Yield adaptability and stability of peanut genotypes estimated under different environments

Adaptabilidade e estabilidade de produção de genótipos de amendoim avaliados em diferentes ambientes

Francisco José Alves Fernandes Távora[1], Fanuel Pereira da Silva[1], Francisco Ivaldo de Oliveira Melo[1], João Bosco Pitombeira[1], Francisco Vieira Costa Neto[2]

ABSTRACT

The evaluation of the yield performance of cultivars under several environments is necessary to asses the crop potential. This study was designed to assess the effects of sowing dates on the pod yield of peanut (*Arachis hypogaea* L.). A series of trials was carried out in ten different environments corresponding to ten sowing dates in Fortaleza city, state of Ceará, (Brazil). Eight peanut genotypes were sown at plant density of 16.67 plants m^{-2} .The plots consisted of four rows, four meters long in a randomized complete block design, with four replications. The Valencia and Spanish groups genotypes were harvested at 90 days after planting (DAP), while the Virginia group was harvested at 110 DAP. The highest yield genotypes 57422 and 7333 (Virginia's group) appeared to be the most unstable and unpredictable ones. Genotype 57422 might be recommended for favorable environments. The short cycle genotypes had a wide range of adaptability and stability. The results support the view that short cycle genotypes should achieve higher degrees of adaptation under limited and irregular water availability conditions, while under more favorable conditions, the long cycle genotypes had a higher yield potential and should be recommended.

Index terms: Arachis hypogaea L., groundnut, yield stability

RESUMO

A avaliação do desempenho de cultivares em diferentes ambientes, repetida no tempo e no espaço, é necessária para definir o potencial de uma cultura. Este estudo foi realizado com o objetivo de determinar o efeito de diversos ambientes, correspondentes a diferentes épocas de plantios na produção de amendoim (*Arachis hypogaea L.*). Oito genótipos foram plantadas em dez diferentes datas em Fortaleza, Ceará, Brasil. A densidade de plantio foi de 16,67 plantas.m^{-2} e cada parcela experimental tinha 2,4m x 4m, consistindo de quatro linhas plantadas no delineamento de blocos completos casualizados com quatro repetições. Os genótipos pertencentes aos grupos Valência e Spanish foram colhidas aos 90 dias após o plantio (DAP), enquanto os do grupo Virgínia, aos 110 dias. Os genótipos mais produtivos pertencentes ao grupo Virgínia (57422 e 7333) foram mais instáveis e menos previsíveis. Todos os genótipos de ciclo curto demonstraram um elevado grau de adaptação. Materiais de ciclo curto devem atingir maiores graus de adaptação sob condições limitadas e irregulares de disponibilidade hídrica, enquanto sob melhores condições hídricas, os materiais do grupo Virgínia devem ser recomendados.

Termos para indexação: Arachis hypogaea, amendoim, estabilidade de produção.

[1] Professores do Departamento de Fitotecnia da Universidade Federal do Ceará, Cx. Postal 12.168, CEP 60.455.740, Fortaleza-CE. E-mail: tavora@ufc.br
[2] Engº. Agrº., MS, Departamento de Fitotecnia, Universidade Federal do Ceará, Fortaleza-CE.

Introduction

Commercial peanut (*Arachis hypogaea L.*) found predominantly in tropical and in a lesser extend in temperate regions of the world. The plant is adapted to a wide variety of climate conditions and is widespread in both humid and semi-arid regions.

The long cycle peanut cultivars are grown in the humid areas of the world and usuallly perform better than the short cycle ones, which are preferred in the semi-arid areas, where predominate the lower yield potential. The reason for that behavior is because the short cycles cultivars are able to make use more apropriately of humid conditions of the regions.

Northeast of Brazil has a very peculiar climate situation. There is a rainfall concentration in the first semester of the year with a great variability of total rainfall as well as a very irregular distribution both in time and space. As a consequence, a climate detrimental effects may ocurr when long mature cycle cultivars are planted.

Peanut in Northeast of Brazil comprises only 1,5% of the total country acreage (IBGE, 1996), although this area has a high potential to be increased mainly because of the adaptability of the crop to water stress as well as to low soil fertility that characterize the areas available for cultivation.

Yield evaluation of peanut cultivars for different years and environmental circumstances is necessary to allow inferences related to the adaptability and stability for different cultivars, regions and water availability situations. Significant variability in pod yield for cultivars grown under different water control, both in field and greenhouse conditions, were reported by Távora et al. (1985 and 1988), and Távora and Melo (1991).

The phenotypic stability studies have been emphasized by Plant Bbreeders in their breeding programs since the development of the statistical procedures that allowed to estimate these parameters for cultivars, lines and hybrids to different environments (Finlay and Wilkinson, 1963; Walker and Fehr, 1978; Beaver and Johnson, 1981; Schlling et al. 1983; Weaver et al. 1983; Lin et al. 1986; Cruz et al. 1989). Eberhart and Russel (1966) developed a model to define stability parameters which may be used to describe the performance of a cultivar over a series os environments. According to this model, the variability of any genotype with respect to the environment, can be subdivided into a predictable part, corresponding to the regression of the characteristics studied over the environment, and an unpredictable one, corresponding to a deviation mean square. The residual mean square of deviation from the regression is the measure of the stability for each genotype as a second stability parameter.

Eberhart and Russel's model has been widely used in studies of adaptability and stability of plant materials. These authors observed that the regression techniques allow the genotype-environment interaction (GE) of each genotype to be partitioned in two parts: (1) the portion of the GE interaction due to the response in performance of the genotype to environments of varying levels of yield, and (2) the portion due to unexplained deviations from regression. A stable genotype is defined as one having an average response in performance to enviroments of varying levels of yield and minimum deviations from regression.

The objectives of this research were to evaluate the adaptability and stability for yield of eight peanut genotypes in ten environments of the State of Ceará, (Brazil) according to the methodology developed by Eberhart and Russel (1966).

Material and Methods

A series of field trials envolving eight peanut genotypes grown in 10 (ten) different environments were carried out in Fortaleza, Ceará , (Brazil) from 1989 to 1998. The individual trials were sown in a sandy soil suited for peanut growth in the following sowing dates: 03.02.1989, 04.02.1990, 03.22.1991, 09.10.1991, 02.28.1992, 03.29.1993, 03.13.1995, 03.15.1996, 03.23.1997 and 03.11.1998. The genotypes used and the source of seed were as flollows

Genotype	Cycle	Group	Origin
Cultivar Tatu	90 days	Valencia	Instituto Agronômico de Campinas, São Paulo, Brazil.
Cultivars 55437 and 7330	90 days	Spanish	ISRA, Senegal.
Cultivar Georgia	90 days	Spanish	United States of America
Experimental Line PI-165317	90 days	Spanish	United States of America.
Experimental Line CE-6811	90 days	Valencia	University of Ceará, Brazil.
Cultivars 57422 and 7333	110 days	Virgnina	ISRA, Senegal

Soil bed preparaetion consisted of plowing followed by harrowing. The weeds were controled by hand hoeing. These procedures were used in all trials. The seeds were planted 60 cm between rows and 10 cm between seeds within rows. Individual plots consisted of four rows four meter long, arranged in a randomized complete block design, replicated four times. All observations were obtained from the two central rows of each plot. Weather data were collected each year from a Weather Station located close to the experimental area.

The genotypes from Valencia and Spanish groups were harvested 90 days after planting (DAP), while the ones from Virginia group at 110 DAP. Pod yield (kg ha^{-1}) was recorded in all environments. Standard analysis of variance was performed over each of the ten enviroments. In addition to the individual analysis of variance for each enviroments, a pooled analysis was performed with the objectives of studying the interaction between lines and enviroments.

The stability and adaptability studies were performed following the method described by Eberhart and Russel (1966) according to the model: $Y_{ij} = \mu_i + B_i I_j + \delta_{ij} + E_{ij}$, where Y_{ij} is the pod yield of the ith genotype in the jth enviroment, μ_i is the overall mean, B_i is the linear regression coefficient, Ij is the environmental index, δij is the deviation from regression and Eij is the random error.

The estimation of the adaptability parameters are given by the average performance of the cultivar (μi) and by the linear coefficient of regression (βi). According to Eberhart and Russel (1966), the adapatability is the capability of a given cultivar to perform well in a better environment. The cultivars with βi=1,0 are of great adaptability and those with βi>1,0 are of specific adaptability at favorable specific environments. Those with βi<1,0 are of specific adaptability under unfavorable environments. The estimation of the stability parameters is given by $\sigma^2_{di} = \sum \delta^2 ij/(a-2)$ where a is the number of environments. In this methodology, stability means a predictability of the cultivar in relation to a linear regression model. A genotype will be considered stable and predictable if it shows a non significant deviation and unstable or unpredictable, the ones with a significant deviation.

It is highly desirable that the genotypes do show a performance above the average in all environments. This assumption will be reached when a genotype that perform well has a higher mean with a regression coefficient equals to the unity and the deviation from regression coefficient equals to zero.

The statistical analyses were performed by using the GENES computer program (Cruz, 2001).

Rainfall distribution patterns were characterized by a high concentration in the first six months of the year, when nine out of the 10 trials were carried out under rain-fed conditions (Table 1). Rainfall distribution also showed a high variability among years, and in six out of the nine years it showed values below to the normal of the area where the trials were carried out; there was plenty of rainfall throughout the rain season only during 1995. This poor distribution of rainfall, associated with sand soil, and low water holding capacity may have affected the performance of the more susceptible cultivars in some critical periods.

Table 1 - Monthly rainfall distribution (mm) and deviation from the normal rainfall registered in the experimental area from 1989 to 1998. Fortaleza, Ceará, Brazil.

Month	1989	1990	1991	1992	1993	1995	1996	1997	1998
					- mm -				
January	270.4	48.5	23.9	123.0	40.8	117.6	98.8	18.0	218.3
February	66.6	113.8	240.0	261.6	113.1	231.3	283.6	51.7	77.7
March	260.6	86.0	491.0	263.7	210.3	527.5	439.4	160.6	382.0
April	282.4	278.6	437.7	249.3	204.5	637.3	374.4	435.1	178.5
May	203.4	197.8	164.3	88.9	87.9	332.9	281.9	213.9	91.8
June	269.3	38.9	72.7	122.8	56.8	144.4	65.5	15.0	178.5
July	129.1	97.4	8.1	13.1	154.1	71.7	24.2	15.6	5.2
August	96.9	11.2	12.7	23.9	26.2	3.1	58.2	10.6	26.3
September	55.2	41.2	0.7	9.0	11.4	2.3	11.2	1.7	3.2
October	14.7	16.7	56.4	5.5	7.6	15.7	14.4	0.5	8.0
November	17.0	12.0	5.1	4.0	7.7	29.5	4.4	32.8	2.8
December	67.4	32.7	0.0	0.9	24.7	3.3	11.7	20.0	9.7
Total	1732	975	1513	1166	945	2117	1668	976	1182
Deviation (1)	+90	-667	-129	-476	-697	+475	+26	-666	-461

1) deviation from the normal rainfall of the area.

Table 2 - Mean temperatures in the experimental area from 1989 to 1998. Fortaleza, Ceará, Brazil.

Month	1989	1990	1991	1992	1993	1995	1996	1997	1998
					- °C -				
January	26.9	27.3	27.9	27.1	28.0	26.9	27.4	28.1	27.7
February	27.3	27.3	27.0	27.0	27.7	26.4	27.3	27.8	28.3
March	26.6	27.5	26.4	27.5	27.3	26.8	26.3	27.6	27.7
April	26.1	27.5	26.5	28.0	27.1	26.4	26.3	26.6	28.2
May	26.2	27.1	26.7	26.9	27.3	26.8	26.8	26.2	27.8
June	26.0	27.0	26.8	26.2	27.0	26.5	25.8	26.6	28.2
July	25.6	26.5	26.3	26.2	26.1	26.0	26.6	26.5	27.0
August	26.2	26.9	26.3	26.3	26.4	26.4	26.7	26.6	26.9
September	26.8	27.1	26.7	25.8	26.8	26.5	27.3	26.8	27.2
October	27.6	27.3	26.6	26.8	27.3	26.9	27.5	27.4	27.5
November	27.8	27.7	27.0	27.2	27.6	27.4	27.8	27.6	27.7
December	27.5	27.7	27.5	29.1	27.7	28.2	28.1	27.9	27.6

1) deviation from the normal rainfall of the area.

Mean temperature in the experimental area showed little variation thoughout the months and among years (Table 2). The mean temperature (26.7°C), as well as the minimum (26.0°C) and maximum temperature (28.0°C) averages were quite satisfactory for peanut growth and production (Ketring and Reid, 1995).

Results and Discussion

The mean pod yield of the ten field trials during the 1989–1998 period varied significantly, with a range from 1,087 kg ha^{-1} to 3,009 kg ha^{-1} (Table 3). The variation in yield within each of the ten environments (sowing dates) were considered adequate for evaluating yield stability of the entries in the test, since there was significant variability among genotypes in seven out of the ten environments studied. This behavior reveals significant interaction among the genotypes and each experimental condition.

The pooled analysis of variance shows significance for genotypes, environments and the genotypes x environments, indicating that the relative yield of environments were different among years (Tables 3 and 4). The significance for environment linear indicates variations in the environments to proportionate alterations among the genotypes (Oliveira et al., 1999). The partitioning of the degree of freedom showed that only the genotype 7333 presented significant deviation from the regression, althowgh the coefficient of determination indicates that 51.7% of the total variation were explained by factors not included in the model.

There was a considerable variation in yield among genotypes and environments. The Virginia type genotypes 57422 and 7333, harvested at 110 DAP, showed the highest pod yields with a percentage of 31.2 and 28.8 above the general mean (2,079 kg.ha^{-1}), respectively. The short cycle genotypes had either intermediary (PI 165317, 55437 and 7330) or lower yields (Georgia, CE 6811 and Tatu). The experimental line PI 165317 was the only one that outyielded 2,000 kg ha^{-1} of pods (Table 5).

The highest productive cultivars (57422 and 7333) were the most unstable and unpredictable genotypes, since they presented significant values for σ^2_d (Table 5). Cultivar 57422 is recommended for favorable environments due to the significant value for $ß_{i.}$. This result revealed a good performance only under favorable conditions. All short cycle genotypes had not achieved significance for the parameters studied. This result suggests that they had a high degree of adaptation to different environments.

The utilization of short cycle materials is recommended for rain fed peanut crops in semi arid areas. Annerose, (1990) reported that short cycle Spanish cultivars have lower probability of suffering a drought under field conditions in the semi-arid of Senegal, than

Table 3 - Mean pod yield of peanut genotypes (kg/ha) evaluated in Fortaleza,Ceará, Brazil from 1989 to 1998.

Cultivar	1989	1990	1991-1	1991-2	1992	1993	1995	1996	1997	1998
57422	2283b	3848a	3557a	3092a	3772a	2500a	2841a	1388b	1551a	2447ab
7333	3374a	3341ab	3388a	2208a	3331a	2168a	2910a	2320a	1145a	2598a
PI 165317	2195b	3130ab	2593ab	2739a	2127b	2365a	1019b	1522ab	850a	2109ab
55437	1059c	2520b	2820ab	2461a	2453b	2222a	1383b	1399b	1471a	2005ab
7330	2080b	2997ab	2526ab	2234a	2033b	2182a	918b	1271b	968a	1952ab
Georgia	1765bc	2905ab	2551ab	1994a	2004b	1856a	1367b	1054b	1265a	1848ab
CE 6811	1485bc	3007ab	2018b	2204a	2309b	1857a	1164b	1241b	588a	2025ab
Tatu	1641bc	2325b	2085b	2166a	1956b	1466a	859b	1103b	861a	1681b
Mean	1985 D	3009 A	26693 B	2388 C	2498 D	2077 D	1558 E	1412 E	1087 F	2083 D

Means within a column followed by the same small letter and within a row by the same capital letter are not significantly significant by tukey test ($p < 0.05$).

Table 4 - Pooled analysis of variance for pod yield of peanut genotypes (kg ha^{-1}) in the State of Ceará, Brazil, from 1989 to 1998.

Source of Variation	d.f.	Mean Sqaure	R^2 (%)
Genotypes (G)	7	6,651,570**	
Environments (E)	9	11,449,752**	
Interaction (G x E)	63	490,386**	
Environmment/Genotype	72	1,860,307ns	
Envionment (Linear)	1	103,047,772**	
Interaction (G x E) Linear	7	361,544ns	
Pooled Deviation	64	443,180**	
Genotype 57422 (Virgínia)	8	679,038ns	79.69
Genotype 7333 (Virgínia)	8	1,259,195**	48.32
Genotype PI 165317 (Spanish)	8	356,651ns	85.27
Genotype 55437 (Spanish)	8	563,395ns	65.98
Genotype 7330 (Spanish)	8	236,456ns	88.36
Genotype Georgia (Spanish)	8	134,677ns	90.59
Genotype CE 6811 (Valencia)	8	196,841ns	90.76
Cultivar TATU (Valencia)	8	119,189ns	90.74
Pooled Error	210	237,792	-

** significant at the 1% level by F test.

the medium and long cycle Virginia cultivars. The results reported in our study suggest that most of the short cycle cultivars achieved better degree of adaptation under limited and irregular water availability. On the contrary, under more favorable conditions, the Virginia lines which have a higher cycle and yield potential should be recommended.

Table 5 - Average pod yield of eight peanut genotypes grown in ten field trials in the State of Ceará, Brazil and the estiamations of the regression coefficients and regression deviations.

Genotypes	Pod yield (kg ha^{-1})	Regression Coefficient (βi)	Regression Deviations (σ^2di)
57422	2728a	1.28*	110047.8*
7333	2678a	0.85ns	255087.1**
PI 165317	2065b	1.13ns	2945.2ns
55437	1979b	0.82ns	81137.0ns
7330	1916b	1.06ns	-597.5ns
Georgia	1861bc	0.89ns	-26042.3ns
CE 6811	1790bc	1.09ns	-10501.3ns
TATU	1614c	0.85ns	-29914.4ns

Values followed by the same letters do not differ by tukey test ($p < 0.05$).
* and ** significant at the 5% and 1% levels, respectively, by t test for βi and by F test for σ^2di.

Conclusions

1. The environmental conditions influenced peanut pod yield;
2. The long cycle Virginia type genotypes had an unstable and unpredictable pod yield and lower adaptability than the Spanish and Valencia short cycle;
3. The Virginia type genotypes had higher pod yield than the Spanish and Valência types;
4. The highest productive genotypes are recommended for favorable, while the short cycle ones for unfavorable conditions.

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