Response of soybean to fertilizer and Rhizobium inoculation in the NR and UWR
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Executive summary
Soybean is becoming important cash and oil seed crop which is relatively drought tolerant and requires lower production inputs, yet grain yields are generally low on farmers’ fields. The low yields are due partly to low soil nutrient levels and low management levels. In order to increase soybean yields on savanna soils that are inherently low in plant available nutrients, field trials were conducted to assess the agronomic and economic benefits of using fertilizer N, P and K as well as rhizobium inoculants for soybean production in the Guinea savanna of Ghana. The five soybean varieties tested responded similarly to the fertilizer treatments at all locations but soybean response to fertilizer and Rhizobium inoculation was inconsistent. Application of P and K fertilizers with or without inoculants tended to increase grain yield relative to the no fertilizer treatment or the treatment with only Rhizobium inoculants. Grain weight was highest for the treatment with Rhizobium inoculants only in Yendi. The synergy between Rhizobium inoculation and PK fertilization was evident at Bamahu and Yendi. However, Rhizobium inoculation did not increase soybean yields at Nyankpala and Wa. Fertilizer application as well as Rhizobium inoculation affected both growth and development of soybean plants and no fertilizer treatment reduced crop growth and grain yield significantly. Most of the locations had been planted to soybean in past years, and indigenous Rhizobium bacteria populations were probably adequate for soybean nodulation. More data is required to confirm soybean response to Rhizobium inoculation in the Guinea savanna zone. These results are preliminary and it would therefore be imperative that the experiments are repeated so as to confirm or reject these current results.

Introduction
Soybean is becoming important cash and oil seed crop which is relatively drought tolerant and require lower production inputs. Soybean may serve the dual purpose for cash and food in many households. However, yields on farmers’ fields in the Guinea savanna zone are relatively low due to erratic rainfall, low soil nutrient levels (particularly nitrogen and phosphorus), use of unimproved varieties and poor management practices. Nitrogen is the most important nutrient element which limits yield in crop production.
Trials were set up to study the effect of fertilizers and Rhizobium inoculation on soybean yield in the Guinea Savanna zone at SARI Experimental fields at Wa, Nyankpala and Yendi. Both locations are in the Guinea Savanna zone of Ghana which is a semi-arid zone, characterized by low, erratic, and poorly distributed monomodal rainfall, averaging about 1100 mm per annum. Most of the rain in the area comes as short duration high intensity storms between May and October. Mean monthly temperatures during the growing season ranged between 26°C and 30°C. The soils are typical upland soils used for soybean production in the Guinea Savanna zone of West Africa.

Materials and Methods
The experiments involving two maturity groups of soybean were conducted in a split-plot design in a randomized complete block with four replications. The experimental area was ploughed and harrowed before the treatments were imposed. For the trial involving medium maturing soybean, the main plot treatments were five soybean varieties (TGX 1834-5E, TGX 1445-3E, TGX 1448-2E, TGX 1904-6F and Jenguma). Five fertilizer treatments (no fertilizer, PK only, Rhizobium + PK fertilizer, Rhizobium only, NPK fertilizer) were applied to the subplots. Each 6-row subplot measured 5.0 x 4.5 m. The N, P and K rates were 25, 60 and 30 kg/ha as N, P₂O₅ and K₂O, respectively. Nitrogen was applied as urea (46% N). Phosphorus was applied as triple superphosphate (46% P₂O₅) and K as muriate of potash (60% K₂O). All fertilizers were applied in a subsurface band about 0.05 m to the side of the soybean row. Farmers do not commonly use fertilizer for soybean production in the area; hence the no fertilizer treatment was the control representing the farmers’ practice. Sowing date of all experiments was between 6 and 19th July, 2012. The medium maturing varieties (100-115 days) were sown in six rows of 5 m in length and 0.75 m apart. Distance between plants was 5 cm in all experiments with one seeding per stand. The soybean varieties were chosen on the basis of their superior performance in on-station and on-farm trials. Weeds were controlled manually using a hand hoe. Soybean grain was harvested at physiological maturity. Data taken included days to 50% flowering (days), plant height (m) and grain yield (kg/ha). Grain and above-ground dry matter yields were determined by harvesting the central two rows of each subplot. Biomass yield was based on samples dried to constant weight at 60°C. Data collected were subjected to analysis of variance (ANOVA) to establish treatment and the interactions effect on grain yield and yield components. Statistical analyses were performed with the Statistical Program SAS for Windows 9.1® (SAS Institute Inc., Cary, NC, USA). Variety and fertilizer treatments were considered as fixed effects and replication were treated as random
Main effects and all interactions were considered significant when $P \leq 0.05$. Simple correlations were used to test association among traits.

**Results and Discussion**

At all locations where this study was conducted, the interaction of variety x fertilizer treatments interactions were not statistically significant for grain yield and yield components, therefore the main effects of variety and fertilizer effects are reported and discussed in this report.

**Nyankpala location**

At the Nyankpala site, differences among the medium maturing varieties were significant for pod number, pod weight per plant as well as grain yield. Jenguma, TGX 1448-2E and TGX 1904-6F had numerically more pods per plant than TGX 1834-5E and TGX 1445-3E. It should be noted that Jenguma and TGX 1448-2E are the same varieties except that they are from different sources. Although TGX 1834-5E recorded numerically fewer pods per plant, its pods were quite heavy and were comparable to those of Jenguma, TGX 1448-2E and TGX 1904-6F. Three varieties (Jenguma, TGX 1448-2E and TGX 1904-6F) had higher but similar grain yields. Their yields on one hand, however, were greater than those of TGX 1834-5E (released as Afayak) and TGX 1445-3E (released as Songda). Fertilizer treatment only had a significant effect on nodule dry weight per plant. Although the use of mineral fertilizer tended to have higher grain production, the yields were not significantly different from those obtained from no fertilizer and only Rhizobium inoculants treatments. The application of Rhizobium inoculants only tended to increased grain yield when compared with the no fertilizer treatment but the difference was not statistically significant. Soybean did not respond to inoculation at this site even with N, P and K fertilizer addition.

**Yendi location**

At the Yendi site, differences among the medium maturing varieties were significant for pod and grain weight per plant only. The varieties differed very little with respect to time required to obtain specific growth stages. The varieties produced similar yields. TGX 1904-6F recorded the highest pod weight per plant (16.2 g/plant) while TGX 1448-2E had the least (9.5 g/plant). Grain weight per plant was highest for TGX 1834-5E and least for TGX 1448-2E. Fertilizer treatment had a significant effect on grain weight per plant and final grain yield at maturity only. Grain weight was highest for the treatment with Rhizobium inoculants only although this was not statistically significantly different from those obtained from the mineral fertilizer treatments. The no fertilizer treatment had the least grain weight per plant. Grain yield and grain weight per plant followed a similar trend. Rhizobium inoculation significantly increased grain yield at Yendi and this yield was comparable to those obtained from the treatments with PK only or PK with Rhizobium inoculants. The synergy between Rhizobium inoculation and PK fertilization was evident at Yendi. The recommended fertilizer rate for soybean (25-60-30 kg/ha as N, P$_2$O$_5$ and K$_2$O, respectively) and the no fertilizer treatments had similar yields at Yendi. The reason for these inconsistencies in grain yield response to NPK fertilization at this site is unclear.