was higher than 0.5 for EY, and lower than 0.5 for PH and EH, indicating the strong effect of environment in PH and EH. A high genetic variability for yield in RPM Composite was expected because 46 accesses of several origins were included in its formation (Table 1).

TABLE 4. Observed means of half-sib families (m_F) of the RET composite (resistance to *Exserohilum turcicum*) and hybrid check (m_C) for three traits. Anhembi, SP, 2000.

Experiments	Ear yield (t ha^{-1})			Plant height (cm)			Ear height (cm)		
	m_F	m_C	m_F%	m_F	m_C	m_F%	m_F	m_C	m_F%
Exp. 01	3.957	7.481	52.9	224	223	100.1	126	123	103.2
Exp. 02	3.921	7.479	52.4	225	233	96.6	134	135	98.7
Exp. 03	4.097	7.900	51.9	224	233	95.8	132	135	97.1
Exp. 04	4.526	7.608	59.5	229	231	99.4	136	137	99.3
Exp. 05	4.880	7.949	61.4	230	235	97.9	140	137	101.9
Exp. 06	4.974	8.084	61.5	228	241	94.6	136	142	95.6
Grouped	4.393	7.750	56.7	227	233	97.4	134	135	99.2

Check: Master- Novartis Seeds; m_F%: in percent of check mean.

TABLE 5. Mean squares (M_1: families and M_2: error)* in the combined analysis of variance and coefficient of variation (CV) for three traits in six experiments with half-sib families of the RPM and RET composites; and estimates of the additive genetic variance ($^{2}_{A}$), coefficient of heritability (h^{2}_{F}) and index of variation (Iv).

Composites	Ear yield (t ha^{-1})			Plant height (cm)			Ear height (cm)		
	M_1	M_2	CV%	M_1	M_2	CV%	M_1	M_2	CV%
RPM	2.2141	0.9300	16.8	830.0	591.1	8.3	946.0	490.8	11.4
RTE	1.1236	0.6709	18.5	931.8	384.6	8.6	1088.8	422.6	15.4
	$\hat{\sigma}^{2}_{A}$	h^{2}_{F}	Iv	$\hat{\sigma}^{2}_{A}$	h^{2}_{F}	Iv	$\hat{\sigma}^{2}_{A}$	h^{2}_{F}	Iv
RPM	554.73	0.580	0.681	318.56	0.288	0.370	606.98	0.481	0.550
RET	195.58	0.403	0.478	729.60	0.587	0.689	888.27	0.612	0.720

*Degrees of freedom: 49 for M_1 and 98 for M_2 in each of the six experiments. $^{2}_{A}$ for yield in g/plant.

For the RET Composite, estimates of the additive genetic variance and coefficient of heritability (Table 5) obtained from the analysis of variance grouped over experiments, were considered as intermediate for EY and very high for PH and EH, as compared with estimates reported by Vencovsky *et al.* (1988), for Brazilian maize populations. For EY, the lower estimates obtained for additive variance can be due to the low level of adaptation of most accesses that formed the RET Composite, or because the lower expression of the character, leading to a lower value of variance. For PH and EH, high variability was expected as a consequence of the diversity of the accesses for those traits. The index of variation (Table 5) indicated appropriate level of variability for all traits, assuring effective changes in the mean through recurrent selection.

Because both RPM and RET composites were synthesized aiming the development of new sources of resistance to *Phaeosphaeria maydis* and *Exserohilum turcicum*, and no other attributes were considered when selecting the parents to be crossed, it was not expected an acceptable pattern for agronomic traits. The results herein discussed indicated that RPM showed a better performance for yield but a lower pattern for plant architecture, as compared to RET. Despite the fact that both composites showed lower yields than the hybrid check, the level of genetic variability assures that expressive gains for yield and for plant and ear height can be attained during the course of the recurrent selection program. Nevertheless, in spite of the improvement for agronomic traits, the main destiny of the populations is not the direct use for commercial purposes but to be preserved as good sources of genetic resistance for the specific diseases already mentioned.

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