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Correlations and path analysis of peanut traits associated with the peg

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ABSTRACT - *By correlation and path-coefficient analysis, the most relevant traits for selection for peanut pod yield were identified among the following: total number of pegs (TNP), number of pegs in the lower third of the plant (NPLTh), number of mature pods (NMP), main stem height (MSH), and reproductive efficiency (EF_1 and EF_2). The trial consisted of 15 $F_{2:3}$ progenies derived from a cross of variety BR 1 and the advanced line CNPA 280 AM, evaluated in a randomized block design with three replications. The lines with best reproductive efficiency were L.8 and L.11. Path analysis detected a strong direct effect of the number of pegs in the lower plant third on the number of mature pods. This finding justifies the use of the number of pegs in the lower plant third in selection of peanut populations for number of mature pods.*

Key words: *Arachis hypogaea*, reproductive efficiency, indirect selection.

INTRODUCTION

The cultivated peanut (*Arachis hypogaea* L.) is a herbaceous legume with a peculiar characteristic of the genus, which is underground formation of the fruit. The pods develop after flower pollination by means of a fibrous structure called gynophore or peg. The pegs, with positive geotropism, emerge after four to seven days and grow downwards, until they penetrate the soil to develop the pod (Santos et al. 2000).

Effective peanut yield is largely dependent on the flowering period and viability of the pegs. Since they grow on all plant stems, the peg length differs. Some pegs cannot reach the soil surface growing a pod in due time since they are too distant from the surface or since there is not time enough, because of the uninterrupted cycle of flowering beginning between 25 and 30 days after emergence, continuing until the end of the cycle. According to some authors, about 30% of the pods that do not reach the full maturity stage are lost at the end of the cycle (Santos and Godoy 1999, Santos et al. 2000).

In peanut breeding programs the selection of productive lines based on the phenotypic traits of pods is difficult since the fruits are hypogeal. Therefore, the choice of directly or indirectly yield-related traits is highly useful for breeders, particularly when working with divergent or segregating populations. Correlation analyses are useful in this regard since information on the nature and magnitude of interrelationships among traits is not only helpful to define the selection potential of an isolated trait but also detects the effects on one particular trait due to the selection for another (Cruz and Regazzi 1997). According to Santos et al. (2000), the importance of the correlations between traits in genetic improvement lies in the fact that they show how the alteration in one trait can affect others during selection. However,

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selection strategies based on the correlations between two traits only can induce errors, since their association may be linked to a third variable or even a group of characters (Cruz and Regazzi 1997).

The applicability of correlations can be more clearly understood in the path analysis, which allows the partitioning of correlation in direct and indirect effects and is therefore a valuable tool in breeding programs of various crops (Gomes and Lopes 2005, Gomes et al. 2007, Vieira et al. 2007). In literature, several studies have demonstrated the utility of correlation analysis in peanut selection based on plant and reproductive traits (Lakshmaiah et al. 1983, Santos et al. 2000, Gomes and Lopes 2005).

This paper investigated the use of correlations and path analysis in peanut lines involving peg-related traits, to identify the most useful for studies of selection for higher pod yield.

MATERIAL AND METHODS

Fifteen lines originated from crosses between the genotypes 1 BR, Valencia botanical type, and CNPA 280 AM, Spanish botanical type, were grown under rainfed conditions, in Abreu e Lima, Pernambuco, from June to September 2008. The soil of the location is an acid, sandy loam Entisol. The soil was limed 30 days before planting with 1.5 tons of lime ha^{-1}. Chemical fertilizers were applied at planting (60 kg ha^{-1} of single superphosphate and 20 kg ha^{-1} KCl), as indicated by the results of soil analysis. Nitrogen was supplied with bovine manure (2 kg m^{-2}). The experimental plots consisted of two rows, 6 m long, in which each line was planted at a spacing of 0.70 x 0.20 cm, one seed per hole. The experimental design was randomized blocks with 17 treatments (15 lines plus 2 cultivar controls) and three replications. The crop management was based on recommendations described by Santos et al. (2006), and samples were taken between 87 and 100 days after planting. During cultivation, the mean temperature and relative humidity were 23.9 °C and 75%, respectively. Total rainfall during the crop cycle was 819 mm (ITEP 2008).

The variables recorded were number of total pegs (TNP) on the main stem and lateral branches, number of pegs located in the lower third of the plant (NPLTh), considering the main stem and lateral branches, main stem height (MSH) and number of mature pods (NMP). Based on the ratio NMP/TNP, the reproductive efficiency (EF_1) was estimated as described by Santos et al. (1997). However, Santos et al. (2000) reported a positive correlation of NMP and NPLTh. Thus, based on the ratio NMP/NPLTh, another measure of reproductive efficiency was assessed: reproductive efficiency of pegs of the lower third (EF_2), aiming to help the breeder in the choice of the trait most responsive to selection effects. Data were collected from 15 randomly selected plants in the plot. In the path analysis, number of mature pods was considered the main trait and the others as dependent explanatory variables.

Analyses of variance and correlations were computed using software Genes (Cruz 2006). The genotypic correlation matrix used for path analysis was tested for multicollinearity resulting in value ($N > 100$), classified as strong by Montgomery and Peck (1981). In this case, path analysis was performed using the procedure *path analysis under collinearity* of the software Genes, adjusting the values of the correlation matrix according to the smallest constant k provided by the software.

RESULTS AND DISCUSSION

The difference between lines for all traits evaluated was statistically significant (Table 1), showing the existence of genetic variability. Considering the reproductive efficiency (EF_1) based on TNP and NMP, the lines L5, L8, L9, L11, L12, L13, and L14 exceeded the mean of this trait.

The reproductive efficiency (EF_1), which is the ratio between the total number of pegs and the number of mature pods, is an important parameter in the assessment of productive peanut lines due to the direct influence on the plant capacity of maturing pods. In upright cultivars, due to the spatial distribution of pegs over all plant parts, the reproductive efficiency (EF_1) tends to be lower, because of the high amount of pegs produced as well as the location of pegs at the top of the plant. According to Santos et al. (1997), the reproductive efficiency in upright peanut genotypes is relatively low (around 22%). In this study, the mean reproductive efficiency (EF1) was between 20% and 41%, with a mean of 29%, which is higher than the values reported in the literature.

Considering the reproductive efficiency (EF_2) based on the ratio NPLTh/NMP, it was observed that L8 and L11 did not differ from each other, but from all other lines, i.e., the number of mature pods was greater (Table 1). This trait indicated a significant increase in the levels of reproductive efficiency (EF_2) for L8 and L11 (51% and 50%, respectively), due to both the greater number of pegs at the plant base and their proximity to the soil. According to Santos et al. (2005), the most efficient plants at transforming pegs into viable

Table 1. Summary of the analyses of variance and means for total number of pegs (TNP), number of pegs in the lower plant third (NPLTh), number of mature pods (NMP), reproductive efficiency (EF_1 and EF_2) and main stem height (MSH) in peanut genotypes

Sources of variation	df	MS					
		TNP	NPLTh	NMP[1]	EF_1 (%)	EF_2 (%)	MSH (cm)
Blocks	2	39.03	39.20	0.26	18.84	20.65	13.95
Genotypes	16	580.22*	548.36*	1.85*	150.90*	137.34*	144.41*
Error	32	7.63	9.91	0.02	0.73	0.92	0.74
CV%		4.44	6.26	3.05	2.40	2.16	2.87
BR 1		75	57	23	31	31	31
280 AM		62	54	23	37	43	24
L.1		71	66	18	25	27	25
L.2		38	23	8	21	35	36
L.3		71	61	17	24	28	36
L.4		64	52	13	20	25	30
L.5		71	66	21	30	32	26
L.6		43	35	12	27	34	17
L.7		67	53	15	22	28	30
L.8		63	51	26	41	51	29
L.9		77	66	23	30	35	42
L.10		61	49	17	28	35	40
L.11		65	50	25	38	50	29
L.12		63	54	19	31	35	23
L.13		66	58	22	33	38	26
L.14		64	56	23	36	41	39
L.15		45	36	13	28	36	22
Mean		62	51	18	29	37	30

[1] Transformed by “x. * significant at P < 0.05 by the F test.

fruits have most pegs in the first 15 cm of plant height, which is the maximum size reached by pegs under field conditions. By combining the data of EF_1 and EF_2, L.8 was identified as the most promising line for selection, and even with the highest NMP.

Santos et al. (2000) studied the correlation between phenotypic traits linked to pegs of several peanut accessions and found a positive correlation between EF (reproductive efficiency) and NPLTh and a negative correlation between EF and TNP, confirming that although laborious, NPLTh contributes most to the selection of genotypes with greater ability to transform pegs into mature pods. The fact that the correlation EF - TNP is negative was ascribed to the large number of pegs formed in upright plants, which can reach a length of more than 60 cm under suitable soil and climate conditions, which is energetically costly for the plant.

Positive and highly significant correlations (phenotypic 0.74 and genotypic 0.74) were found between TNP and NMP (Table 2). Mallikarjuna Swamya et al. (2003) studied 21 accessions of peanut traits of the subspecies fastigiata and

Table 2. Genotypic and phenotypic correlations in peanut between total number pegs (TNP), number of pegs in the lower plant third (NPLTh), number of mature pods (NMP), main stem height (MSH)

	Correlation	TNP	NPLTh	NMP	MSH
TNP	r_G	1	0.912**	0.746**	0.315
	r_F	1	0.911**	0.743**	0.315
NPLTh	r_G		1	0.882**	0.227
	r_F		1	0.881**	0.225
NMP	r_G			1	0.114
	r_F			1	0.111

** significant (P < 0.01) by the t test.

hypogaea observed high-magnitude phenotypic correlations between TNP and NMP (0.94). Nigam et al. (1984) also found a high correlation coefficient between phenotypic TNP and NMP (0.88) in accessions of the botanical types Spanish, runner and hybrids. These data corroborate the results of this study, confirming the high value of the positive correlation between TNP and NMP. The correlation between these traits is quite promising for selection of high-yielding plants in peanut populations.

TNP is closely linked to peanut yield since pods are formed from the pegs. However, the amount of pegs is not solely responsible for pod yield; other intrinsic factors such as size and height contribute to its development. Santos et al. (2000) studied the phenotypic correlation between gynophore-related traits of several peanut accessions and found a positive correlation TNP - MSH and no significant correlation NPLTh - MSH. In this study, the correlations were not significant both among and between TNP - MSH and NPLT - MSH, perhaps due to the short stature of the plants analyzed (on average 30 cm), despite the application of the recommended crop management and no occurrence of severe environmental events. Despite the absence of MSH - NPLTh correlation, literature reports that the lower the main stem of the peanut plant, the larger is the number of pegs located in the lower third of the plant (Lakshmaiah et al. 1983, Santos et al. 1997, Mallikarjuna Swamy et al. 2003) and therefore the greater the efficiency in forming fruits (Santos et al. 2000).

Positive phenotypic (0.88) and genotypic (0.88) NMP - NPLTh correlations, both high, were observed. Santos et al. (2000) studied the phenotypic correlation between gynophore-related traits of several peanut accessions and found a positive correlation NMP - NPLTh. The high correlation values of the ratio NMP/NPLTh found in this study are even more promising since the peanut plant produces a number of flowers ranging from 250 to 350 per cycle, depending on the botanical variety (Vara Prassad et al. 1999).

Another interesting possibility in the use of the correlation NMP -NPLTh is the short stature of peanut plants in this experiment (on average 30 cm) which enabled the pegs to reach the ground more easily. In this work no significant correlations were found between MSH and any other trait. In literature, several studies with peanut report a lack of association between plant height and pod-yield related traits.

Khan et al. (2001) analyzed the genetic correlations and path coefficients between several yield-related traits in 70 cultivated and exotic peanut accessions and found that plant height was not correlated with pod number or pods/plant yield. Based on the partitioning of the correlations, the authors claim that in the study population, the direct effect of plant height on yield was negative. Kotzamanidis et al. (2006) studied the correlation between traits in 21 segregating peanut lines from the cross: Virginia x Virginia, Valencia x Valencia, Virginia x Spanish, and Virginia x Valencia. The authors found that among all combinations studied with the lines of each group, the correlation between plant height and pod yield was only positive in Virginia x Virginia. This is justified by the growth habit of the lines, whose main stem or branch is usually located below 20 cm.

The values obtained by partitioning the correlations and the diagram illustrating the direct effects on the main variable based on path analysis are shown in Table 3, respectively. It was found that the effect of the TNP-related

Table 3. Direct and indirect effects on number of mature pods (NMP), of the variables: total number of pegs (TNP), number of pegs in the lower plant third (NPLTh) and main stem height (MSH), evaluated in peanut genotypes

Associations	Genotypic path coefficient		
	Direct effect	Indirect effect	Correlation
TNP			
Direct effect on NMP	0.109		
Indirect effect via NPLTh		0.610	
Indirect effect via MSH		0.024	
Total			0.743
NPLTh			
Direct effect on NMP	0.669		
Indirect effect via TNP		0.099	
Indirect effect via MSH		0.111	
Total			0.881
MSH			
Direct effect on NMP	0.012		
Indirect effect via TNP		0.034	
Indirect effect via NPLTh		0.065	
Total			0.111

traits on the main variable NMP was low (0.109), indicating the limited response in breeding studies. In such cases Vencovsky and Barriga (1992) conclude that indirect factors must be considered simultaneously in the selection processes. Based on this statement, the indirect effect via NPLTh (0.610) can be indicated as the main cause of the correlation between TNP and NMP (Table 3). When partitioning the correlation for NPLTh, the direct effect on NMP is highest, and is therefore the most relevant in the process of selection (Table 3).

For the estimates of the path coefficient for MSH, low values were found for both direct and indirect effects for all possibilities of associations, confirming the low magnitude of the correlations shown in Table 2.

The reproductive efficiency of EF_1 and EF_2 was highest for L.8 and L.11 and the number of mature pods was greatest, indicating the usefulness for selection. For environments under temporary water stress, the inclusion of these traits can make a great difference in the establishment of production.

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Correlações e análise de trilha em caracteres associados ao ginóforo do amendoim

RESUMO - *O presente trabalho teve por objetivo verificar entre os caracteres de amendoim: número de ginóforos totais (NGT), número de ginóforos no terço inferior da planta (NGTI), número de vagens maduras (NVM), altura da haste principal (AHP), eficiência reprodutiva (EF_1 e EF_2), via análise do coeficiente de correlação e coeficiente de trilha, os de maior contribuição na seleção para produção de vagens maduras. O ensaio constituiu de 15 progênies $F_{2:3}$, resultantes do cruzamento entre a variedade BR 1 e a linha avançada CNPA 280 AM. O delineamento adotado foi blocos ao acaso com três repetições. As linhagens de melhor desempenho para eficiência reprodutiva foram as identificadas como L.8 e L.11. Na análise de trilha, o número de ginóforos no terço inferior da planta mostrou forte efeito direto sobre número de vagens maduras, credenciando-o para a seleção em populações de amendoim para número de vagens maduras.*

Palavras-chave: Arachis hypogaea, *eficiência reprodutiva, seleção indireta.*

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