

# Diallel cross analysis for young plants of brachytic maize (*Zea mays* L.) varieties

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## ABSTRACT

Six brachytic maize varieties were crossed in a diallel mating scheme. Both varieties and crosses were grown hydroponically in a greenhouse, in randomized complete blocks with three replications in two seasons. Four brachytic double cross hybrids were used as checks. Twenty-eight days after planting, data for eight traits were taken for weights of the total plant (TPW), top plant (TOW), total roots (TRW), seminal roots (SRW), and nodal roots (NRW) and number of total roots (TRN), seminal roots (SRN), and nodal roots (NRN). Ten plants were measured in each plot and all the analyses were accomplished with plot means. In the diallel cross the top plant contributed 57.6% of the total plant weight, for seminal roots 15.4%, and for nodal roots 27.0%. Root number distribution was 36.7% seminal roots and 63.3% nodal roots. Approximately the same ratios were observed in the checks. The average heterosis effects were nonsignificant for all traits; the other components of heterosis (variety and specific heterosis) also were not important sources of variation in young plants. The overall results suggest that nonadditive gene action is not an important source of variation for the plant and root system of young plants. The positive correlation coefficients for combinations of traits indicated that they are under the control of a polygenic system.

## INTRODUCTION

The root system of the maize (*Zea mays* L.) plant has increasingly deserved attention of the maize breeders because of its direct effect on performance. The importance of roots is related to: 1) physical support of the plant and its relation to lodging resistance; 2) root size, form and vigor that affect absorption of nutrients, drought resistance, and tolerance to toxic elements (Al and Mn) in the soil, and 3) root development in the presence of insect pests such as *Diabrotica* sp. However, compared to the great amount of information on the top part of the maize plant little is known about the roots.

Some studies have focused on the relation between the root system and agronomic traits of the adult plant. Misra (1956) concluded that a rapid development of the root system in the early phases is an important aspect of plant resistance to drought. Garcia Jr. *et al.* (1979) found that the relative length of the radicle and visual classification of the root system are efficient criteria for the identification of genotypes that are tolerant to toxic Al when grown in pure sand with 75 ppm Al. In the same way, Lima *et al.* (1992) evaluated two cycles of divergent selection for Al-tolerance, based on the radicle length of young plants grown in nutrient solution with 4.5mg/l Al. Some authors have found a relation between plant lodging and some root traits, such as the number of adventitious roots (Wilson, 1930), number of nodal roots (Andrew and Solanki, 1966; Nass

and Zuber, 1971; Pereira *et al.*, 1977), root vigor (Rogers *et al.*, 1977), and weight of nodal roots (Vello and Alleoni, 1979).

Little is known on the relation between the root system and grain yield. Smith and Walworth (1926) attributed high yields to varieties with a large number of seminal roots, but Mangelsdorf and Goodsell (1929) concluded that seminal roots do not seem to be an efficient criterion for selection of high yielding genotypes. Rogers (1976) concluded that wider root dispersion affects yield positively.

The objective of this project was to study the root system and the aerial part of young plants of brachytic maize varieties *per se* and in crosses (diallel cross). The brachytic type of maize has been suggested as an alternative to short stature varieties in the tropics for improvement of cultivar structural characteristics (Paterniani, 1973; Miranda Filho, 1974).

## MATERIAL AND METHODS

Six brachytic (*br<sub>2</sub>br<sub>2</sub>*) maize varieties were used: (1) Piranão-VD1, (2) Piranão-VD2, (3) Piranão-VF1, (4) CIMMYT-br2, (5) Composite SCDent-br2, (6) Composite SCFlint-br2. Paterniani *et al.* (1977) provided a description of the first four varieties: (1) = dent type variety obtained from the cross Piramex-III x Tuxpeño-br2 (from CIMMYT, México); (2) = brachytic version of the dent type variety ESALQ-VD2, formerly known as Dent Composite; (3) = brachytic version of the flint type variety ESALQ-VF1, formerly known as Flint Composite, and (4) = brachytic and flint type variety introduced from CIMMYT (México) in 1972. Souza Jr. and Zinsly (1985) described (5) and (6), as wide base brachytic populations obtained from crossing dent and flint commercial single crosses, respectively, followed by backcrossing the *br<sub>2</sub>* allele using Piranão-VD2 as the donor parent. The six varieties were crossed in a diallel mating scheme, using paired rows with 50 plants per row. The first ears were used for crosses between rows and the second ears of prolific plants, as well as the remaining plants not used in crosses, were used for sib-crosses within rows for renewing seeds of the parental varieties. The following commercial hybrids were used as checks: double crosses Ag-351, Ag-453, and Ag-454 and the single cross Ag-8113; all brachytic types from Agrocere S/A.

The experiments for evaluating the root system were conducted during two seasons (January/February and March/April, 1982) in a greenhouse at the Department of Genetics (ESALQ-USP), Piracicaba, SP,

Brazil. The experiments were in a randomized complete block design with three replications in each season. Each block included the six varieties, the 15 crosses, and the four hybrid checks. Each plot was represented by 14 plants that were grown individually in a 20 x 30 cm plastic bag with washed sand as substrate. Irrigation was applied daily, and nine days after planting 50 ml of nutrient solution (Hoagland and Aron 1938) was added per pot on alternate days. Stock solutions (ml/l water) were  $\text{KH}_2\text{PO}_4$  (1),  $\text{KNO}_3$  (5),  $\text{Ca}(\text{NO}_3)_2$  (5),  $\text{MgSO}_4$  (2) and a micronutrient solution (g/l) with  $\text{H}_3\text{BO}_3$  (2.86),  $\text{MnCl}_2 \cdot 4 \text{H}_2\text{O}$  (1.81),  $\text{ZnCl}_2$  (0.10),  $\text{CuCl}_2$  (0.04),  $\text{H}_2\text{M}_0\text{O}_4 \cdot \text{H}_2\text{O}$  (0.02), and Fe-EDTA prepared with 26.1 g of disodium-EDTA in 286 ml of NaOH.N and mixed with 24.9 g of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , left overnight before completing to one liter.

The experimental results were collected 28 days after planting, by randomly taking 10 plants per plot for counting and weighing the components of the root system. The seminal roots originate directly from the seed, including the radicle. The nodal roots are those near the stalk. The upper part of the plant was separated by cutting the plant near the first node. After washing to remove the sand, the seminal roots, the nodal roots, and the upper part of the plant were stored in newspaper bags. The materials were dried under forced air 70°C until constant weights were attained. The following traits were analyzed: TPW, total plant weight; TOW, top plant weight; TRW, total root weight; SRW, seminal root weight; NRW, nodal root weight; TRN, total root number; SRN, seminal root number, and NRN, nodal root number. All the weights were in g/plant and the analyses for all traits were on an individual plant (plot mean) basis.

The preliminary analyses of variance were first performed for each season and then jointly for both seasons. Only combined analysis was used because no interaction with seasons was detected for any trait. The analysis of variance according to the diallel scheme was performed for each trait with means over both seasons (six replications) and by the model given by Gardner and Eberhart (1966):  $Y_{ii'} = \mu + \frac{1}{2}(v_i + v_{i'}) + \theta(h + h_i + h_{i'} + s_{ii'} + e_{ii'})$ , where  $Y_{ii'}$  is the observed mean of the cross  $ixi'$ ;  $v_i$  is variety effects;  $\bar{h}$  is the average heterosis of all crosses;  $h_i$  is variety heterosis effects;  $s_{ii'}$  is the specific heterosis, and  $e_{ii'}$  is the average plot error associated with the  $ixi'$  cross. Also,  $\theta = 1$  for crosses ( $i \neq i'$ ) and  $\theta = 0$  for varieties ( $i = i'$ ). The analysis of variance was performed according to Gardner (1967).

Because of the nonsignificant expression of heterosis for all traits, the reduced model  $Y_{ii'} = \mu + \frac{1}{2}(v_i + v_{i'}) + \delta_{ii'}$  was used for estimating constants ( $\mu$  and  $v_i$ );  $\delta_{ii'}$  is the deviation from the model and includes the

error term. The formulae for obtaining the least squares estimates and the sums of squares are:

$$\hat{\mu} = \frac{2Y_{..}}{n(n-1)}; \hat{v}_i = \frac{2}{n+2}(Y_{ii} + Y_i) - \frac{4Y_{..}}{n(n+2)}, \text{ and}$$

$$SS(\text{var}) = \frac{1}{n+2} \sum_i (Y_{ii} + Y_i)^2 - \frac{4Y_{..}^2}{n(n+2)}$$

$$SS(\text{deviations}) = \sum_{i \leq i'} Y_{ii'} - \frac{1}{n+2} \sum_i (Y_{ii} + Y_i)^2 - \frac{Y_{..}^2}{n(n+1)(n+2)}$$

where  $Y_i = \sum_{i'} Y_{ii'}$  and  $Y_{..} = \sum_{i,i'} Y_{ii'}$ .

The SS(var.) is the same for the complete model and SS (deviations) is the SS(heterosis) of the complete model.

## RESULTS AND DISCUSSION

The overall means of varieties and crosses were very similar for all traits and the check means were always higher than varieties and crosses (Table I). The ratio between the diallel mean and check mean varied from 80.6% to 86.1% for the weighted traits, while for root number the ratio was about 95% (Table II). The check hybrids were consistently more vigorous for either the aerial plant or for the root weight and to a lesser extent for root number. It seems that strong selection during the hybrid development indirectly led to positive changes in the root system and in the whole plant. The check hybrids were more vigorous than varieties or variety crosses for the traits evaluated in young plants. Differences in the basic germplasm used cannot be ignored. Smith and Walworth (1926) associated higher yields with higher seminal root number in dent varieties of maize. On the other hand, Mangelsdorf and Goodsell (1929) concluded that the number of seminal roots would not be a good criterion for selection of outstanding genotypes.

In both diallel and checks most of the weight was due to the aerial part of the young plant, i.e., 57.6% in the diallel and 59.0% in the check hybrids (Table II). In the root system, the weight was partitioned for seminal and nodal roots as 15.4% and 27.0% in the diallel, and 15.0% and 26.0% in the checks, respectively. For root number, most were nodal roots (*cir.* 63%) as compared with seminal roots (*cir.* 37%) in both diallel and checks. Spencer (1940) also found a greater number of nodal roots three or four weeks after planting. After six weeks, the nodal root weight was about 25 times the seminal root weight, and a ratio of 2:1 was found when

comparing top vs. root weights, two weeks after planting. Foth (1962) observed a fast initial development of top and roots, followed by a period of faster development of the top plant. In the next phase the top:root ratio decreased as a consequence of the increase in the number of adventitious roots, and the

**Table I** - Means of varieties, crosses and checks for five traits of young plants of maize over six replications (two seasons).

Entry	TOW	SRW	NRW	SRN	NRN
1	0.866	0.223	0.415	5.4	10.0
2	0.614	0.164	0.310	5.3	8.5
3	0.648	0.184	0.298	5.0	9.0
4	0.687	0.225	0.319	5.7	9.0
5	0.742	0.190	0.408	5.4	9.2
6	0.740	0.201	0.335	5.1	9.2
1x2	0.823	0.225	0.375	6.0	9.2
1x3	0.801	0.223	0.371	5.5	9.0
1x4	0.845	0.215	0.363	5.8	9.8
1x5	0.648	0.184	0.321	4.9	9.0
1x6	0.727	0.174	0.332	5.4	9.5
2x3	0.831	0.194	0.343	4.7	9.2
2x4	0.698	0.216	0.320	5.4	9.3
2x5	0.696	0.168	0.352	5.0	8.3
2x6	0.833	0.203	0.403	5.2	9.4
3x4	0.631	0.174	0.297	5.2	8.7
3x5	0.661	0.186	0.325	5.6	9.1
3x6	0.695	0.203	0.309	5.6	8.7
4x5	0.732	0.212	0.360	5.0	9.2
4x6	0.822	0.183	0.387	5.2	10.0
5x6	0.788	0.214	0.339	5.1	8.7
Ag-351	0.771	0.203	0.324	5.5	8.2
Ag-453	1.099	0.241	0.456	5.4	10.1
Ag-454	0.889	0.229	0.436	5.2	9.6
Ag-813	0.908	0.258	0.397	6.4	10.1
Varities	0.716	0.198	0.348	5.3	9.1
Crosses	0.749	0.198	0.346	5.3	9.1
Checks	0.917	0.233	0.403	5.6	9.6

Varieties: (1) Piranão-VD1, (2) Piranão-VD2, (3) Piranão-VF1, (4) CIMMYT-br2, (5) Comp. SCDent-br2, (6) Comp. SCFlint-br2. Traits: TOW = top plant weight (g); SRW = seminal root weight (g); NRW = nodal root weight (g); SRN = seminal root number; and NRN = nodal root number.

**Table II** - Components of the total plant weight and total root number of young plants of maize in the diallel (varieties and crosses) and checks.

Traits	Diallel mean	Checks mean
Top plant weight	0.739	0.917
Seminal root weight	0.198	0.233
Nodal root weight	0.347	0.403
Total root number	14.45	15.17
Seminal root number	5.30	5.61
Nodal root number	9.14	9.56

ratio increased again when the root system stopped growing during the grain filling period.

The complete analysis of variance indicated that the variation due to seasons, replications, and entries were all highly significant ( $P \leq 0.01$ ) (Table III). The differences among groups (varieties, crosses, and checks) were highly significant for all traits, and from Table I it is clear that the greatest difference was due to [varieties and crosses] vs. checks. The interaction entries (E) x season (S) was not an important source of variation.

No significant differences were detected for any source of variation for total root weight and nodal root weight (Table IV). The variety effects were significant only for total plant weight, top plant weight, total root number, and nodal root number. Average heterosis was nonsignificant for all traits. Significance at  $P < 0.05$  was found in some traits for variety heterosis (TPW) and specific heterosis (TPW, TOW, and SRW). Because of some heterogeneity in the error variance of the two seasons, the actual level of probability should be higher than 5%. Nonsignificance for average heterosis (all traits) and for other heterosis components

in most instances indicates that nonadditive gene effects are not an important source of variation for both plant top and root system of young plants. On the other hand, one can hypothesize that a lack of genetic divergence between the parent varieties can also contribute to the nonexpression of the heterosis.

Average heterosis was low for all traits but grain yield (Table V). Under the hypothesis of unidirectional dominance, the average heterosis is a powerful indicator of the existence of nonadditive gene effects. Nonsignificant specific heterosis has been observed in most of the variety diallel crosses for yield (Hallauer and Miranda Filho, 1988). Miranda Filho and Vencovsky (1984) also reported nonsignificant specific heterosis for yield, plant height, and ear height, even though significant effects were detected for average heterosis and for variety heterosis in some instances. Souza Jr. and Zinsly (1985) studied the same set of brachytic varieties in diallel crosses and found specific heterosis to be nonsignificant for yield. All other components of heterosis were significant, indicating genetic divergence among the brachytic varieties. Therefore, the lack of heterosis in our study is most

Table III - Analysis of variance for eight traits of young plants of maize in varieties, crosses and checks in randomized complete blocks with three replications in two seasons.

Source	d.f.	TPW <sup>a/</sup>	TOW <sup>a/</sup>	TRW <sup>a/</sup>	SRW <sup>a/</sup>	NRW <sup>a/</sup>	TRN	SRN	NRN
Seasons (S)	1	1499.2**	568.9**	220.4**	7.48**	146.1**	116.0**	532.9**	117.0**
Reps/S	4	113.62**	62.24**	10.86**	0.59**	13.24**	1.85 <sup>ns</sup>	34.48**	41.27**
Entries (E)	24	16.49**	7.04**	2.22**	0.34**	1.16**	3.51**	7.67**	17.66**
Varieties	5	13.56**	4.75*	2.44*	0.33*	1.55*	2.14*	3.71 <sup>ns</sup>	15.55*
Crosses	14	7.54**	3.38**	1.02 <sup>ns</sup>	0.22*	0.54 <sup>ns</sup>	2.48**	7.16*	12.41*
Checks	3	24.84**	11.08**	3.37**	0.32 <sup>ns</sup>	2.03*	9.44**	18.00**	47.61**
Groups	2	73.98**	32.39**	8.38**	1.20**	3.21**	5.27**	9.18 <sup>ns</sup>	14.78 <sup>ns</sup>
E x S	24	4.47 <sup>ns</sup>	2.51*	0.91 <sup>ns</sup>	0.18 <sup>ns</sup>	0.57 <sup>ns</sup>	1.13 <sup>ns</sup>	3.28 <sup>ns</sup>	4.70 <sup>ns</sup>
Pooled error	96	3.22	1.50	0.81	0.12	0.51	0.91	3.38	5.91
Mean		1.327	0.768	0.559	0.204	0.356	14.6	5.4	9.2
Coef. variation %		13.5	15.9	16.1	17.0	20.1	6.5	10.8	8.4

<sup>a/</sup>: Mean squares multiplied by 10<sup>2</sup>; ns, \* and \*\*: F-test nonsignificant and significant at  $P < 0.05$  and  $P < 0.01$ , respectively.

Table IV - Analysis of variance for eight traits of young plants of maize in variety diallel crosses.

Source	d.f.	TPW <sup>a/</sup>	TOW <sup>a/</sup>	TRW <sup>a/</sup>	SRW <sup>a/</sup>	NRW <sup>a/</sup>	TRN	SRN	NRN
Populations	20	1.468**	6.158**	2.210 <sup>ns</sup>	3.940*	1.286 <sup>ns</sup>	3.800**	9.910*	2.094**
Varieties	5	1.788*	7.363*	2.854 <sup>ns</sup>	4.153 <sup>ns</sup>	1.836 <sup>ns</sup>	7.480**	7.965 <sup>ns</sup>	3.751**
Heterosis	15	1.361**	5.756*	1.996 <sup>ns</sup>	3.869*	1.103 <sup>ns</sup>	2.573 <sup>ns</sup>	10.558*	1.542 <sup>ns</sup>
Avg. het.	1	0.445 <sup>ns</sup>	4.545 <sup>ns</sup>	0.004 <sup>ns</sup>	0.008 <sup>ns</sup>	0.005 <sup>ns</sup>	0.000 <sup>ns</sup>	0.015 <sup>ns</sup>	0.000 <sup>ns</sup>
Variety het.	5	1.539 <sup>ns</sup>	5.923 <sup>ns</sup>	2.396 <sup>ns</sup>	2.530 <sup>ns</sup>	1.517 <sup>ns</sup>	2.665 <sup>ns</sup>	8.334 <sup>ns</sup>	2.038 <sup>ns</sup>
Specific het.	9	1.336*	5.798*	1.995 <sup>ns</sup>	5.042*	0.995 <sup>ns</sup>	2.808 <sup>ns</sup>	12.996*	1.437 <sup>ns</sup>
Error <sup>b/</sup>	120	0.578	2.837	1.383	2.200	0.870	1.594	5.602	0.945

<sup>a/</sup>: Mean squares multiplied by 102; <sup>b/</sup>: pooled with the E x S interaction.

ns, \* and \*\*: F-test nonsignificant and significant at  $P < 0.05$  and  $P < 0.01$ , respectively.

**Table V** - Estimates of the mean ( $\mu$ ), average heterosis ( $\bar{h}$ ) and variety effects ( $v_i$ ) for eight traits of young plants and three traits of adult plants.

$v_i$	TPW	TOW	TRW	SRW	NRW	TRN	SRN	NRN	GY	PH	EH
$v_1$	0.160	0.100	0.060	0.020	0.041	0.929	0.296	0.639	0.974	0.219	0.196
$v_2$	-0.033	-0.017	-0.017	-0.013	-0.004	-0.451	-0.052	-0.411	-1.674	-0.108	-0.038
$v_3$	-0.120	-0.065	-0.056	-0.010	-0.046	-0.493	-0.142	-0.348	0.433	0.024	-0.010
$v_4$	-0.018	-0.018	0.001	0.016	-0.015	0.499	0.198	0.287	0.920	0.105	0.106
$v_5$	-0.033	-0.042	0.009	-0.011	0.021	-0.553	-0.197	-0.351	-0.538	-0.162	-0.170
$v_6$	0.044	0.042	0.002	-0.002	0.003	0.069	-0.104	0.184	-0.115	-0.078	-0.084
$\mu$	1.284	0.739	0.545	0.198	0.347	14.45	5.30	9.14	5.403	1.729	1.020
$\bar{h}$	0.032	0.033	-0.001	0.000	-0.001	0.001	-0.01	0.00	0.860	0.037	0.030
h%	2.7	4.5	-0.3	0.0	-0.3	0.01	-0.1	0.0	15.9	2.1	2.9

$v_i$ : Estimates according to the reduced model  $Y_{iir} = \mu + \frac{1}{2}(v_i + v_i') + \delta_{iir}$  (see text); except for GY (grain yield, t/ha), PH (plant height, m) and EH (ear height, m) which were adapted directly from Souza Jr. and Zinsly (1985). h%: Average heterosis in percent of midparent.

**Table VI** - Correlation coefficients in combinations of 11 traits for observed means of the diallel crosses (above diagonal) and for variety ( $v_i$ ) effects (below diagonal).

Traits	TPW	TOW	TRW	SRW	NRW	TRN	SRN	NRN	GY <sup>[a]</sup>	PH <sup>[a]</sup>	EH <sup>[a]</sup>
TPW	—	0.98	0.94	0.64	0.87	0.62	0.27	0.65	0.14	0.37	0.36
TOW	0.98	—	0.86	0.57	0.80	0.60	0.21	0.66	0.46	0.42	0.40
TRW	0.94	0.84	—	0.70	0.92	0.62	0.36	0.59	0.33	0.25	0.25
SRW	0.71	0.67	0.39	—	0.36	0.50	0.48	0.34	0.44	0.35	0.39
NRW	0.84	0.74	0.94	0.39	—	0.52	0.19	0.58	0.16	0.14	0.11
TRN	0.82	0.81	0.75	0.98	0.48	—	0.69	0.86	0.32	0.49	0.47
SRN	0.69	0.66	0.66	0.94	0.38	0.93	—	0.23	0.11	0.30	0.30
NRN	0.84	0.84	0.76	0.95	0.50	0.98	0.85	—	0.35	0.46	0.43
GY	0.33	0.32	0.31	0.79	0.01	0.71	0.61	0.72	—	0.69	0.58
PH	0.53	0.55	0.45	0.88	0.15	0.86	0.89	0.80	0.82	—	0.94
EH	0.54	0.56	0.46	0.86	0.16	0.86	0.95	0.77	0.67	0.97	—

[a]: original means from Souza Jr. (1981).

probably due to the lack of nonadditive effects for genes controlling the traits studied 28 days after planting.

It seems that heterosis (or nonadditive genetic effects) was not an important source of variation for the eight traits evaluated 28 days after planting, and the genetic potential of varieties for those traits can be effectively evaluated in the varieties *per se*. In the diallel crosses, the variety effect ( $v_i$ ) is the only meaningful parameter to provide information on the genetic value of varieties (Table V). Piranão-VD1 was outstanding in relation to other varieties for all the studied traits, in agreement with Souza Jr. and Zinsly, 1985 (Table V).

For all combinations of traits, including the traits reported by Souza Jr. and Zinsly (1985), there was a positive association, thus indicating that they are under the control of the same polygenic system (Table VI). In this sense, favorable genotypic combinations affect additively all traits in the same direction of change. Such a hypothesis would also explain the superiority of the hybrid checks over varieties and variety crosses for all traits studied.

The overall results indicate that the expression of traits of the root system and aerial plant evaluated in young plants are under the control of a predominantly

additive genetic system with practically no expression of heterosis in crosses. A positive association between traits of young plants with grain yield, plant height and ear height of adult plants (Souza Jr. and Zinsly, 1985) was also found.

## ACKNOWLEDGMENT

Publication supported by FAPESP.

## RESUMO

Foram utilizadas seis variedades de milho braquítico em cruzamento dialélico. As variedades, híbridos e testemunhas (quatro híbridos braquíticos) foram avaliadas em solução nutritiva em casa de vegetação em blocos completamente casualizados com três repetições em duas épocas. Os seguintes caracteres foram avaliados 28 dias após a semeadura: peso total da planta, peso da parte aérea, peso total de raízes, peso de raízes seminais, peso de raízes nodais, número total de raízes, número de raízes seminais e número de raízes nodais. Foram tomadas dez plantas por parcela e todas as análises foram realizadas com médias de parcelas.

No esquema dialélico o peso total da planta foi assim distribuído: 57,6% para a parte aérea, 15,4% para raízes seminais e 27,0% para raízes nodais. O número total de raízes foi assim distribuído: 36,7% para raízes seminais e 63,3% para raízes nodais. Aproximadamente as mesmas relações foram observadas para as testemunhas. A heterose média foi muito baixa e não significativa para todos os caracteres. Os outros componentes da heterose (heterose de variedade e heterose específica) também não se mostraram importantes como fontes de variação. Os resultados gerais levaram a concluir que a ação gênica não aditiva não é importante como fonte de variação para os caracteres da parte aérea e do sistema radicular em plantas jovens. Os coeficientes de correlação positivos para as combinações de caracteres indicam que eles estão em maior ou menor grau sob o controle do mesmo sistema poligênico.

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(Received April 25, 1995)