Yield and stability of groundnut (*Arachis hypogaea* L.) varieties in the derived savanna areas of South-western Nigeria

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ABSTRACT

Three improved and multiple disease-resistant groundnut lines (UGA 3, UGA 4 and UGA 13) and a local cultivar (Ogbomoso cultivar) were evaluated for yield and stability on farmers' fields at Oyo, Ogbomoso and Shaki in the derived savanna areas of South-western Nigeria in 1997 and 1998. Pod yields differ between the locations and ranged from 0.54 to 0.74 t ha^{-1}. The three improved varieties had similar yields ranging from 0.71 to 0.83 t ha^{-1} while Ogbomoso cv. had the lowest yield of 0.34 t ha^{-1}. Significant genotype × environment interaction influence on pod yield was partitioned into different interaction principal component analysis (IPCA) axes by using additive main effects and multiplicative interaction model (AMMI). The first IPCA (IPCA 1) axis accounted significantly for the interaction. The biplot graph of mean yields and IPCA 1 scores showed that UGA 3 with IPCA 1 score of -0.003 had a stable yield while other variety yields were unstable across the trial sites. The yield responses of the groundnut varieties to changes in environment were quantified by linear regression models: $Y=0.40 - 0.09X^{ns}$ for Ogbomoso cv.; $Y=0.61 + 0.30X^{**}$ for UGA 13; $Y=-0.81 + 2.44X^{**}$ for UGA 4, and $Y=0.16 + 1.28X^{***}$ for UGA 3. The models indicated that a change in the environment had less impact on yields of Ogbomoso cv. and UGA 13 while an improved environment would increase the yield potential of UGA 4 and UGA 3 substantially. UGA 3 which was high yielding and stable across the different sites will fit well into the peasant farming system in South-western Nigeria.

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RÉSUMÉ

AGBAJE, G. O. & OYEKAN, P. O. : *Rendement et stabilité des variétés d' arachide* (Arachis hypogaea L.) *dans les zones de la savane dérivée du sud-ouest du Nigéria.* Trois lignes d'arachide (UGA 3, UGA 4, et UGA 13) améliorée et resistantes aux maladies multiples et une variété locale (Ogbomoso cultivar) étaient évaluées pour le rendement et la stabilité sur les champs des cultivateurs à Oyo, Ogbomoso et Shaki, dans les zones de la savane dérivée du sud-ouest du Nigéria en 1997 et 1998. Le rendement de cosse diffère entre les emplacements variait de 0.54 à 0.74 t ha^{-1}. Les trois variétés améliorées avaient des rendements semblables variant de 0.71 à 0.83 t ha^{-1} alors que Ogbomoso cultivar (cv.) avait le plus moindre rendement de 0.34 t ha^{-1}. Génotype considérable × influence d'interaction environnementale sur le rendement de cosse était divisé en différents axes d'analyse de composant principal d' intéraction (ACPI) utilisant les effets principaux d' additif et le modèle d'intéraction multiplicative (PAIM). Les axes de la première analyse de composant principal d'intéraction (ACPI 1) est considérablement responsable de l'intéraction. Le graphique bitracé des rendements moyens et les résultats d' ACPI 1 montraient qu' UGA 3 avec le résultat de -0.003 d' ACPI 1 avait un rendement stable alors que les rendements des autres variétés sont instables à travers les sites d' essai. Les réactions de rendement des variétés d' arachide aux changements dans l'environnement étaient évaluées quantitativement par les modèles de régressions linéaires : $Y = 0.40 - 0.09X^{ns}$ pour Ogbomoso cv.; $Y = 0.61 + 0.30X^{**}$ pour UGA 13; $Y = -0.81 + 2.44X^{**}$ pour UGA 4 et $Y = 0.16 + 1.28X^{***}$ pour UGA 3. Les modèles indiquaient qu'un changement dans l'environnement avait plus moins d'impact sur les rendements d' Ogbomoso cv. et UGA 13 alors qu'un environnement amélioré pourrait augmenter le potentiel d'UGA 4 et UGA 3 substantiellement. UGA 3 qui avait un rendement élevé et stable à travers les différents sites peut s'intégrer bien dans le système de petit champ paysan au sud-ouest du Nigéria.

Introduction

The South-western part of Nigeria is regarded as a marginal area for groundnut production, with bulk of production located in the derived savanna areas of the region where environmental conditions are more favourable for its cultivation (Ojomo & Adelana, 1970). The popular variety cultivated by the farmers in this area (Ogbomoso cultivar) had been reported to be low yielding with less than 400 kg/ha of unshelled pod weight, and it is highly susceptible to leaf spot *Cercospora* spp. and rosette virus disease (Oyekan, 1995). Recent efforts to introduce new multiple disease-resistant varieties to this area resulted in the selection of UGA 3, UGA 4, and UGA 13 (Oyekan & Agbaje, 1999).

The new concept of selecting varieties for farmers involved the evaluation of varieties within the poor and difficult environments where the farmers operate (Simmonds, 1991). The various farmers' environments would influence yield and make selection for a variety difficult due to genotype by environment interaction. Genotype by environment (G × E) interaction is an important issue among plant breeders and agronomists. Yields are influenced by varied soil types among farmers. Elberhart & Russel (1966) identified rainfall pattern and dates of planting as sources of environmental influence which induce G × E interaction. Genotypes cannot, therefore, be selected based on yield alone, but a method that combines yield and stability across a geographical area would be of benefit to farmers. Kang & Pham (1991) observed that growers would prefer to use a high-yielding cultivar that performs consistently from year to year. They may even be willing to sacrifice some yield if they are guaranteed, to some extent, that a cultivar would produce consistently from year to year.

Yield stability statistics ensured the selection of consistently performing cultivars instead of high yields alone (Kang, 1993). Traditional stability analysis methods of Finlay & Wilkinson (1963), Elberhart & Russel (1966), Perkins & Jinks (1968), Shukla (1972) and others are being replaced with new statistical methods in explaining the G × E interaction in agronomic yield trials. A modified stability analysis suggested by Hilderbrand (1984) which regressed treatment or variety yields on an environmental index (i.e., the mean site yield) to assess, *posteriori*, the reaction of treatments or variety on the overall environmental conditions have been used in on-farm research trials. Recent technological developments, especially with the availability of computers to run complex mathematical equations, the additive main effects and multiplicative interaction model (AMMI) which incorporates the traditional methods of analysis like analysis of variance, principal component analysis and linear regression had been developed to effectively explain G × E interaction (Crossa *et al.*, 1991).

The objective of this study is to select stable and high-yielding varieties for farmers in the derived savanna areas of South-western Nigeria, and also to assess the varieties' responses to changes in the environment by using AMMI and the modified stability analysis methods.

Materials and methods

UGA 3, UGA 4 and UGA 13 groundnut varieties recommended for cultivation in the derived savanna areas of South-western Nigeria (Oyekan & Agbaje, 1999) and a local check (Ogbomoso cultivar) were evaluated for yield and stability on farmers' fields at Shaki (8.39N 3.25E), Oyo (7.50N 3.55E), and Ogbomoso (8.05N 4.11E) in 1997 and 1998. Six farmers were selected in each location with the assistance of Oyo State Agricultural Development Programme extension agents to carry out the trial for 2 years. The experiment was designed as randomised complete block design with six replicates, and was to be managed by farmers. Each farmer was regarded as a replicate; hence, the treatments were not replicated on farmers' field.

After tilling the soil with the hoe, planting was done during early Jun 97 and early Jul 98. The seeds were treated with Apron plus (Metalaxyl) for protection against soil pests. They were planted at two seeds per stand with an inter-row and intra-row plant spacings of 60 and 20 cm, respectively. The plot size per variety consisted of four 6-m long rows. Single super phosphate (18 % P_2O_5) fertilizer at a rate of 200 kg ha^{-1} was applied at planting by broadcasting. The weeds were controlled manually by hoeing before the pegging stage and subsequently by hand picking. Harvesting was done in late Oct 97 and late Nov 98 from the two innermost rows in each plot. The unshelled pods were sun-dried for 3 weeks and used to estimate pod yield in tonnes ha^{-1}.

The data were analyzed from four farmers per location, with a total of 24 farmers for the 2 years. The yield data from six environments (i.e., 3 locations × 2 years) and four groundnut genotypes were subjected to AMMI stability analysis according to the procedure of Crossa *et al.* (1991) to explain the G × E interaction. The statistical analysis was performed by MATMODEL (Gauch, 1992). Biplot of the interaction principal component analysis scores and yield values from the environments and genotypes were used to graphically interprete the genotype × environment interaction according to Kempton (1984). The responses of the groundnut varieties to changes in environment were quantified with linear regression models according to Hilderbrand (1984), where each variety yield was regressed on environmental index (i.e., mean yield per farmer).

Results and discussion

Total monthly rainfall during the growing season (Jun-Oct) varied in all the locations (Fig. 1). Rainfall was low from Jul to Aug 97 and in Jul 98. Rainfall was higher in Oyo than in Ogbomoso, while Shaki had the lowest rainfall in 1997 and 1998. Oyo had a total rainfall of 723 mm in 1997 and 653 mm in 1998, while Shaki had 528 mm in 1997 and 514 mm in 1998.

Pod yields differed between farmer's sites (treatments), varieties, and the six environments (Table 1). UGA 3, UGA13 and UGA 4 had similar yield values which ranged from 0.71 to 0.83 t/ha, while Ogbomoso cv. had a significantly lower yield (0.34 t/ha) than all other varieties (Table 2). This confirmed an earlier observation by Oyekan & Agbaje (1999) that the multiple disease-resistant lines (UGA 3, UGA 4 and UGA13) had higher yields

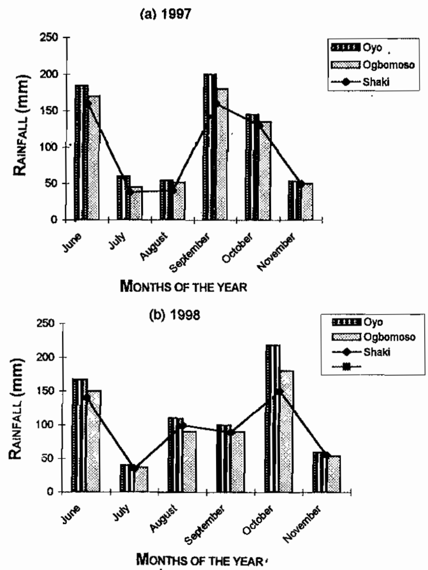

Fig. 1. Rainfall data in 1997 and 1998 across three sites in South-western Nigeria.

TABLE 1

AMMI Analysis of Variance for Pod Yield in Four Groundnut Varieties in South-western Nigeria

Sources of variation	*Degree of freedom*	*Sum of square*	*Mean square*
Total	95	12.56	
Treatment (farmers)	23	7.80	0.33***
Genotypes (G)	3	3.72	1.24***
Environments (E)	5	1.51	0.30***
G × E interaction	15	2.56	0.17***
IPCA 1	7	2.18	0.31***
IPCA 2	5	0.31	0.06
IPCA 3	3	0.06	0.02
Error	72	4.76	0.06

*; **; ***; Significant at $P<0.05$, 0.01, and 0.001, respectively.
IPCA - Interaction principal component analysis axis.

TABLE 2

Influence of Genotype × Environment Interaction on Pod Yield (t/ha) of Four Groundnut Varieties in South-western Nigeria

	Environments (E)						
	1997			1998			
Variety/Genotype	*Oyo (E1)*	*Ogbomoso (E2)*	*Shaki (E3)*	*Ilora (E4)*	*Ogbomoso (E5)*	*Shaki (E6)*	*Variety mean (t/ha)*
UGA 3	0.93	0.90	0.80	0.54	0.55	0.54	0.71
UGA 4	1.63	0.82	0.61	0.59	0.59	0.71	0.83
UGA 13	0.85	0.79	0.79	0.71	0.82	0.88	0.80
Ogbomoso cv.	0.30	0.38	0.28	0.35	0.43	0.30	0.34
Environment mean (t/ha)	0.93	0.72	0.63	0.54	0.59	0.61	

LSD (0.05): (i) Genotype = 0.14; (ii) Environment = 0.17; (iii) G × E interaction = 0.34

than Ogbomoso cv. The influence of environment on yield (Table 2) showed that the lowest yield (0.54 t/ha) recorded for Oyo in 1988 (E4) was similar to yields from three other environments (E3, E5 and E6) which ranged from 0.59 to 0.63 t/ha. In 1997, Oyo (E1) and Ogbomoso (E2) sites had 0.93 and 0.72 t/ha pod yields, respectively, and these were significantly higher than pod yields from E4.

Ojomo & Adelana (1970) reported that groundnut yields differ between years and between locations in South-western Nigeria, and that low rainfall with bright sunshine favoured higher yield. The variation in yields, therefore, was due to differences in rainfall pattern between the environments. Yield was significantly higher in E1 than in the other environments, due to the favourable, low rainfall from Jul to Aug which coincided with the period of flowering and pod development. The low yield in 1998 was due to low rainfall during the vegetative period, followed by high rainfall at the onset of flowering until maturity.

The G × E interaction was significant (Table 1). Table 2 shows that improved varieties had higher yields than Ogbomoso cv. in 1997 (E1 to E3). In 1998 (E4 - E6), Ogbomoso cv. had similar yields with UGA 3 and UGA 4 in Oyo and Ogbomoso. However, UGA 13 had higher yield than Ogbomoso cv. in all locations in 1998. Table 1 shows that the first IPCA was significant, accounting for 85 per cent of the sum of square variation caused by the G × E interaction. The biplot graph (Fig. 2) explained the interaction.

It showed that UGA 3 was the most stable variety across the six environments due to its IPCA scores which were almost zero, indicating that the variety interacts less with the environment and will give favourable yields under both favourable and unfavourable conditions. UGA 4 had high, positive interaction with the environment and will

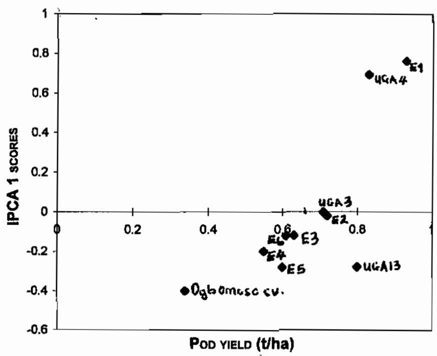

Fig. 2. Biplot graph showing the relationship between IPCA 1 scores and mean yields of four groundnut varieties and six environments in South-western Nigeria.
V1 - UGA 3; V2 - UGA 4; V3 - UGA 13; V4 - Ogbomoso cv. E1 - Oyo site in 1997; E2 - Ogbomoso site in 1997; E3 - Shaki site in 1997; E4 - Oyo site in 1998; E5 - Ogbomoso site in 1998; E3 - Shaki site in 1998.

perform well only under a favourable environment. UGA 13 had high yield, while Ogbomoso cv. had poor yield, but they both interact negatively with the environment and are adaptable to a less favourable environment. The yield of varieties that interact with the environment are not stable or consistent across the derived savanna environment, and cannot be recommended for wide cultivation. Although UGA 13 is adaptable to peasant environment, its yield was not significantly higher than that of UGA 3 which adapts well to both favourable and unfavourable environments.

The impact of changes in the environment on yield potential of the groundnut varieties was determined by using the modified stability (Fig. 3). Analysis of variance for the linear regression equation was significant for all the varieties except that of Ogbomoso cv. A unit change in

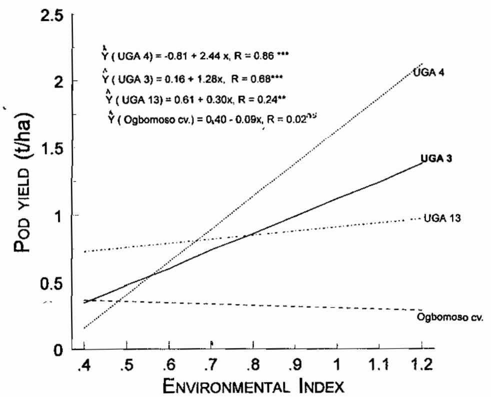

Fig. 3. Linear response of yield in four groundnut varieties to environmental changes.

environmental index (EI) in the equation resulted in an increase in yield by 2.44 t/ha for UGA 4, 1.28 t/ha for UGA 3, and 0.30 t/ha for UGA13 while yield for Ogbomoso cv. was reduced by 0.09 t/ha (Fig. 3). This means that UGA 3 and UGA 4 are sensitive to environmental changes, and under favourable environment their yield potential will increase. UGA 13 and Ogbomoso cv., from the equations, responded poorly to environmental changes, indicating their limited productivity even under an improved management system.

From the study, UGA 3 is recommended for wide cultivation and replacement for Ogbomoso cv. across the derived savanna areas of South-western Nigeria, because of its higher and stable yield, and for its better yield potential under improved farming systems.

REFERENCES

Crossa, J., Fox, P. N., Preiffer, W. H., Rajaram, S. & Gauch, H. G. (1991) AMMI adjustment for statistical analysis of an international wheat yield trial. *Theor. Appl. Genet.* **81,** 27-37.

Elberhart, S. A. & Russel, W. A. (1966) Stability parameters for comparing varieties. *Crop Sci.* **6,** 36-40.

Finlay, K. W. & Wilkinson, G. N. (1963) The analysis of adaptation in a plant breeding programme. *Aust. J. agric. Res.* **14**, 742-754.

Gauch, H. G. (1992) Statistical analysis of regional yield trials. In *AMMI analysis of factorial designs*. Publ. Elsivier, Amsterdam, 278 pp.

Hilderbrand, P. E. (1984) Modified stability analysis of farmers managed on-farm trials. *Agron. J.* **76,** 271-274.

Kang, M. S. (1993) Simultaneous selection for yield and stability in crop performance trials: Consequences for growers. *Agron. J.* **85** (3), 754-757.

Kang, M. S. & Pham, H. N. (1991) Simultaneous selection for high yielding and stable crop genotypes. *Agron. J.* **83,** 161-165.

Kempton, R. A. (1984) The use of biplots in interpreting variety by environment interactions. *J. agric. Sci. (Camb)* **103,** 123-135.

Ojomo, A. O. & Adelana, B. O. (1970) Variety × environment interactions in groundnut variety tests in western Nigeria. *J. agric. Sci. (Camb)* **75,** 419-420.

Oyekan, P. O. (1995) Evaluation of performance of improved groundnut varieties in southern Guinea savanna zone of Oyo state. In *In-house review bulletin of crop production programme,* pp.10-11. Institute of Agricultural Research andTraining (IAR & T), Ibadan, 1995.

Oyekan, P. O. & Agbaje, G. O. (1999) Performance of new improved groundnut varieties in the derived savanna areas of South-western Nigeria. *Trop. Oilseeds J.* **4,** 29-34.

Perkins, J. M. & Jinks, J. L. (1968) Environmental and genotype environment components of variability. III. Multiple lines and crosses. *Heredity* **23**, 239-256.

Shukla, G. K. (1972) Some statistical aspects of partitioning genotype-environmental components of variability. *Heredity* **29**, 237-245.

Simmonds, N. W. (1991) Selection for local adaptation in a plant breeding programme. *Theor. Appl. Genet.* **82**, 363-367.