

Potential of twenty exotic germplasms to improve Brazilian maize architecture

Amadeu Regitano Neto¹, Luciano Lourenço Nass² and José Branco de Miranda Filho³

ABSTRACT

Temperate and temperate x tropical germplasms were introduced into the maize breeding of the Department of Genetics (ESALQ-USP). Twenty populations designated as P-1 to P-20 and a check population were evaluated in a randomized complete block design with two replications at Piracicaba, SP, Brazil. Plots were 2.0 m long, spaced 1.0 m apart, with 10 plants per plot after thinning. The following traits were evaluated: PH, plant height; EH, ear height; TB, tassel branch number; KW, 100 kernels weight; EL, ear length; ED, ear diameter; KR, kernels per row, and RN, number of rows of kernels. The means of the exotic populations showed a variation in performance for all traits. The population means were greater than check means for KW, EL, and KR. Populations P-9, P-10, P-12, and P-13 showed low relative ear placement values (EH/PH index), indicating that these materials could contribute to lower ear placement in local populations. P-1 and P-9 showed a high potential to reduce TB. The phenotypic correlation coefficients among populations were positive for most combinations, except for RN with PH, EH, TB, and KW. Predictions of 19 composite means were obtained for all traits.

INTRODUCTION

Maize (*Zea mays* L.) is a monoecious plant essentially 100% cross-pollinated through wind movement. It is grown from 58°N to 40°S latitude (Hallauer and Miranda Filho, 1988). The great amount of natural genetic variability, with approximately 300 races identified, and the favorable characteristics of its life cycle and reproduction have made maize the most extensively genetically studied crop species (Paterniani, 1993).

The mechanisms for creating genetic variability include hybridization, mutagenic agents, introgression

of exotic germplasm, and more recently biotechnology. The importance of exotic germplasm introductions in maize breeding programs has been emphasized by many authors (Wellhausen, 1956, 1965; Brown and Goodman, 1977; Hallauer, 1978; Duvick, 1984; Hallauer and Miranda Filho, 1988). Crossing of exotic with adapted germplasm has been the usual procedure for incorporating exotic germplasm (Hallauer, 1978).

In Brazil, the contribution of the Mexican race Tuxpeño to improve the yield performance of hybrids and open-pollinated varieties is a remarkable example of exotic germplasm utilization (Paterniani, 1990). Since 1980, Brazilian breeders have made several introductions of new maize germplasm (Moro *et al.*, 1981; Lima *et al.*, 1982; Miranda Filho and Vencovsky, 1984; Magnavaca *et al.*, 1989; Miranda Filho, 1992). These materials were introduced mainly to improve yield potential, as sources of disease or pest resistance, and to decrease the plant and ear height of local populations.

¹ CPG - Departamento de Genética, ESALQ/USP, Caixa Postal 83, 13400-970 Piracicaba, SP, Brasil. Send correspondence to A.R.N.

² CENARGEN/EMBRAPA, SAIN Parque Rural, 70770-900 Brasília, DF, Brasil.

³ Departamento de Genética, ESALQ/USP, Caixa Postal 83, 13400-970 Piracicaba, SP, Brasil.

We report on the characterization of 20 exotic populations, including germplasm of temperate and tropical x temperate origins, which may be useful for breeding purposes.

MATERIAL AND METHODS

Exotic maize populations have been periodically introduced into the maize breeding program of the Department of Genetics (ESALQ-USP). Table I shows all the populations used in this project, their original designations, and their climate origins. They were designated as P-1 to P-20. The population seed samples were multiplied through biparental crosses and an equal number of seeds from each pollinated ear was taken to represent each sample.

A randomized complete block design with two replications was conducted in 1994/95 in Piracicaba, SP, Brazil, located at latitude 22°42'S, longitude 47°38'W and at an altitude of 537 m. Plots were 2.0 m long, spaced 1.0 m apart, with 10 plants per plot after thinning. The check used was an advanced generation of a single cross hybrid.

Data were collected for eight traits: PH, plant height (cm); EH, ear height (cm); TB, tassel branch number; KW, 100 kernels weight (g); EL, ear length (cm); ED, ear diameter (cm); KR, kernels per row, and

RN, number of rows of kernels. The mean of five random and competitive plants was determined for all traits within each plot, except for KW, which was taken after harvest as a sample of each population.

In the analysis of variance, the variation among populations was partitioned into two groups: P-I (P-1-P-9), formerly studied by Miranda Filho (1992), and P-II, an introduced set of populations with no prior evaluation under our environmental conditions.

Following the experimental evaluation, predictions of 19 composite means for all traits were obtained based on a hypothetical model, considering absence of heterosis, starting from the most promising pair of populations, for the whole set of material. Thus, the predicted means were estimated using the average of the population means (Hallauer and Miranda Filho, 1988). The phenotypic and genotypic coefficients of correlation were used here as a measure of the degree of association between traits, and were calculated according to Vencovsky and BARRIGA (1992).

RESULTS AND DISCUSSION

The means of the exotic populations showed a differential performance for all traits (Table II). The exotic means were greater than the check means for KW, EL, and KR. The check was very uniform, with plant architecture of the modern hybrids, i.e., low plant and ear height and low tassel branch number.

Tropical maize cultivars generally produce tall plants, with ears placed in the upper part of the plant. Such characteristics contribute to lodging susceptibility (Miranda Filho, 1985; Paterniani, 1990). Consequently, ear placement (EH/PH) is a useful trait in maize breeding for tropical areas, and it is not expected to be highly affected by environmental conditions because it is a relative value (Miranda Filho, 1992). The observed means for populations P-9, P-10, P-12, and P-13 showed values smaller than the check (Table II), indicating that these materials may contribute to lower the ear placement height in local populations. The population P-9 showed the same trend (EH/PH = 0.40) in a previous evaluation at the same location (Miranda Filho, 1992).

Another trait of interest is the tassel branch number (TB) which has been associated with plant efficiency. Some studies have shown that smaller tassels are favorable for higher grain yield, mainly under adverse conditions (Buren *et al.*, 1974; Mock and Schuetz, 1974). A survey carried out by Paterniani (1981) indicated a significant correlation between tassel branch number

Table I - Designation of 20 exotic maize populations and their origins.

Population	Original designation	Germplasm origin
P-1	BSSS-S2(S)C2	Temperate
P-2	Corn Belt x Brazilian Syn	Temperate x tropical
P-3	Early x Colombian	Temperate x tropical
P-4	BSSS(R)C7	Temperate
P-5	Corn Belt x Mexican Syn	Temperate x tropical
P-6	Corn Belt x Caribbean	Temperate x tropical
P-7	BS8 x SK (Kitale)	Temperate x tropical
P-8	Colus 71-428-612	Temperate
P-9	(BS-10 x BS-14) x Antigua 2D	Temperate x tropical
P-10	Corn Belt Composite x IDRN	Temperate x tropical
P-11	BS2(NS)C3	Temperate
P-12	Arg CD Syn6	Temperate
P-13	PCM-4 Syn6	Temperate
P-14	Alequat C1 Syn6	Temperate
P-15	Arg AC Syn6	Temperate
P-16	Thick Rind 76-1677-1768	Temperate
P-17	883 Z 045	Temperate
P-18	AG32 x W117	Temperate
P-19	LG11	Temperate
P-20	882 Z 103	Temperate

Table II - Means of eight traits in 20 maize populations and check.

Populations	Traits								
	PH	EH	TB	KW	EL	ED	KR	RN	EH/PH
P-1	160.5	81.5	10.2	18.7	13.6	3.8	29.6	12.8	0.51
P-2	173.5	96.5	19.3	19.7	15.8	3.8	34.0	14.0	0.57
P-3	178.5	89.0	20.0	25.3	15.7	3.9	27.7	13.4	0.50
P-4	206.5	107.5	16.1	30.4	17.5	4.7	35.0	13.0	0.52
P-5	196.0	102.0	18.1	22.3	17.5	4.0	36.3	13.6	0.52
P-6	169.5	88.0	16.1	19.9	14.3	3.9	30.8	12.6	0.52
P-7	162.0	85.5	17.5	23.0	17.3	3.8	37.2	13.2	0.53
P-8	156.5	83.0	18.9	21.8	13.4	3.8	29.7	12.9	0.53
P-9	156.5	67.0	10.9	18.3	15.2	4.4	31.2	14.9	0.43
P-10	168.5	78.0	15.2	18.6	12.0	3.6	30.0	12.5	0.46
P-11	171.0	92.0	20.8	26.3	14.4	4.3	31.4	13.5	0.54
P-12	173.0	85.5	21.3	25.6	17.0	4.4	36.7	14.4	0.49
P-13	156.5	75.0	15.0	21.3	15.8	3.9	32.9	12.7	0.48
P-14	150.5	78.0	17.9	18.4	14.0	3.7	30.0	12.8	0.52
P-15	191.0	99.0	17.1	23.4	17.1	4.2	34.5	12.8	0.52
P-16	223.0	126.0	24.0	28.4	17.2	4.2	36.9	13.0	0.57
P-17	219.0	124.5	23.2	23.3	17.6	4.2	38.6	14.0	0.57
P-18	219.5	122.0	24.5	29.5	18.2	4.5	39.1	13.4	0.56
P-19	228.5	128.5	26.8	28.0	18.2	4.0	38.6	11.6	0.56
P-20	223.0	125.0	23.9	22.3	18.2	4.1	38.6	12.8	0.56
P - Mean	184.2	96.7	18.8	23.2	16.0	4.1	33.9	13.2	0.52
Check	144.5	72.8	9.5	21.7	12.8	4.1	24.7	13.6	0.54
% (check)	127.5	132.8	197.9	106.9	125.0	100.0	137.3	97.0	96.3
Brazilian Populations	233.5 (44)*	136.0 (42)	22.1 (12)	26.8 (21)	16.8 (18)	4.4 (19)	30.9 (27)	12.8 (29)	0.58

*Number of estimates at Piracicaba, SP, Brazil (estimates compiled specially for comparisons in this paper).

PH: plant height, EH: ear height, TB: tassel branch number, KW: 100 kernels weight, EL: ear length, ED: ear diameter, KR: kernels per row, and RN: number of rows of kernels.

and ear placement (EH/PH). The mean of exotic populations was twice the check mean for TB, however P-1 and P-9 showed good performance for this trait. The potential of both populations to reduce TB was also observed by Miranda Filho (1992).

Highly significant ($P < 0.01$) differences were detected for all traits among populations and exotics, except for KR and RN (Table III). The mean squares of PH, EH, and TB, traits closely related to plant architecture, showed significance for all sources of variation. The significant differences among exotic populations were expected, because they originally had different proportions of tropical and temperate germplasm and have undergone selection under temperate conditions.

Association between two characteristics can be evaluated by phenotypic, genotypic, and environmental correlations (Falconer, 1989). The nature of the correlations and their magnitudes are very important in breeding programs, because these estimates quantify

the possibilities of indirect gain by selection on correlated characters. This depends on estimates of heritabilities for each trait and genetic correlations between them (Hallauer and Miranda Filho, 1988; Vencovsky and BARRIGA, 1992).

The correlation coefficients (Table IV) were expected to be high and positive due to the differential adaptation among the populations, with all traits showing the same degree of adaptation within a population. The phenotypic correlations indicate a positive association for most combinations of traits, except for RN with PH, EH, TB, and KW. The estimates of correlation coefficients were, for most of the traits, smaller than those observed in a similar evaluation at Piracicaba, SP (Miranda Filho, 1992).

The genotypic correlations were greater than the phenotypic correlations, except for association between ED-KW, RN-ED, and RN-KR. For RN-ED the estimates were equal. Because we dealt with a fixed set

Table III - Mean squares, means and coefficients of variation (CV%) for eight traits in 20 maize populations.

Source	d.f.	Mean square							
		PH	EH	TB ¹	KW ¹	EL ²	ED ³	KR ¹	RN ²
Populations (P)	20	1501.2**	765.8**	448.1**	281.6**	750.0**	161.6**	338.6*	105.2 ^{ns}
Exotics	19	1422.6**	748.7**	384.3**	294.2**	689.8**	169.8**	270.9*	108.6 ^{ns}
P-I	8	628.8**	289.2*	251.4**	290.0*	519.5*	197.6**	222.1 ^{ns}	100.4 ^{ns}
P-II	10	1813.0**	992.7**	325.2**	288.8**	839.8**	155.4**	258.6 ^{ns}	115.3 ^{ns}
P-I vs. P-II	1	3868.5**	1984.0**	2038.2**	381.2*	552.4 ^{ns}	90.8 ^{ns}	784.8*	107.5 ^{ns}
P vs. check	1	2994.5**	1090.3**	1661.6**	42.5 ^{ns}	1893.0**	7.2 ^{ns}	1624.0**	39.6 ^{ns}
Error	20	128.4	117.4	63.1	83.4	147.7	44.8	133.0	57.8
Mean		184.2	96.7	18.8	23.2	16.0	4.1	33.9	13.2
CV%		6.3	11.4	13.7	12.7	7.8	5.3	11.0	5.9

^{1, 2, 3}Mean squares were multiplied by 10, 10² and 10³, respectively.

*, **, ^{ns}Significance level at P < 0.05, P < 0.01 and non-significant, respectively.

For abbreviations see Table II.

Table IV - Phenotypic (above diagonal) and genotypic (below diagonal) correlations between combinations of eight traits in 20 maize populations.

Traits	PH	EH	TB	KW	EL	ED	KR	RN
PH	1.00	0.97	0.74	0.69	0.76	0.49	0.77	-0.19
EH	1.00	1.00	0.81	0.67	0.74	0.40	0.77	-0.23
TB	0.77	0.85	1.00	0.64	0.60	0.23	0.65	-0.16
KW	0.86	0.93	0.83	1.00	0.65	0.70	0.54	-0.10
EL	0.86	0.88	0.72	0.79	1.00	0.56	0.88	0.10
ED	0.58	0.53	0.28	0.65	0.63	1.00	0.46	0.38
KR	1.11	1.20	1.09	0.83	0.94	0.64	1.00	0.03
RN	-0.45	-0.49	-0.50	-0.46	0.10	0.33	0.01	1.00

For abbreviations see Table II.

of genetic material, the genotypic correlation coefficients were limited for these populations. Furthermore, genotypic correlations inherently have large errors, because these estimates were obtained using components of variance and covariance calculated from the analysis of variance and covariances (Hallauer and Miranda Filho, 1988).

Composite populations have been widely used as base populations in many breeding programs. The number of possible composites using 20 populations would exceed a million different combinations, considering only equal contribution of the parental varieties (Vencovsky and Barriga, 1992). For tropical maize breeding, there is interest in joining populations with desired agronomic characteristics, such as low plant or ear height or smaller tassels. This could be achieved by selection among parental varieties (Hallauer and Miranda Filho, 1988), combining only elite varieties in the composite formation.

We used traits with heritability ranging from medium to high (Geraldi *et al.*, 1985; Hallauer and Miranda Filho, 1988). Non-additive gene effects are less important in their expression for these traits and heterosis is generally of a low magnitude (Miranda Filho, 1992). Predictions can be drawn based on a hypothetical model, considering absence of heterosis. The evolution of the predicted composite means, for each trait, as a consequence of the increasing number of varieties involved in the synthesis, starting from the most promising pair of populations, was investigated (Figure 1).

Selection of parental varieties could be effective in moving the composite mean towards a desired level, but in some instances using just a few populations in the synthesis would not generate enough variability in other important traits, such as production or seed weight. When P-9 participates in the starting pair of populations (see Table II), a very acceptable mean is ensured for PH, EH, TB, and RN in the composite (Figure 1). In addition, other populations were outstanding as source of genes for desirable traits, i.e., lower plant height (P-14 and P-9), lower ear height (P-9 and P-13), smaller tassels (P-1 and P-9), longer ears (P-18, P-19 and P-20), thicker ears (P-4 and P-18), larger number of kernel rows (P-9 and P-12), larger number of kernels per row (P-18 and P-20), and grain weight (P-4 and P-12).

Currently, the introduction of exotic populations is aimed at the introgression of desirable alleles into local varieties and not exclusively for synthesis of composites among the exotics. Our predictions of composite means (Figure 1) may serve as a guide for both purposes.

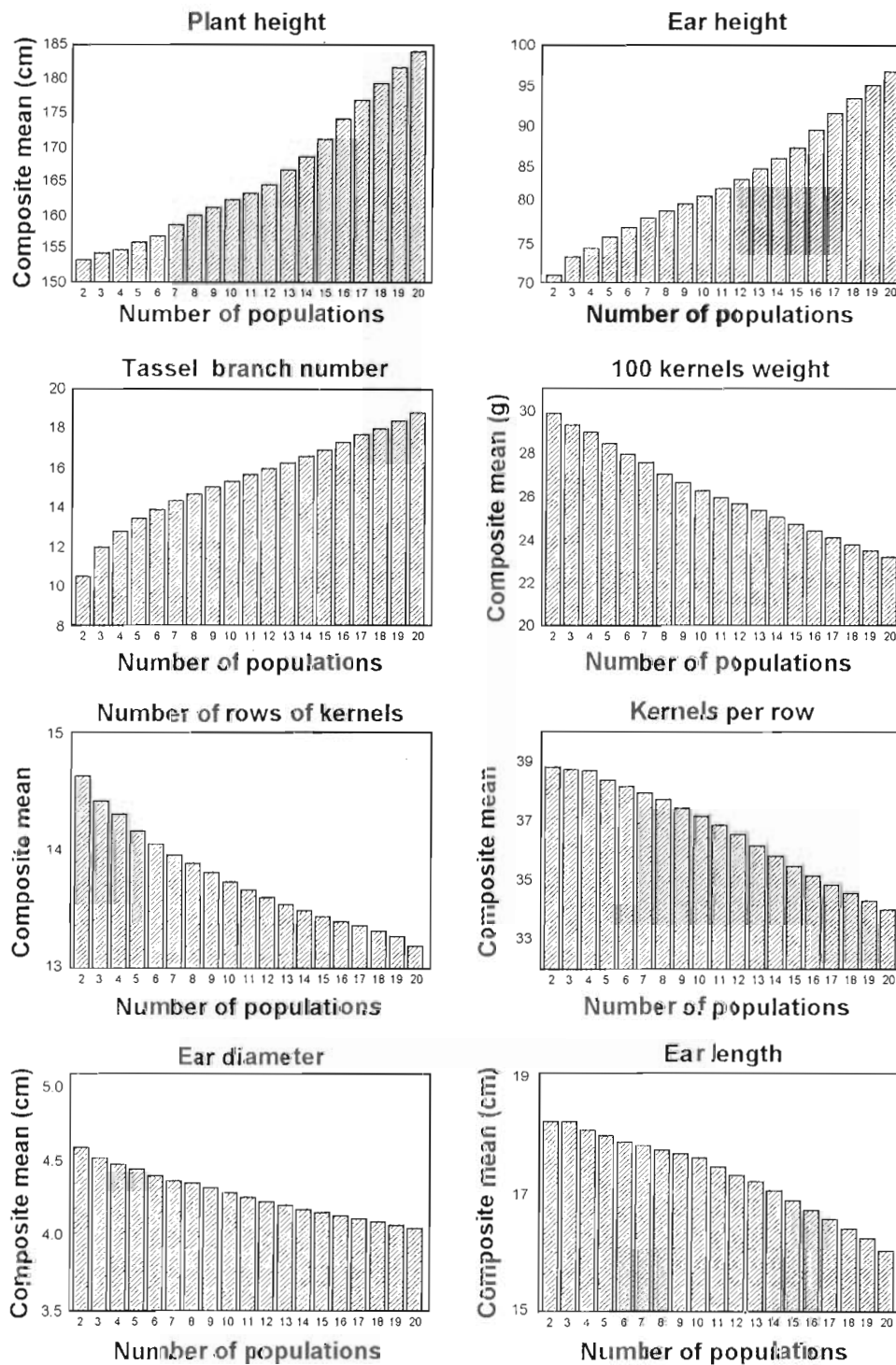


Figure 1 - Prediction of composite means with different numbers of populations.

ACKNOWLEDGMENTS

Publication supported by FAPESP.

RESUMO

Vinte populações de milho foram introduzidas dos Estados Unidos, representando germoplasmas originários de

clima temperado e tropical x temperado. As populações e uma testemunha foram avaliadas na área experimental do Departamento de Genética (ESALQ/USP) em experimento em blocos casualizados com duas repetições. Os seguintes caracteres foram avaliados: altura da planta (PH), altura da espiga (EH), número de ramificações do pendão (TB), peso de 100 grãos (KW), comprimento da espiga (EL), diâmetro da espiga (ED), número de grãos por fileira (KR) e número de fileiras de grãos (RN). A variação observada nas médias das

populações exóticas para todos os caracteres foi devida à adaptação diferenciada desses genótipos no ambiente estudado. As populações exóticas apresentaram médias superiores à testemunha para peso de 100 grãos, comprimento da espiga e número de grãos por fileira. As populações P-9, P-10, P-12 e P-13 mostraram baixos valores para posição relativa da espiga, sendo consideradas promissoras para reduzir esse índice nas populações locais. P-1 e P-9 são indicadas para diminuir o número de ramificações do pendão. Os coeficientes de correlação fenotípica entre populações foram positivos para todas as combinações, exceto para número de fileiras de grãos com altura da planta, altura da espiga, número de ramificações do pendão e peso de 100 grãos. Algumas populações exóticas apresentaram elevado potencial para contribuir no melhoramento da arquitetura das plantas em populações adaptadas. Foram obtidas predições de médias de 19 compostos, para os oito caracteres, envolvendo as populações exóticas estudadas.

REFERENCES

- Brown, W.L. and Goodman, M.M.** (1977). Races of maize. In: *Corn and Corn Improvement* (Sprague, G.F., ed.). Am. Soc. Agron. Madison, Wisconsin, pp. 49.
- Buren, L.L., Mock, J.J. and Anderson, I.C.** (1974). Morphological and physiological traits in maize associated with tolerance to high plant density. *Crop Sci.* 14: 426-429.
- Duvick, D.N.** (1984). Genetic diversity in major crops on the farm and in reserve. *Econ. Bot.* 38: 61-178.
- Falconer, D.S.** (1989). *Introduction to Quantitative Genetics*. 3rd edn. Longman Inc., New York, pp. 340.
- Geraldi, I.O., Miranda Filho, J.B. and Vencovsky, R.** (1985). Estimates of genetic parameters for tassel characters in maize (*Zea mays* L.) and breeding perspectives. *Maydica* 30: 1-14.
- Hallauer, A.R.** (1978). Potential of exotic germplasm for maize improvement. In: *Maize Genetics and Breeding* (Walden, W.L., ed.). John Wiley & Sons, New York, pp. 229.
- Hallauer, A.R. and Miranda Filho, J.B.** (1988). *Quantitative Genetics in Maize Breeding*. 2nd edn. Iowa State Univ. Press, Ames, Iowa, pp. 468.
- Lima, M., Gimenes-Fernandes, N., Miranda Filho, J.B. and Pereira, J.C.V.A.** (1982). Introduction of maize (*Zea mays* L.) germplasms as sources for downy mildew (*Peronosclerospora sorghi*) resistance. *Maydica* 27: 159-168.
- Magnavaca, R., Oliveira, A.C., Morais, A.R., Gama, E.E.G. and Santos, M.X.** (1989). Family hybrid selection of quality protein maize (*Zea mays* L.). *Maydica* 34: 63-71.
- Miranda Filho, J.B.** (1985). Breeding methodologies for tropical maize. In: *Breeding Strategies for Maize Production Improvement in the Tropics* (Brandolini, A. and Salamini, F., eds.). Bergamo, Italy, pp. 177.
- Miranda Filho, J.B.** (1992). Exotic germplasms introduced in a Brazilian maize breeding program. *Braz. J. Genet.* 15: 631-642.
- Miranda Filho, J.B. and Vencovsky, R.** (1984). Analysis of diallel crosses among open-pollinated varieties of maize (*Zea mays* L.). *Maydica* 29: 217-234.
- Mock, J.J. and Schuetz, S.H.** (1974). Inheritance of tassel branch number in maize. *Crop Sci.* 14: 885-888.
- Moro, J.R., Napolini Filho, V., Vianna, R.T. and Gama, E.E.G.** (1981). Introdução de novos germoplasmas de milho no Brasil. *Pesq. Agrop. Bras.* 16: 867-882.
- Paterniani, E.** (1981). Influence of tassel size on ear placement in maize (*Zea mays* L.). *Maydica* 26: 85-91.
- Paterniani, E.** (1990). Maize breeding in the tropics. *Crit. Rev. Plant Sci.* 9: 125-154.
- Paterniani, E.** (1993). Métodos tradicionais de melhoramento do milho. In: *Cultura do Milho: Fatores que Afetam a Produtividade* (Bull, L.T. and Cantarella, H., eds.). Potafos, Piracicaba, pp. 23.
- Vencovsky, R. and Barriga, P.** (1992). *Genética Biométrica no Fitomelhoramento*. Sociedade Brasileira de Genética, Ribeirão Preto, pp. 496.
- Wellhausen, E.J.** (1956). Improving American corn with exotic germplasm. *Proc. Annu. Hybrid Corn Ind. Res. Conf.* 11: 85-96.
- Wellhausen, E.J.** (1965). Exotic germplasm for improvement of Corn Belt maize. *Proc. Annu. Hybrid Corn Ind. Res. Conf.* 20: 31-45.

(Received April 18, 1997)