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Research Article

# Pod Yield Stability of Best Groundnut Varieties from National Agricultural Research Stations Program in West Africa

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## Abstract

This study aimed to evaluate different varieties of groundnut introduced from four breeding programs in West Africa for their stability and adaptability in agro-ecological zones of Niger. The study used a randomized complete block design with three replicates at three locations. Analysis of variance revealed significant variation among varieties and the effect of environment on pod yield was highly significant (P<0.001). GGE biplot analysis was used to identify the best varieties for each environment and assess the stability of the newly introduced varieties. The GGE biplot described all the observed variations and explained 98.42% of the total variation, indicating a strong genotype by environment interaction effect. The evaluation of varietal performance indicated that Pyr-370 and Rafeet Car thrived exceptionally well in Bengou and Magaria, respectively, while El_Tarna exhibited the highest performance at Tarna. Variety SH470P was the most stable and productive among the introduced varieties in the different environments, while ICGV86124 was stable but low yielding. On the other hand, the introduced varieties ICGV86024, ICGV-IS14857 and Pyr-370 demonstrated superior productivity, yet their performance inconsistency underscored inherent instability.

## Keywords

GGE Biplot, Stability Analysis, Genotype x Environment Interaction, Pod Yield, Multi-Environment Trial

## 1. Introduction

Groundnut (*Arachis hypogaea* L., 2n = 4x = 40), is an allotetraploid legume crop cultivated for its versatile utility as oil crop, food, and livestock feed [1]. Groundnut kernels are rich in lipids (45-50%), protein (25-30%) carbohydrates (5-12%) and fiber (3%) [2, 3] Additionally, the haulms of the plant provide a rich source of high-protein feed for animals [4, 5]. Its cultivation spans approximately 32.27 million hectares worldwide, resulting in annual production of roughly 53.92 million tons of shelled grain [6]. Despite their contribution to the world global production (about 31.6%), African countries do not satisfy their domestic demand for groundnuts [7]. The sub-Saharan Africa (SSA) region exhibits one of the world's lowest levels of groundnut productivity, typically averaging less than 1 ton per hectare (< 1 t $ha^{-1}$) [8].

In Niger, groundnut is a major source of income for

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smallholder farmers. It is the most important legume crop after cowpea and is use both as a cash crop and food crop [9]. Several groundnut varieties have been developed and release by the National Agricultural Research Institute (INRAN) and the International Crops Research Institute for the Semi-Arid Tropics. However, groundnut productivity in Niger is still low (<1 t $ha^{-1}$) [10]. Increasing the productivity and yield per hectare can be achieved by introduction of high yielding groundnut varieties in the agricultural system of Niger. This study was therefore undertaken to evaluate different groundnut varieties introduced through the Innovation and Cultivar Improvement in West Africa Group (IAVAO) from five breeding programs in West-Africa (Mali, Senegal, Burkina Faso, Niger and ICRISAT/Mali). The objective of this study was to assess the stability and adaptability of the introduced varieties in agro-ecological zones of Niger.

# 2. Materials and Methods

## 2.1. Genetic Material and Field Establishment

A total of 21 varieties (7 commercially released varieties of Niger, 5 varieties from Senegal, 3 varieties from Mali, 3 varieties from Burkina Faso, and 3 varieties developed by International Crops Research Institute for the Semi-Arid Tropics station of Mali) were tested in 2021 cropping season. The characteristics of the varieties are highlighted in Table 1. The experiment was conducted using a randomized complete block design with three replicates in three locations (Bengou, Tarna, and Magaria). Each replicate was comprised of 21 plots of 4 $m^2$ (1 m x 4 m). Spacing applied was 50 cm between rows and 15 cm within rows. the trial was conducted at three. Bengou, Tarna, and Magaria had respectively a total rainfall of 503, 470 and 797 mm in 2021 cropping season.

***Table 1.*** *Groundnut varieties and their origin.*

| Variety Code | Varieties | Origin | Cycle | Pest resistance | Drought Tolerance |
|---|---|---|---|---|---|
| V1 | 55-33 | Senegal | 80 | Sensitive | Tolerant |
| V2 | 55-437 | Niger | 90 | Sensitive | Tolerant |
| V3 | Diankadap é | Mali | 85 | Resistant | Tolerant |
| V4 | El_Tarna | Niger | 85 | Tolerant | Tolerant |
| V5 | ICG9346 | Niger | 85-90 | | Tolerant |
| V6 | ICGV86015 | Senegal | 90 | Tolerant | |
| V7 | ICGV86024 | Mali | 90 | Resistant | Tolerant |
| V8 | ICGV86124 | Mali | 85 | Resistant | Tolerant |
| V9 | ICGV93305 | Burkina Faso | 90 | | |
| V10 | ICGV-IS13825 | ICRISAT Mali | 90 | | |
| V11 | ICGV-IS13989 | ICRISAT Mali | | | |
| V12 | ICGV-IS14857 | ICRISAT Mali | | | |
| V13 | Kiema | Burkina Faso | 90 | | Tolerant |
| V14 | Mai Jimiri_1 | Niger | 90 | | Tolerant |
| V15 | Pyr-370 | Senegal | 90-100 | | |
| V16 | Rafeet Car | Senegal | 90 | | Tolerant |
| V17 | Sanmut 24 | Niger | 80-90 | Resistant | |
| V18 | SH470P | Burkina Faso | 90 | | |
| V19 | T169-83 | Niger | 90 | Sensitive | Tolerant |
| V20 | T177-83 | Niger | 90 | Sensitive | Tolerant |
| V21 | Taaru | Senegal | 90 | | Tolerant |

### 2.2. Data Collection

Data collected include, days to first flowering, days to 50% maturity, late leaf spot scores, plant biomass, 100-seed weight, shelling percentage, harvest index and pod yield. In the course of this study, only pod yield was considered for statistical analysis. Pod yield was calculated based on the weight of the total harvested pods from a 1m$^2$ area at physiological maturity for all locations and expressing this weight in kilograms as a percentage of the total planted area.

### 2.3. Statistical Analysis

Analysis of variance (ANOVA) for pod yield data was conducted using R software version 4.2.2 to determine the genotype, environment and genotype by environment interaction effects. GGE biplot method was employed to analyze and assess the interaction and yield stability. The GGE biplot was generated based on the first two principal components (PC1 and PC2). Subsequently, GGE biplot analysis was also applied to produce graphical representation for (i) assessing mean performance and stability, (ii) identifying which-won-where pattern, and (iii) assessing the ranking discrimination and representativeness of test locations.

## 3. Results and Discussions

### 3.1. Variability Among Varieties for Pod Yield

Analysis of variance at 0.05 probability level revealed that there was significant variation among the groundnut varieties ($P < 0.01$). Effect of environments on pod yield was highly significant ($P < 0.001$), while effect of varieties by environments interactions was significant at 0.05 probability level. This implies that yield of varieties in each environments varies significantly. In this investigation, the climate conditions documented for each location varied distinctly. In consideration of this aspect, the significant variations observe (Table 2) can be ascribed to environmental factors.

***Table 2.*** *Analysis of variance for yield data obtained from groundnut varieties trials conducted in Bengou, Magaria and Tarna in 2021 cropping season.*

| Source of variation | DF | Sum Sq. | Mean Sq. | F value | Pr (>F) | |
|---|---|---|---|---|---|---|
| Rep | 2 | 70.05 | 35.03 | 1.42 | 2.7406 | . |
| Env | 2 | 10993.15 | 5496.57 | 222.29 | <0.001 | *** |
| Varieties | 20 | 1089.83 | 54.49 | 2.2 | 0.005 | ** |
| Varieties.Env | 40 | 1714.92 | 42.87 | 1.73 | 0.012 | * |
| Residual | 124 | 3066.19 | 24.73 | | | |

### 3.2. GGE Biplot Analysis

The GGE biplot analysis was employed to identify the best varieties for each environment and assess the stability of the newly introduced varieties based on the discriminating and representativeness of the GGE biplot view [10]. The biplot described all the observed variations and explained 98.42% of the total variation, with PC1 (axis 1) explaining 81.80% and PC2 (axis 2) explaining 16.82% (Figure 1). This high percentage of variability of GGE biplot indicates that there is strong genotype by environment interaction effect resulting in high variation of pod yield among the groundnut varieties across the three testing environments [5, 11].

Genotypes or environments characterized by high positive PC1 scores are indicative of high productivity or high potential locations respectively. In the biplot (Figure 1) Variety Pyr-370 exhibited the highest positive PC1 score demonstrating its high yielding potential, while Bengou exhibited the largest PC1 score, highlighting its significance as a best environment.

Conversely, genotypes or environments with PC1 scores close t0 zero were categorized as less productive or possessing lower potential, respectively. According to the biplot (Figure 1), ICGV86015 and El_Tarna exhibited the lowest yields, while Magaria was identified as a location with limited potential.

Variety performance in each environment is shown is Figure 2. For the three environments, varieties with the smallest perpendicular lines with the average environmental axis are considered the most stables [12]. Variety SH470P was the most stable and productive variety in the various environments, while varieties 55-33, 55-437, and ICGV86124 were stable but low yielding (Figure 2). Varieties Mai Jimiri_1, and ICGV-IS13989 were moderately stable in the environments. In contrast, Pyr-370 was the most unstable high yielding variety across the environments.

Consequently, varieties ICGV-IS 13989 and ICG 9346 are the ideal varieties, as shown by their positions (Figure 2). Varieties close to the ideal accessions are also said to be good. On the other hand, varieties ICGV 86015, Kiema, EL_Tarna, and Diankadape are identified as the least favorable varieties due to their significant distance from the concentric circle.

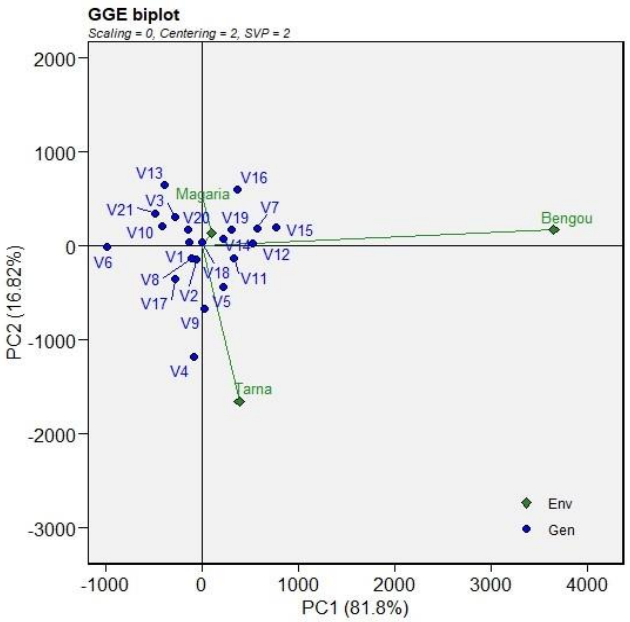


*Figure 1. GGE biplot graphical representation of the 21 groundnut varieties in the three locations.*

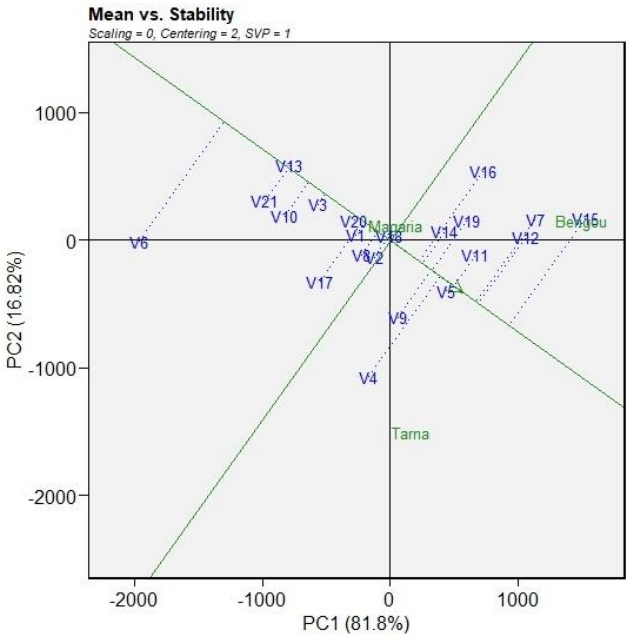


*Figure 2. Evaluation of the performances of the varieties in the three environments.*

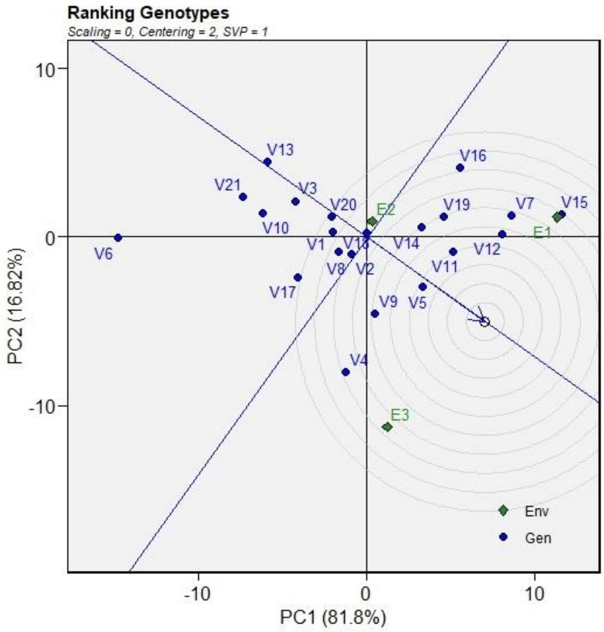


*Figure 3. Ranking of varieties.*

The careful selection of test environments necessitates a comprehensive evaluation of the capacity to distinguish genetic variations [14, 15]. In terms of discrimination and representativeness, Bengou emerges as an outstanding test environment, due to its elongated vector and minimal angle with an ideal environment. However, variety SH470P, Mai Jimiri_1, and ICGV-IS14857 were the most discriminating among the varieties studied (Figure 4).

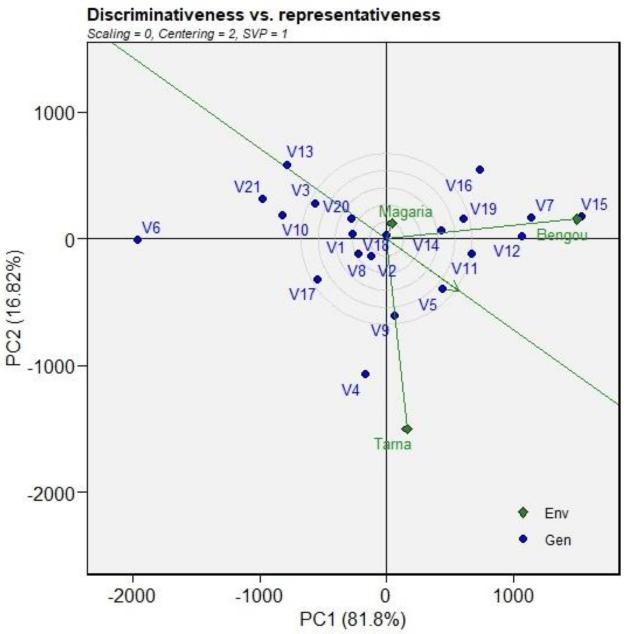


*Figure 4. Discriminativeness and representativeness of the accessions with the environments.*

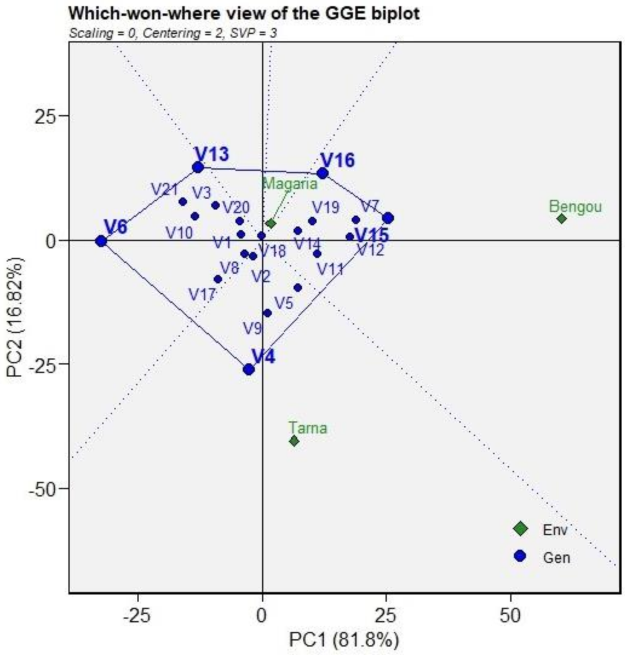


***Figure 5.*** *"Which-won-where" plot showing the most suitable varieties for each test environment.*

"which-won-where" biplot is a polygon representation that allows for the visualization of genotype by environment interaction patterns, ultimately facilitating the identification of specific adaptations [16]. Varieties situated at the corners of the polygons in the biplot are considered the top-performing varieties in their respective environments and showcase superior performance and adaptability within those environments [16]. These varieties' prominence suggests that they are highly responsive and exceptional in terms of their potential yield within their specific environments [17]. The varieties El_Tarna, ICGV86015, Kiema, Pyr-370, and Rafeet Car were all located at the corners of the polygon (Figure 5), indicating that these varieties were outstanding in terms of their yield in those environments. The evaluation of varietal performance indicated that Pyr-370 and Rafeet Car thrived exceptionally well in Bengou and Magaria, respectively, while El_Tarna exhibited the highest performance at Tarna.

## 4. Conclusions

The GGE biplot analysis used in this study aimed to evaluate the adaptability of newly introduced groundnut varieties in Niger and to identify high-yielding varieties. The results of the analysis indicated that SH470P, Mai Jimiri_1, and T169-83 were widely adapted, with SH470P being the most productive. However, it is worth noting that among these three varieties, only SH470P is an introduced variety, while Mai Jimiri_1 and T169-83 are from the Niger breeding programs. On the other hand, the introduced varieties ICGV86024, ICGV-IS14857, and Pyr-370 were found to be the most productive, but lacked stability. These varieties are recommended for further testing over multiple years. Furthermore, it is recommended to expand the scope of our study to incorporate other significant agronomic traits such as disease resistance and drought tolerance.

## Abbreviations

ANOVA: Analysis of Variance
GGE biplot: Genotype Main Effect plus Genotype by Environment Interaction
IAVAO: Innovation and Cultivar Improvement in West Africa Group
ICRISAT: International Crops Research Institute for the Semi-Arid Troprics
INRAN: National Agricultural Research Institute of Niger
PC: Principal Component

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## Author Contributions

**Coulibaly Adama Mamadou:** Conceptualization, Methodology, Funding Acquisition, Supervision, Writing–review & editing
**Abdoul-Razak Oumarou Mahamane:** Data Curation and Formal Analysis, Writing–original draft
**Halidou Yayé Tidjani:** Data Curation and Formal Analysis, Writing–review & editing
**Mahamadou Elhadji Gounga:** Supervision, Writing–review & editing

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## Conflicts of Interest

The authors declare no conflicts of interest.

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