QUANTITATIVE DESCRIPTORS AND THEIR DIRECT AND INDIRECT EFFECTS ON CORN YIELD

DESCRITORES QUANTITATIVOS E SEUS EFEITOS DIRETOS E INDIRETOS NA PRODUTIVIDADE DO MILHO

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ABSTRACT: The objective of this study was to evaluate the direct and indirect effects of ten quantitative descriptors of agronomic importance in productivity of 25 maize hybrids and their respective influences of heritability. The experiment in randomized blocks with four replications, was conducted in 2010/2011 crop in a soil under humid subtropical climate. The quantitative descriptors were: ear length, ear diameter, cob diameter, number of rows of grains, stem diameter, plant height, ear height, weight of 100 grains, grain weight per ear and number of grains per ear. The grain weight per ear and ear length showed high correlation with grain yield, and the descriptors with the highest potential for selecting superior genotypes and showing high heritability.

KEYWORDS: Correlation. Path analysis. *Zea mays.*

INTRODUCTION

The protein demand growth reflects on the impulse in the corn production (*Zea mays* L.), which justifies the increases in the production of the culture, a fact that is also conditioned by genetic advances (LAURIE et al., 2004). Corn has been undergoing constant evolution in relation to levels of income, and in Brazil, in 2010, there was increased production of about 10% (CONAB, 2010).

Productivity is a complex character, and influenced by many characters and controlled by multiple factors that interact with genotypes and environmental conditions (ALLARD, 1971; KASHIANI et al. 2010; ZILIO et al. 2011). For expression of high levels of production, the corn crop depends, in addition to proper management techniques, the interaction of genetic material, with the soil and climatic conditions (DUVICK, 2005). In corn, variations in the choice of cultivar and the interactions with the environment may represent half of the productivity (CRUZ, et al., 2005).

Studies evaluating direct and indirect effects on yield components associated with the heritability, can significantly improve the efficiency of breeding programs through the selection indices (KASHIANI et al., 2010). Moreover, when heritability is considered low, the use of correlations between the characteristics may applied to improve the selections, especially when they are difficult to be measured (MALOSETTI et al., 2008).

The path analysis proposed by Wright (1921), is the most usual tool to establish the exact correlation in terms of cause and effect, providing direct relations, which is the causal effect, and indirect relations, intermediated by one or more independent variables. The inter-relations between the yield components instead of morphological characteristics can, through the linear relation, obstruct the importance of the direct effects and especially indirect in the production components in the corn culture (CARVALHO et al., 2004).

The corn crop does not have effective compensatory feature, Barros (1998) states that the ear length has little contribution to the determination of income, being a secondary factor for the estimation of productivity, and particular to each genotype (LOPES et al., 2007). In addition, work is needed to deepen the understanding of the cause and effect on yield in corn, especially when it is considered a large number of hybrids and with different purposes. The objective was to evaluate the yield of 25 corn hybrids through direct and indirect effects of ten quantitative descriptors of agronomic importance and the respective influences of heritability for selection factors.

MATERIALS AND METHODS

The study was conducted in an experimental area in the town of Guarani das Missões, Mission region of Rio Grande do Sul, whose location is: latitude 28 ° 08'27 "south, longitude 54° 33'29" west

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and average elevation of 267 meters. The climate is mesothermal humid Cfa type (KOPPEN, 1948) and the predominant soil is sandy clay loam soil (EMBRAPA, 2006). We evaluated 25 corn hybrids grown in a randomized block design with four replications. The scaling of the plots was 5.6 x 5 m, behaving then, eight lines of crop spaced 0.7 m. The tillage was performed in the first ten days of August 2010, seeking final population of 60,000 plants ha^{-1}. The basic fertilization was performed according to the characteristics of soil (clay content: 58 %, pH 5.7, SMP: 6.3, P: 4.2 mg L^{-1}, K: 95 mg L^{-1}, MO: 28 g dm^{-3}; CTC: 19.43 cmolc L^{-1}, base saturation: 83.4 %), and recommendations of the Commission ... (2004) , so that there were used 250kg ha^{-1} of a mineral formulation 5-20-20. There were also two applications of nitrogen, at a dose of 60 kg ha^{-1} each, in the vegetative stages V4 and V6. For weed control herbicides used were the basis of atrazine and nicosulfuron, and pest control, insecticide chlorpyriphos and cypermethrin.

In the twelve central plants in each plot were evaluated following qualitative descriptors: stem diameter (SD), 10 cm of the soil surface, plant height (PH), the soil surface to the insertion of the tassel, height of ear insertion (HEI), the soil surface to the ear, ear diameter (ED), at the middle portion of the ear, cob diameter (CD), in the middle portion of cob, ear length (CL), number of rows of grains (NRG), grain weight per ear (GWE) - average mass of 16 ears, number of grains per ear (NGE) - average of the mass 100 grains and grain weight per ear, grain weight of 100 (W100), grain yield (YIELD) - in 20 plants in the plot, corrected to 13% moisture.

The results were submitted to variance analysis and correlation of Person to 5% probability of error and means were compared by Scott Knott test for estimates of heritability (SCOTT, KNOTT, 1974) and stratification between the associations of characters, was applied to path analysis (WRIGHT, 1921) with respect to productivity.

RESULTS AND DISCUSSION

The phenotypic relationships (Table 1) are explained in general, through the simultaneous effect on two genes of a character. It is observed that there was high agreement in the magnitude of association between PH and HEI, as well as in relation to the CD and ED. This result represents the effective selection of materials with reduced size and increased ear length, moreover, these descriptors have high heritability, not hindering the selection process.

Table 1. Phenotypic relationship between variables in 25 corn hybrids and heritability, genetic variation and environmental. Guarani das Missões – RS, 2010/2011.

	SD	PH	HEI	ED	CD	CL	NRG	GWE	NGE	W100	YIELD
SD	1	0.07	0.43	-0.21	-0.03	0.08	-0.31	-0.21	-0.41	0.3	-0.49
PH		1	0.65	0.13	-0.21	0.37	0.21	0.47	0.41	0.13	0.28
HEI			1	0.2	-0.11	0.59	-0.08	0.37	0.13	0.35	0.04
ED				1	0.59	0.15	0.78	0.45	0.57	-0.18	0.34
CD					1	-0.14	0.34	-0.24	-0.09	-0.23	-0.15
CL						1	0.01	0.48	0.27	0.32	0.31
NRG							1	0.36	0.73	-0.57	0.36
GWE								1	0.79	0.32	0.77
NGE									1	-0.3	0.7
W100										1	0.09
YIELD											1
h^2 (%)	55.12	95.75	88.12	93.54	86.7	86.71	76.01	98.43	97.34	95.78	43.21
CVg	5.59	9.53	9.38	4.92	9.22	6.74	9.01	12.69	13.1	7.97	12.6
CVg/Cve	0.55	2.48	1.35	1.88	1.27	1.27	0.89	1.12	3.85	2.38	1.28

Note: variables: diameter stem (mm SD), plant height and ear insertion height (m PH and IEA), cob diameter and ear diameter (mm ED and CD), ear length (cm CL) number of rows of grains (NRG), number of grains per ear (NGE), mass per ear (GWE g), weight of 100 grains (W100 g), grain yield (YIELD kg ha^{-1}), h^2 (heritability), CVg (coefficient of genetic variation), CVe (coefficient of environmental variation).

High association was found between the descriptor NGE both with productivity, as with the mass of grains per ear, and the latter is also related to productivity. This shows that the largest number of grains, provides greater mass of grains per ear, which is reflected in higher yields in corn, regardless of the weight of 100 grains.

The high heritability characters found in GWE, NGE and W100, also resulted in high values of the relationship between genetic and environmental variation, making the criteria more appropriate to result in appropriate selections. These criteria demonstrate the genetic variability available in the population, and reliability parameters of the data. This is because the low heritability tends to impede the selection of materials for the great environmental influence (CRUZ et al., 2005). However, if an indirect character has a high heritability and is correlated with the variable of interest with low heritability, indirectly facilitates the selection criteria (KUREK et al., 2001).

Regarding productivity, the heritability was low (43%), probably due to the fact that this variable is influenced by several factors (RAMALHO et al., 1993). In a study of 15 maize cultivars, Wannows et al. (2010) observed low heritability for grain yield (39%), while the remaining variables have shown high values. Faluba et al. (2010), in a study with the same culture, ascertained values close to those obtained in this study as the heritability. Although the authors observe the genetic variation and environmental (CVg/CVe) for plant height, lower than those investigated.

Through the verification path analysis the variable with the greatest influence among the ten characters was the GWE, as it presented greater direct effect on YIELD (0.70) furthermore, this descriptor provided more indirect effect for the other variables. Although there weren't negative indirect effect of NGE and W100 (-0.20 and -0.32), these, did not result in represented effects, being disregarding the effects (Table 2).

In a study on corn in the path analysis, Nemati et al. (2009), report that the mass of ear has direct effect on crop productivity. According to the authors, this occurs due to increased uptake and translocation of assimilates to consecutive increasing the mass of grain in the ear. Likewise, Bello et al. (2010) observed a major direct effect of this variable in the production of maize, followed by the number of grains per ear, with index of 0.58 and 0.52, respectively.

The variable CL, beyond the simple positive correlation, took full effect in the same proportion, being little affected by indirect effects, except for GWE. Likewise, on a path analysis of 11 maize hybrids, Samonte et al. (2005) observed that the variables that were most related to grain yield were ear length and grain weight per ear. These characteristics are the main determinants of productivity, and can provide 82% variation in maize, while other portions are unknown (ZIREHZADEH et al . , 2011).

There was a direct negative effect on the variable NGE in YIELD, although totalized ratio was of 0.7 (Table 2). This was due to the indirect effect of GWE , 0.9. In analysis with open pollinated varieties of corn in path analysis, Balbinot Junior et al. (2005), ascertained that the number of kernels per row was the component most associated with productivity. Partially corroborating data, Kumar and Kumar (2000), suggest indirect selection for yield of maize by the number of rows per ear.

Table 2. Path analysis between eleven components of yield in 25 maize hybrids. Guarani das Missões - RS 2010/2011.

FV	Pathway	P	FV	Pathway	p	FV	Pathway	P
SD	Direct effect YIELD	-0.01	PH	Direct effect YIELD	0.05	HEI	Direct effect YIELD	-0.17
	Indirect effect PH	0.03		Indirect effect SD	-0.02		Indirect effect SD	-0.11
	Indirect effect HEI	-0.07		Indirect effect HEI	-0.11		Indirect effect PH	0.03
	Indirect effect ED	-0.23		Indirect effect ED	-0.02		Indirect effect ED	-0.03
	Indirect effect CD	0.04		Indirect effect CD	-0.02		Indirect effect CD	-0.01
	Indirect effect CL	0.05		Indirect effect CL	0.02		Indirect effect CL	0.04
	Indirect effect NRG	0.02		Indirect effect NRG	-0.01		Indirect effect NRG	0.04
	Indirect effect GWE	-0.24		Indirect effect GWE	0.55		Indirect effect GWE	0.43
	Indirect effect NGE	0.13		Indirect effect NGE	-0.13		Indirect effect NGE	-0.04

	Indirect effect W100	-0.08		Indirect effect W100	-0.03		Indirect effectW100	-0.09
	TOTAL	-0.49		TOTAL	0.28		TOTAL	0.04
	Direct effect YIELD	-0.16		Direct effect YIELD	0.12		Direct effect YIELD	0.06
	Indirect effect SD	0.05		Indirect effect SD	0.01		Indirect effect SD	-0.02
	Indirect effect PH	0.01		Indirect effect PH	-0.01		Indirect effect PH	0.02
	Indirect effect HEI	-0.03		Indirect effect HEI	0.02		Indirect effect HEI	-0.10
	Indirect effect CD	0.07		Indirect effect ED	-0.09		Indirect effect ED	-0.02
ED	Indirect effect CL	0.01	CD	Indirect effect CL	-0.09	CL	Indirect effect CD	-0.02
	Indirect effect NRG	0.04		Indirect effect NRG	-0.02		Indirect effect NRG	-0.01
	Indirect effect GWE	0.53		Indirect effect GWE	-0.28		Indirect effect GWE	0.56
	Indirect effect NGE	-0.19		Indirect effect NGE	0.03		Indirect effect NGE	-0.09
	Indirect effect W100	0.05		Indirect effect W100	0.06		Indirect effect W100	-0.09
	TOTAL	0.34		TOTAL	-0.15		TOTAL	0.31
	Direct effect YIELD	-0.06		Direct effect YIELD	0.7		Direct effect YIELD	-0.33
	Indirect effect SD	0.08		Indirect effect SD	0.05		Indirect effect SD	0.1
	Indirect effect PH	0.01		Indirect effect PH	0.02		Indirect effect PH	0.04
	Indirect effect HEI	0.01		Indirect effect HEI	-0.06		Indirect effect HEI	-0.02
	Indirect effect ED	-0.12		Indirect effect ED	-0.07		Indirect effect ED	-0.09
NRG	Indirect effect CD	0.04	GWE	Indirect effect CD	-0.03	NGE	Indirect effect CD	-0.02
	Indirect effect CL	0.01		Indirect effect CL	0.4		Indirect effect CL	0.03
	Indirect effect GWE	0.42		Indirect effect NRG	-0.02		Indirect effect NRG	-0.01
	Indirect effect NGE	-0.24		Indirect effect NGE	-0.2		Indirect effect GWE	0.9
	Indirect effect W100	0.16		Indirect effect W100	-0.04		Indirect effect W100	0.09
	TOTAL	0.36		TOTAL	0.77		TOTAL	0.7
	Direct effect YIELD	-0.28		Indirect effect ED	0.02		Indirect effect GWE	0.37
	Indirect effect SD	-0.07		Indirect effect CD	-0.09		Indirect effect NGE	0.1
W100	Indirect effect PH	0.01	W100	Indirect effect CL	0.021	W100	TOTAL	0.09
	Indirect effect HEI	-0.05		Indirect effect NRG	0.03			

Note: variables: diameter stem (mm SD), plant height and ear insertion height (m PH and IEA), cob diameter and ear diameter (mm ED and CD), ear length (cm CL) number of rows of grains (NRG), number of grains per ear (NGE), mass per ear (GWE g), weight of 100 grains (W100 g), yield (YIELD kg ha^{-1}).

Another character that showed negative relationship with YIELD was the W100 (-0.29), although it has totalized positive effect indirectly caused by GWE. The data confirm the study by Nemati et al. (2009), which observe that the thousand grain weight showed a negative effect on the yield of corn being more influenced by indirect character. On the other hand, Prakash et al. (2006) and Rafiq et al. (2010) observed that productivity was directly correlated with the weight of 100 grains, although they noted the number of rows of grains and ear length with a significant relationship.

Despite the high correlation between GWE and NGE, indirect effect occurs with YIELD, as GWE suffers indirect negative effect by NGE, there is an interdependence between the characters. Thus, it can be stated that the selection for more productive hybrids may be preceded by the selection of the MSA, despite the negative indirect effect of NGE. The simple correlation, although unusual, has shown similarities in the specific outcomes between direct and indirect components obtained through path analysis in maize hybrids (IVANOV et al., 2007).

By analyzing the relationship between NRG and YIELD, it appears that there was the same pattern of effect to most of the variables. The direct effect was virtually nonexistent, however, will amount to 0.36, which arises from the GWE (0.42), despite the negative inference of NGE. Other authors observed positive effect of the number of rows of grains in grain yield (ALVI et al., 2003; SRECKOV et al., 2011). Sumathi et al. (2005), observed negative influence of high productivity, reporting the change in plant architecture of modern materials.

In general, the high coefficient of determination of path analysis (0.85) and low effect of the residual variable (0.29) show that there was intense relationship of cause and effect between variables and their relationships with grain yield.

CONCLUSION

The descriptors number of grains per ear (NGE) and mass per ear (GWE), resulted ib high heritability and relationship to grain yeld, making them the descriptors with the highest potential for graind yield.

RESUMO: O objetivo do trabalho foi avaliar o efeito direto e indireto de dez descritores quantitativos de importância agronômica na produtividade de 25 híbridos de milho, bem como suas respectivas influências de herdabilidade. O experimento em blocos casualisados com quatro repetições, foi conduzido na safra 2010/2011 em Latossolo Vermelho distrófico, sob clima subtropical úmido. Os descritores quantitativos avaliados foram: comprimento de espiga, diâmetro de espiga, diâmetro de sabugo, número de fileira de grãos, diâmetro do colo, altura da planta, altura de inserção da espiga, massa de 100 grãos, massa de grãos por espiga e número de grãos por espiga. A massa de grãos por espiga e o comprimento da espiga apresentaram alta relação com a produtividade de grãos, sendo os descritores com maior potencial para a seleção de genótipos superiores e apresentando altas herdabilidades.

PALAVRAS-CHAVE: Correlação. Análise de trilha. *Zea mays.*

REFERENCES

ALLARD, R. W. **Princípios do melhoramento genético de plantas**. São Paulo: Edgard Lucher, 1971. 381 p.

ALVI, M. B.; RAFIQUE, M.; TARIQ, M. S.; HUSSAIN, A.; MAHMOOD, T.; SARWAR, M.. Character Association and Path Coefficient Analysis of Grain Yield and Yield Components Maize (*Zea mays* L.) **Pakistan Journal of Biological Sciences**, Faisalabad, v. 6, n. 2, p. 136-138, 2003.

BALBINOT JÚNIOR, A. A.; BACKES, R. L.; ALVES, A. C.; OGLIARI, J. B. FONSECA, J. A. Contribuição de componentes de rendimento na produtividade de grãos em variedades de polinização aberta de milho. **Revista Brasileira de Agrociência,** Pelotas, v. 11, n. 2, p. 161-166, 2005.

BARROS, A. H. C. **Análise de crescimento, do desenvolvimento e da produtividade da cultura de milho (*Zea mays* L.): Experimentos e modelos**. 1998. 85 f. Dissertação (Mestrado) – Universidade Federal de Viçosa, Viçosa.

BELLO, O. B.; ABDULMALIQ, S. Y.; AFOLABI, M. S.; IGE, S. A. Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F1 hybrids in a diallel cross. **African Journal of Biotechnology**, Nairobi v. 9, n. 18, p. 2633-2639, 2010.

CARVALHO, M. A. C.; SORATTO, R. P.; ATHAYDE, M. L. F.; ARF, O.; SÁ, M. E. Produtividade do milho em sucessão a adubos verdes no sistema de plantio direto e convencional. **Pesquisa Agropecuária Brasileira**, Brasília, v. 39, n. 1, p. 47-53, 2004.

COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO (CQFS RS/SC). **Manual de adubação e de calagem para os Estados do Rio Grande do Sul e Santa Catarina**. Porto Alegre: SBCS/Núcleo Regional Sul, 2004. 400 p.

CONAB. Companhia Nacional de Abastecimento. **Acompanhamento de safra brasileira**: grãos, sexto levantamento, março 2010 / Companhia Nacional de Abastecimento. – Brasília: Conab, 2010. Disponível em: <http://www.conab.gov.br/conabweb/ download/safra/06_levantamento_mar2010. pdf> Acesso em: 22 mar. 2011.

CRUZ, C. D.; REGAZZI, A. J.; CARNEIRO, P. C. S. **Modelos biométricos aplicados ao melhoramento genético**. 3. ed. Viçosa: UFV, 2005. 480 p.

DUVICK, D. N. The contribution of breeding to yield advances in maize (*Zea mays* L.), **Advances in Agronomy**, New York, v. 86, p. 83-145, 2005.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. Centro Nacional de Pesquisa de Solos - CNPS. **Sistema Brasileiro de Classificação de Solos**. Brasília: EMBRAPA-SP/EMBRAPA-CNPS, 2006. 412 p.

FALUBA, J. DE S.; MIRANDA, G. V.; DELIMA, R. O.; SOUZA, L. V. DE; DEBEM, E. A.; OLIVEIRA, A. M. C. Potencial genético da população de milho UFV 7 para o melhoramento em Minas Gerais. **Ciência Rural**, Santa Maria, v. 40, n. 6, p. 1250-1256, 2010.

IVANOV, V. R.; KRAPTCHEV, B.; NAIDENOVA, N.; NEDEV, T. Genotypic correlation and path-coefficient analysis of some productivity elements in sweet corn (*Zea mays* L.). **Comptes Rendus de L'Academie Bulgare des Sciences**, Sofia, v. 60, n. 9, p. 1011-1014, 2007.

KASHIANI, P.; SALEH, G. Estimation of genetic correlations on sweet corn inbred lines using SAS mixed model. **American journal of Agricultural and Biological Sciences**, New York, v. 5, p. 309-314, 2010.

KASHIANI, P.; SALEH, G.; ABDULLAH N. A. P.; ABDULLAH, S. N.. Variation and genetic studies on selected sweet corn inbred lines. **Asian Journal Crop Science**, Punjab, v. 2, p. 78-84, 2010.

KOPPEN, W. **Climatologia: con un Estudio de los Climas de la Tierra**. México: Fondo de Cultura Economica, 1948, 466 p.

KUMAR, M. V. N.; KUMAR, S. S.. Studies on character association and path coefficients for grain yield and oil content in maize (Zea mays L.). **Annals of Agricultural Research**, Ghaziabad, v. 21, p. 73-80, 2000.

KUREK, A.J.; CARVALHO, F.I.F. de; ASSMANN, I.C.; CRUZ, P.J. Capacidade combinatória como critério de eficiência na seleção de genitores em feijoeiro. **Pesquisa Agropecuária Brasileira**, Brasília, v. 36, p. 645-651, 2001.

LAURIE, C. C.; CHASALOW, S. D.; LEDEAUX, J. R.; CARROLLA, R. M. C.; BUSH, D.; HANGE, B.; LAI, C.; CLARK, D.; ROCHEFORD, T. R.; DUDLEY, J. W. The genetic architecture of response to long–term artificial selection for oil concentration in the maize kernel. **Genetics**, Bethesda, v. 168, p. 2141-2155, 2004.

LOPES, S. J.; DAL'COL, A. L.; STORCK, L.; DAMO, H. P.; BRUM, B.; SANTOS, V. J. Relações de causa e efeito em espigas de milho relacionadas aos tipos de híbridos. **Ciência Rural**, Santa Maria, v. 37, n. 6, p. 1536-1542, 2007.

MALOSETTI, M.; RIBAUT, J.; VARGAS, M.; CROSSA, J.; VAN EEUWIJK, F. A. A multi-environment QTL mixed model with an application to drought and nitrogen stress trials in maize (*Zea mays* L.). **Euphytica**, Wageningen, v. 161, p. 241-257, 2008**.**

NEMATI, A.; SEDGHI, M.; SHARIFI, R. S.; SEIEDI, M. N.. Investigation of correlation between traits and path analysis of corn (Zea mays L.) grain yield at the climate of ardabil region (Northwest Iran). **Notulae Botanicae Horti Agrobotanici Cluj-Napoca**, Cluj-Napoca, v. 37, n. 1, p. 194-198, 2009.

PRAKASH, O.; SHANTHI, P.; SATYANARAYANA, E.; KUMAR, R.S.. Studies on inter relationship and path analysis for yield improvement in sweet corn genotypes (*Zea mays* L.). **New Botanist,** New Delhi, v. 33, p. 91-98, 2006.

RAFIQ, C. M.; RAFIQUE, M.; HUSSAIN, A.; ALTAF, M. Heritability, correlation and path analysis in maize. **Journal of Agricultural Research**, Punjab, v. 48, n. 1, p. 35-38, 2010.

RAMALHO, M.A.P.; SANTOS, J.B.; ZIMMERMANN, M.J. de O. **Genética quantitativa em plantas autógamas: aplicações ao melhoramento genético do feijoeiro**. Goiânia: UFG, 1993. 271.

SAMONTE, S. O. P. B.; TAGLE, S. A. L.; LALES, J. S.; VILLEGAS, G. M.; RAMOS, E. A. Path analysis of traits affecting grain yield and its components in corn. **Philippine Agricultural Scientist**, Laguna, v. 88, n. 4, p. 400-407, 2005.

SCOTT, A. J.; KNOTT, M. A cluster analyses method for grouping mean in the analyses of variance. **Biometrics**, Arlington, v. 130, p. 507-512, 1974.

SRECKOV, Z.; NASTASIC, A.; BOCANSKI, J.; DJALOVIC, I.; VUKOSAVLJEV, M.; JOCKOVIC, B.. Correlation and path analysis of grain yield and morphological traits in test–cross populations of maize. **Pakistan Journal of Botany**, Karachi, v. 43, n. 3, p. 1729-1731, 2011.

SUMATHI, P.; NIRMALAKUMARI, A.; MOHANRAJ, K. Genetic variability and traits interrelationship studies in industrially utilized oil rich CYMMIT lines of maize (*Zea mays* L.).
The Madras Agricultural Journal, Tamil Nadu, v. 92, n. 10-12, p. 612-617, 2005.

WANNOWS, A. A.; AZZAM, H. K.; AL-AHMAD, S. A. Genetic variances, heritability, correlation and path coefficient analysis in yellow maize crosses (*Zea mays* L.). **Agriculture and Biology Journal of North America**, Mildford, v. 10, p. 630-637, 2010.

WRIGHT, S. Path coefficients and path regressions: alternative complementary concepts. **Biometric**, Arlington, v. 16, p. 189-202, 1921.

ZILIO, M.; COELHO, C. M. M.; SOUZA, C. A.; SANTOS, J. C. P.; MIQUELLUTI, D. J. Contribuição dos componentes de rendimento na produtividade de genótipos crioulos de feijão (*Phaseolus vulgaris* L.). **Revista Ciência Agronômica**, Ceará, v. 42, n. 2, p. 429-438, 2011.

ZIREHZADEH, M.; SHAHIN, M.; HEDAYA, N. Evaluation of correlation between morphophysiological characters in maize hybrids by Kernel yield using path analysis world academy of science. **Engineering and Technology**, [S.l.] v. 73, 2011.