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Research Application Summary

# Yield stability of promiscuous soybean genotypes in Uganda

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## Abstract

A field experiment was conducted in five major soybean growing areas in Uganda with 12 promiscuous soybean genotypes. Seeds of genotypes were inoculated with fresh culture of *Bradyrhizobium* sp. strain USDA 3456 and grown in the fields for two rainy seasons. Experiments were conducted in randomized complete block design with three replicates. Grains were harvested at maturity, weighed to estimate yields in kg ha$^{-1}$. Data were subjected to ANOVA, AMMI, and GGE analysis. Genotype by environment interaction was significant ($P<0.01$). Kabanyolo I, Namsoy 4M, Wondersoya, Maksoy 5N, and Nam II were stable genotypes for grain yield. Nam II and Namsoy 4M had the highest yield and the environment Kasese season B had the highest performance (1726.6 kg ha$^{-1}$). Nakabango B and Kasese B were the most discriminating environments. This study provides information that can guide cultivars recommendation in major soybean growing areas in Uganda.

Key words: AMMI, *Bradyrhizobium*, promiscuous soybean, Uganda

## Résumé

Une experimentation a été conduite dans cinq des zones majeures de production de soja en Ouganda, avec douze accessions de soja à nodulation facile. Les semences de ces accessions ont été inoculées avec une culture fraîche de la souche USDA 3456 de *Bradyrhizobium* sp, avant d'être plantées dans les champs pendant les deux saisons pluvieuses de l'année 2015. Un dispositif de blocs aléatoires complets a été utilisé avec trois répétitions dans chaque localité. Les graines de soja ont été récoltées à maturité, ces graines ont été pesées et les rendements moyens en kilogramme par hectare ont été évalués. Les données collectées ont été soumises à une analyse de variance, puis des analyses d'effets additifs et multiplicatifs de l'interaction et des interactions genotypes et genotypes-environment ont été réalisées. L'interaction genotypes-environment était significatif ($P<0.1$). les accessions Kabanyolo I, Namsoy 4M, Wondersoya, Maksoy 5N, et Nam II étaient stables pour le rendement en grains. Les accessions Nam II et Namsoy 4M avaient les rendements les plus élevés et la localité Kasese en saison B avait la plus grande performance (1726.6 kg ha$^{-1}$). Les localités Nakabango et Kasese aucours de la saison B étaient les plus discriminants. La présente étude a fourni des informations pouvant servir à identifier les variétiés de soja à recommander pour être cultivées dans chaque localité et pour chaque saison en Ouganda.

Mots clés: AMMI, *Bradyrhizobium,* soja à nodulation facile, Ouganda

## Background

Soybean (*Glycine max*, L. Merrill) is an important crop worlwide. It is a nodulating legume crop that accounts for approximatively 84.5% of the grain legumes trade in the world (Abate *et al*., 2011). Statistics from FAOSTAT (2013), showed low soybean productivity in Africa, at 2.2 million tons from 1.8 million ha of land, giving an average yield of 1,254 kg ha$^{-1}$, representing about 50% of the world's average at 2,475 kg ha$^{-1}$. One approach to boost African soybean production and productivity is to develop promiscuous soybean cultivars. For instance, unlike most soybean cultivars which require *Bradyrhizobium japonicum* for nodulation, promiscuous soybean cultivars have capability of nodulating with indigenous and readily available *Bradyrhizobium* strains (Pulver *et al*., 1985), thus avoiding the extra cost and labour required by seed inoculation. Breeding for promiscuous cultivars in soybean has shown success. At the International Institute of Tropical Agriculture (IITA), scientists have released promiscuous soybean lines which they found to efficiently nodulate *Bradyrhizobium* spp. *Bradyrhizobium* spp belong to the cowpea "cross-inoculation" group (Gwata *et al*., 2004), and are found widely spread in African tropical soils.

As most quantitative traits, promiscuous nodulation in soybean is affected by genotype by environment interaction (GEI). In this case GEI is described in terms of genotype stability and adaptability. Stability designates the ability of a genotype to perform consistently in various environments, adaptability, in contrary, refers to the ability of a genotype to perform well in some environments and poorly in other environments (Balzarini *et al*., 2005). This later enables stratify the production areas, in order to release and recommend cultivars specifically adapted to each stratum (Ramalho *et al*., 1993). It is therefore crucial to investigate the stability status of cultivars in order to make adequate cultivars selection and recommendation in breeding programs.

The main methods used to study yield stability include main effects and multiplicative interaction model (AMMI), principal component analysis (PCA), linear regression analysis, analysis of variance (ANOVA) and GGE biplot analysis. Most commonly used statistical methods in analyzing yield stability include additive main effects and multiplicative interaction model (AMMI) and genotype and genotype-by environment interaction (GGE) (Kandus *et al*., 2010).

The objective of this study was to evaluate the yield stability of promiscuous soybean genotypes in Uganda, using the additive main effects and multiplicative interaction (AMMI) and genotype and genotype-by environment interaction (GGE) biplot models.

## Study description

The study was conducted in five contrasting agro-ecological zones representing the major soybean growing areas in Uganda, namely: Ngetta, Nakabango, Kasese, Kabanyolo, and Kamwenge. Twelve promiscuous soybean genotypes were inoculated with fresh culture of *Bradyrhizobium* sp. strain USDA 3456, and planted in a randomized complete block design (RCBD) with three replicates at each site. Each plot was 1.8m x 4m wide, with 0.1m within rows. The experiments were conducted for two consecutive seasons (first rainy season (2015A) and second rainy season (2015B) of 2015 at each site, resulting in 12 testing environments (see Table 1). Fields were weeded three time in a season. At maturity, yield (kg $ha^{-1}$) was determined for each genotype. Yield data were subjected to analysis of variance, then stability analysis was performed on genotype means using additive main effects and multiplicative interaction (AMMI) and genotype and genotype by environment (GGE) models in Breeding View graphical user interface with a statistical analysis package (VSN International Ltd. Versions: 1.9 2015) embedded in Breeding Management System (BMS) Version 3.0.9.

## Results

Genotype, environment, and interaction effects were all highly significant ($p<0.01$). Environment had the highest contribution to the total variation (88.76%), while the contribution of the interaction genotype-environment was the lowest (1.78%). Genotypes Kabanyolo I, Namsoy 4M, Wondersoya, Maksoy 5N, and Nam II were the most stable, in that order. The genotypes K-local and UG5 were the least stable (Fig. 1).

**Table 1. Planting dates, pH and nutrient contents of soil fetched from experiment sites**

| Sites | Seasons | Planting[#] date (dd/mm) | pH | o.m[‡]% | Nmg/kg | Av. P[†] Cmoles/kg | K | Na | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|
| Kabanyolo | 2015A | 01/04 | 4.92 | 2.64 | 0.26 | 4.48 | 0.38 | 0.20 | 2.80 | 0.84 |
| | 2015B | 18/09 | 4.86 | 2.66 | 0.24 | 4.51 | 0.37 | 0.21 | 2.70 | 0.81 |
| Ngetta | 2015A | 12/04 | 4.78 | 1.93 | 0.19 | 4.20 | 0.21 | 0.17 | 2.50 | 0.75 |
| | 2015B | 20/09 | 6.11 | 1.91 | 0.14 | 12.31 | 0.76 | 0.60 | 4.56 | 1.50 |
| Kamwenge | 2015A | 03/04 | 4.95 | 2.29 | 0.23 | 4.48 | 0.18 | 0.20 | 3.13 | 0.94 |
| | 2015B | 14/10 | 5.45 | 2.50 | 0.18 | 7.45 | 0.32 | 0.05 | 3.12 | 1.03 |
| Kasese | 2015A | 02/04 | 5.07 | 3.34 | 0.33 | 17.82 | 0.32 | 0.09 | 5.32 | 1.60 |
| | 2015B | 13/10 | 5.08 | 3.29 | 0.31 | 17.77 | 0.33 | 0.11 | 5.29 | 1.58 |
| Nakabango | 2015A | 08/04 | 5.12 | 3.52 | 0.35 | 4.55 | 0.42 | 0.20 | 5.00 | 1.50 |
| | 2015B | 25/09 | 5.17 | 3.55 | 0.34 | 4.55 | 0.43 | 0.22 | 4.87 | 1.46 |

[†]Av. P: available Phosphorus; [‡]o.m: Organic matter; [#]dd/mm = day/month

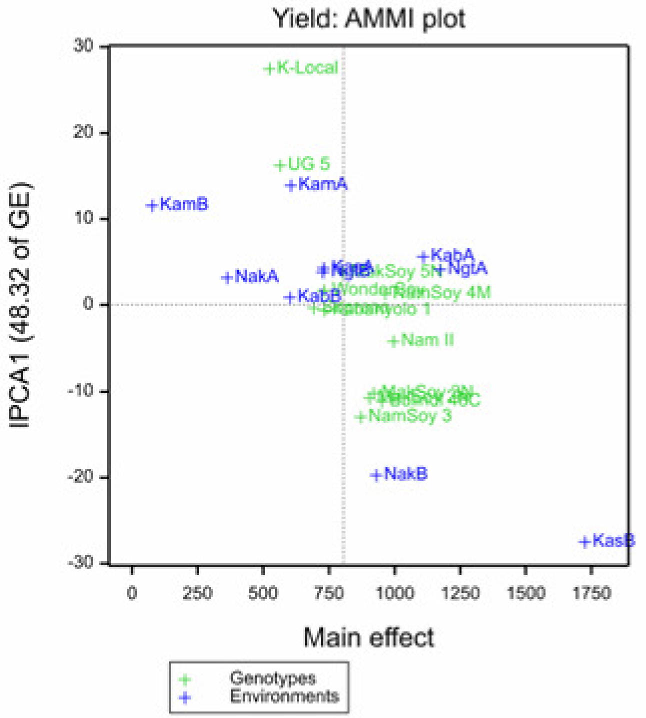


**Figure 1. AMMI biplot showing stability of the genotypes**

**Table 2. Additive Main effect and Multiplicative Interaction (AMMI) analysis of variance for yield**

| Source | d.f.# | s.s | m.s.† | Contributions (%) |
|---|---|---|---|---|
| Total | 182 | 32322919 | 2869126 | |
| Genotypes | 11 | 2696489 | 245135*** | 8.54 |
| Environments | 9 | 22921217 | 2546802*** | 88.76 |
| Interactions | 99 | 5066483 | 51177** | 1.78 |
| IPCA 1 | 19 | 2448318 | 128859*** | 48.32 |
| IPCA 2 | 17 | 979435 | 57614** | 19.33 |
| Residuals | 63 | 1638730 | 26012 | |

# d.f.: degree of freedom; † m.s.: mean square; **: significant at 0.01; ***: significant at 0.001

Among the stable genotypes, Nam II and Namsoy 4M had the highest average yield (996 and 964 kg $ha^{-1}$, respectively). Although stable, the genotypes Kabanyolo I, Wondersoya, and Maksoy 5N had average yield (average yields ranged from 731 to 803 kg $ha^{-1}$). Overall, K-local and UG5 registered the lowest yields. The GGE biplot (Fig. 2) showed that PCA 1 and 2 explained 76.95% of the total variation. Two main mega environments were demarcated. One big mega environment was made up of Kasese A, Kabanyolo A, Kamwenge A and B, Nakabango A and B, Ngetta A and B with Nam II as the best performing genotype. A smaller mega environment was made up of Kasese B, Kabanyolo B, Ngetta B, Nakabango

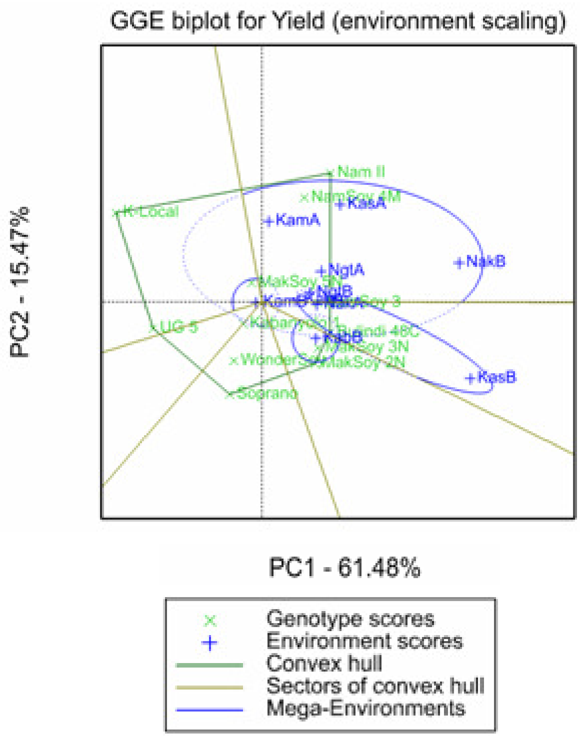


**Figure 2. GGE biplot showing mega environments and the which won where pattern of the genotypes**

A, and Kabanyolo A with Bulindi 48C as the best genotype. Bulindi 48C appeared to have specific adaptation to the environment Kasese B, as it outperformed all other genotypes in that environment and only had such high performance in that environment. The environments Ngetta B, Nakabango A, and Kabanyolo A were common to both mega environments. The environment Kasese B had the highest performance (1726.6 kg ha$^{-1}$), while the lowest performance was registered in Kamwenge B (77 kg ha$^{-1}$). Nakabango B and Kasese B were the most discriminating environments.

## Research application

Overall, the genotype mean yields in our study (525 to 996.1 kg ha$^{-}$1) were relatively low compared to 1044 to 1409 kg ha$^{-1}$ recorded in a previous study conducted by Tukamuhabwa *et al.* (2012) in Uganda, and compared to the average yield (1254 kg ha$^{-1}$) achieved in Africa (FOASTAT, 2013). This could be attributed to the within row spacing of 0.1m practiced in our experiments. The recommended intra-row spacing for soybean is 0.05m. The genotypes Nam II and Namsoy 4 M that proved stable with relatively high grain yields could be recommended for production in most areas of Uganda. However, genotype Bulindi 48C that outperformed all others in Kasese season B could be recommended to be grown in Kasese during the second season. Kasese and Nakabango that showed high discriminating power in season B, would be suitable environments for cultivar testing.

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