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Full Length Research Paper

Comparative analysis of groundnut varieties in different agro-ecologies of Sierra Leone

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Nine groundnut trials were conducted in the Southern Province of Sierra Leone in 2012 and 2013. The objectives of the trials were to evaluate the performance of two improved/groundnut varieties (Samnuts 22 and 23) and one improved local variety in the transitional rain forest and the savanna grassland agro-ecologies in the Southern Province of Sierra Leone, and to evaluate the responses of the varieties to phosphorous fertilizer. The experiments were laid out in a randomized complete block design with three replications. Grain yield by the treatment combination was significantly higher in the transitional rain forest than in the savanna grassland. The variety Samnut 23 performed significantly higher in terms of grain yield than the varieties Samnut 22 and Slinut 1, while the variety Samnut 22 produced more stover yield than Samnut 23 and the improved local variety in the two agro-ecologies considered in both years, an indication that Samnut 23 could be recommended for grain production while Samnut 22 recommended for fodder production in both agro-ecologies. Addition of single super phosphate (SSP) fertilizer enhanced the performance of all the varieties and also increased the formation of nodules by the varieties and had significant effect on biomass production. The improved local variety was an early maturing variety; Samnut 23 was a medium maturing variety, while Samnut 22 was a late maturing variety.

Key words: Forest transitional, savanna woodland, Samnut, *Arachis hypogaea*, agro-ecologies, haulm, stover, biomass, fodder.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), also known as peanut, is an important food and cash crop across West Africa. The crop is cultivated mainly by small-household and resource-poor farmers (including women). Cultivated groundnut (*A. hypogaea* L.) belongs to genus *Arachis* in subtribe Stylosanthinae of tribe Aeschynomenea of family Leguminosae. It is a self-pollinated, tropical annual legume (Ntare et al., 2008). It is a legume that ranks 4th among the oilseed crops and 13th among the food crops of the world. It provides high quality edible oil (48 to 50%), (used in cooking, margarines, salads), easily digestible protein (26 to 28%), and about half of the 13 essential vitamins and more than a 3rd (7) of the 20 essential minerals necessary for normal human growth and maintenance. In addition it produces high quality fodder for livestock (Taru et al., 2008; Multipurpose Groundnut Feb, 2009)

Groundnut is by far the most important grain legume grown in Sierra Leone. It is predominantly grown in the Northern Province of Sierra Leone (IDRC, 1982). Planting is done at the onset of the rains (1st Season in most areas in Sierra Leone) between April and June and harvesting is done in August and September. Production in Sierra Leone is completely by hand using hoes as a tool and no input of fertilizer or pesticides using predominantly disease susceptible local varieties.

According to Food and Agriculture Organization (FAO), groundnut production data (FAO STAT, 2008) yields of groundnut in Africa are much lower than the average world yields, and yields in Sierra Leone are very low (0.6 to 0.7 tons/ha.). Researchers attribute this low yield to biotic, abiotic and socio-economic factors (Caliskan et al., 2008; Pande et al., 2003; Upadhyaya et al., 2006) including soil nutrient deficiencies (especially calcium and phosphorous) moisture stress, pest (especially rodents) and disease problems, low plant population poor weed control and unavailability and lack of access to quality seed of improved varieties.

Some of the most crucial characteristic differences between agro-ecologies are climatic - the rainfall distribution pattern and average temperatures. The average rainfall in the growing period of the crop was different both in the quantity, and pattern of distribution in the 2 years of growth in the two agro-ecologies. Kamara et al. (2011) indicated the influence of agro-ecology on groundnut pod yield in the Sudan and Northern Guinea savannah in North Eastern Nigeria.

The importance of phosphorous for legume production has been recognized for a long time. Franco and Avillio (1976) suggested that legumes may require more phosphorous than non-legume because of their higher requirement of phosphorous for symbiotic nitrogen fixation. Anil et al. (2008) stated that among the essential plant nutrients phosphorous is most important for seed production, helping to form a healthy and sound root system which is essential for nutrient uptake from the soil. Further, phosphorous is a component of adenosine diphosphate (ADP) and adenosine triphosphate (ATP). Phosphorous plays a role in cell division, flowering, crop maturation, root development and nodulation

Phosphorus (P) deficiency is the most frequent nutrient stress for growth and development of grain legumes including groundnut (Kamara et al., 2008). One of the most important soil nutrients for crop production is phosphorous. Phosphorus plays an important role in the maturity of the crop, root development, photosynthesis, nitrogen fixation and other vital physiological processes. In the order of importance to crop performance, phosphorus is rated second to nitrogen (Gervey, 1987). Sharma and Yaday (1997) reported that phosphorus plays a beneficial role in legume growth by promoting extensive root development and thereby ensuring a good yield. Balasubramanian et al. (1980) observed in a fertility study that phosphorus application results in better nodulation and seed yield. Rhodes (1983) reported that phosphorus application improved nodulation and seed yield of cowpea. El-Dsouky and Attia (1999) also attributed increased number and weight of nodules, nitrogen activity and groundnut yield to phosphorus fertilization. Kwari reported that, low phosphorus content of the soil may restrict *rhizobia* population and legume root development, which in turn can affect their N_2 fixing potential (Kwari, 2005). Studies conducted by researchers in Savanna regions of Nigeria showed that application of P at the rate 20 to 40 $kgha^{-1}$ significantly improved the performances of the grain legumes, groundnut (Balasubramanian and Nnadi, 1980); and soybean (Kamara et al., 2007).

Crop species and varieties, differ in their tolerance to low soil P and in their ability to utilise soluble P sources under different climatic, soil, and management conditions.

The N_2 Africa project introduced the present work through a grant through International Institute of Tropical Agriculture (IITA) from Wageningen University (Prime Sponsor) to assess performance of two varieties of groundnut at different locations in two agro-ecologies in Sierra Leone. Specifically, these experiments considered two (2) improved/exotic groundnut varieties (Samnuts 22 and 23) for evaluation of their performances and their responses to phosphorous fertilizer in the transitional rain forest and savanna woodland agro-ecologies in Southern Sierra Leone.

MATERIALS AND METHODS

The experimental set up was a randomized block design, with groundnut variety and P rate arranged in a factorial combination, replicated three times.

Two P rates were used; No SSP (-P) application and application of 270 g SSP per 12 m^2 plot (+P). Three varieties were used in these trials; Samnut 22, Samnut 23 and Slinut 1 (local control released by SLARI). Planting was done in six randomized plots, making one block in a randomized complete block design with three replications. Each plot consisted of six (6) rows with twenty (20) plants per row. The intra row distance was 20 cm, and the inter row distance was 50 cm. No P was added to the -P plots and 270 g SSP was added to 12 m^2 plot for the +P plots by banding at planting. One seed of groundnut was planted per hill for all the varieties. Each of the trials was weeded three times before harvest.

Data collection and analysis

Data was collected on % germination, Above ground biomass in subsample area of 2 m^2, oven dry weight of biomass subsample, mean nodule per treatment (sub sample of 10 plants per plot), total fresh weight of all pods in central 2 × 2 m plot, total fresh weight of all haulms in 2 × 2 m plot, oven dry weight of subsample of haulms, 100 seed weight, grain yield, and stover (haulm + husk/empty pods yield).

Data analysis was with Genstat discovery edition 3. The combined analysis was analyzed as a split - split plot design with year as the main plot factor, ecology as the sub plot factor and treatment combination (variety + or -P) as the sub-sub plot. Means were compared with least significant difference (LSD) at 5% probability.

Experimental sites

The experiment in both years was conducted at different sites

Table 1. Seed yield of treatment combination per ecology.

Treatment combination	Ecology	
	Transitional rainforest	Savanna woodland
	Seed yield (kg/ha)	Seed yield (kg/ha)
Samnut 22 (- P)	651	497
Samnut 22 (+ P)	832	631
Samnut 23 (- P)	898	620
Samnut 23 (+ P)	1167	839
Slinut 1 (- P)	277	227
Slinut 1 (+ P)	372	352

$LSD_{5\%}$ = 84.6.

within the same vicinity to eliminate any residual effect of fertilizer application and as a precautionary disease control mechanism. The agro-ecologies targeted in the study were the transitional rain forest and the savannah woodland in the Southern Province of Sierra Leone.

RESULTS AND DISCUSSION

Seed grain yield

The mean grain yields for both ecologies for the crop in 2012 at 846 kg/ha was significantly higher than the mean grain yield in 2013 at 363 kg/ha at the 5% level of probability. This may be due to rainfall distribution pattern. Rainfall in 2013 was heavy at 2710 mm but came in heavy downpours for a shorter period, while rainfall in 2012 was less heavy at 2420 mm but was more evenly distributed. The transitional rain forest ecology produced more grain yield in both years than the savanna woodland ecology, confirming report by Kamara et al. (2011) of the influence of agro-ecology on groundnut seed yield in Northern Nigeria. The seed yield of the different varieties including their interaction effect with ecology and the treatment combinations (+ and - P) were significantly different at the 5% level of probability, as shown in Table 1. The variety Samnut 23 had the highest mean grain yield in both 2012 and 2013 in both ecologies followed by Samnut 22 as is similarly reported by Bala et al. (2011) for the same varieties at the IAR experimental farm in Samaru in Nigeria. There is a consideration (Bala et al., 2011) that variety Samnut 23 is inherently higher-yielding than Samnut 22 which implies that the variety is more efficient in the manufacture of assimilate and partitioning of same to the reproductive sink. This may explain the superiority in seed yield production of Samnut 23 over variety Samnut 22. The superior performance of Samnut 23 over Samnut 22 in all agro-ecologies tried within 2 years is also reported by Kamara et al. (2011) who worked in two locations within 2 years (2005 and 2006) in the tropical savannas in Northeast Nigeria.

Phosphorous treated plots produced significantly higher seed grain yield that plots without phosphorous. Similar results are reported by Tran Thi (2003) and Anil et al. (2008) who report increase grain yield with phosphorous application. Das (2008) observe an increase in seed yield of chickpea with incremental doses of phosphorous up to 60 kg P_2O_5 /ha^{-1}. Thu Hha (2003) observe that in poor alluvial soil, yield was significantly higher than the control with 60 kg P_2O_5/ha, while the sandy soil required 90 kg P_2O_5/ha to produce a significantly higher yield. It was also observed that agronomic efficiency for P show a similar trend and is maximized at 60 and 90 kg P_2O_5/ha, in the poor alluvial and sandy soils, respectively. Rajkishore (2005) reported that the number of filled pods per plant, total number of pods per plant at harvest and pod yield per hectare and consequently yield in groundnut were influenced by different levels of phosphorus application.

Haulm yield

Significantly more haulm was produced by the crop in 2012 = 2334 kg/ha than the crop in 2013 = 1106 kg/ha (p =.001, $LSD_{5\%}$ = 354.1). The crops in the transitional rain forest agro-ecology produced a significantly higher average haulm yield = 1808 kg/ha than those grown in the savanna woodland agro-ecology =1650 (p = <0.001, $LSD_{5\%}$ = 227.9). The varietal responses to phosphorous treatment and their interaction with environment were also significant (Table 2). However, the local variety produced more haulm yield in the savanna woodland ecology than in the forest transition ecology, rendering this variety more adaptable for haulm production in this ecology. The variety Samnut 22 produced more haulm than the varieties Samnut 23 and the local variety/check Slinut 1. All the varieties showed increased haulm yield (increased dry matter production) with the application of phosphorous in both ecologies. Das et al. (2008), Ranjit (2005), Kamara et al. (2010) and Kausale et al. (2007) also report increase in haulm production with addition of phosphorous. Singh and Ahuja (1985) reported that applied phosphorous increase the leaf area and increase accumulation of dry matter.

Patel et al. (1990) and Deshmukh et al. (1995) reported

Table 2. Haulm production of treatment combinations per ecology.

Treatment combination	Ecology	
	Transitional rainforest (kg/ha)	Savanna woodland (kg/ha)
Samnut 22 (- P)	2237	1969
Samnut 22 (+ P)	2966	2433
Samnut 23 (- P)	1323	1401
Samnut 23 (+ P)	2311	1434
Slinut 1 (- P)	867	1321
Slinut 1 (+ P)	1144	1278

$LSD_{5\%}$ = 266.7.

Table 3. Mean husk production of treatment combination per ecology.

Treatment combination	Ecology	
	Transitional rain forest (kg/ha)	Savanna woodland (kg/ha)
Samnut 22 (- P)	389	410
Samnut 22 (+ P)	615	439
Samnut 23 (- P)	455	393
Samnut 23 (+ P)	646	516
Slinut 1 (- P)	206	237
Slinut 1 (+ P)	296	343
Mean	434.5	389.7

$LSD_{5\%}$ = 132.6.

that dry matter accumulation in groundnut is as a result of leaf and stems growth during the vegetative phase and a combination of pod and kernel growth concurrent with shifts in leaf and stem mass during reproductive phase. Dry matter accumulation due to 40 and 80 kg ha^{-1} P levels was 10.0 and 9.8%, respectively; moreover no P. The increase in dry matter due to P could be mainly due to active involvement of P in carbohydrate metabolism which helps in putting more vegetative growth

Husk yield

The husk produced by the varieties was significantly affected by the treatment combination (variety + or - P), ecology and their interactions at the 5% level of probability (Table 3). The varieties produced significantly more husk in 2012 than in 2013 ($p <.004$); this may be due to the superior performance of the crop in 2012 than in 2013. The ecology had significant effect on husk production ($p = 0.321$) with the transitional rain forest producing on the average more husk yield than the savanna woodland ecology probably due to more pod production in the transitional rainforest. The variety Samnut 22 produced significantly more husk in the transition rainforest ecology than in the savanna woodland ecology. All of the varieties showed increased production of husk with the addition of phosphorous. Phosphorous addition increased the dry matter production in the varieties as stated also by Ranjit (2005) and Kamara et al. (2010).

The mean husk production was not significantly different between the varieties Samnut 22 and Samnut 23; however, the husk weight produced by both varieties was significantly different from the husk weight produced by Slinut 1 ($P < 0.001$).

The husk produced by Slinut 1 is thin/light weight with a smooth reticulation, while husk produced by Samnut 22 and Samnut 23 are robust with rough reticulation.

Stover yield

The varieties (treatment combinations) and their interaction effect with year and ecology were very significant for mean stover production. Year had a significant effect on stover production by the different treatment combinations, with more stover being produced in 2012 than in 2013 ($p = 0 .002$). This is due to the superior performance of the crop in 2012 than in 2013. The agro-ecology also had a significant effect on stover production ($p = 0.036$). More stover was produced in the transitional rainforest than in the savanna agro-ecology.

The treatment combinations had significant difference

Table 4. Mean Stover production of treatment combination/ecology.

Treatment combination	Ecology	
	Transitional rain forest (kg/ha)	Savanna woodland (kg/ha)
Samnut 22 (- P)	2625	2440
Samnut 22 (+ P)	3581	2872
Samnut 23 (- P)	1778	1794
Samnut 23 (+ P)	2957	1950
Slinut 1 (- P)	1073	1558
Slinut 1 (+ P)	1440	1621
Mean	2242.33	2039.17

$LSD_{5\%}$ = 182.4.

Table 5. Mean Nodule production by the treatment combination per ecology.

Treatment combination	Ecology	
	Transitional rainforest (kg/ha)	Savanna woodland (kg/ha)
Samnut 22 (- P)	100.4	191.1
Samnut 22 (+ P)	169.4	178.4
Samnut 23 (- P)	88.7	58.8
Samnut 23 (+ P)	130.2	70.0
Slinut 1 (- P)	83.8	155.1
Slinut 1 (+ P)	154.0	183.8
Mean	121.08	139.53

$LSD_{5\%}$ = 10.10.

in their response to stover production in the different ecologies (Table 4). Phosphorous addition had a significantly higher effect on stover production of Samnut 22 and Samnut 23. The response to phosphorous addition in Slinut 1 though numerically higher was not statistically significant at the 5% level. The response to phosphorous addition was highest in the variety Samnut 22 which produced more stover than the varieties Samnut 23 and Slinut 1

Nodule formation

The treatment combinations (variety -/+ phosphorous) and their various interaction with ecology and year were very significant and had significant effect on the mean number of nodules produced by the varieties at the 5% level of significance. There was no significant difference between the nodules produced by the varieties in 2012. There was however, a significant difference between nodules produced by the varieties in 2013 in the two agro-ecologies with varieties in the savanna woodland producing more nodules than varieties in the transitional rainforest. The variety Samnut 22 produced the most nodules followed by the local variety, Slinut 1 and then Samnut 23. Agro-ecologies had significant effect on nodule production. There was a significant effect of the addition of phosphorous on nodule production (Table 5). Addition of phosphorous increased nodule production as is reported also by Kausale et al. (2007), Yakubu et al. (2010) and Anil et al. (2008). High response of the varieties to phosphorous with respect to nodule formation may be due to low native phosphorous content in Sierra Leonean soils in addition to the role of phosphorous in groundnut production - root formation, nodule initiation, nodule growth and functioning in nitrogen fixation.

Biomass production

The above ground biomass produced was significantly affected by the year ($p = 0.008$), ecology ($p = 0.004$) and by the varieties ($p = <0.001$) and their various interactions (p = all less than 0.005). Significantly more biomass was produced in 2012 = 3174 kg/ha than in 2013 = 1964 ($p = 0.008$). Significantly more biomass was produced by the varieties grown in the savanna woodland than in the transitional rainforest agro-ecology (Table 6).

The variety Samnut 22 produced more biomass than Samnut 23 and Slinut 1. This variety is of a long duration to maturity. The local variety Slinut 1 produced more biomass than Samnut 23. All the varieties responded to phosphorous addition for biomass production. The plots having addition of phosphorous produced more biomass

Table 6. Mean biomass production by the treatment combinations per ecology.

Treatment combination	Ecology	
	Transitional rain forest (kg/ha)	Savanna woodland (kg/ha)
Samnut 22 (- P)	1972	3132
Samnut 22 (+ P)	3199	3371
Samnut 23 (- P)	1818	2473
Samnut 23 (+ P)	2198	2285
Slinut 1 (- P)	1619	2932
Slinut 1 (+ P)	2645	2794
Mean	2241.8	2831.2

$LSD_{5\%}$ = 396.9

than plots with no addition of phosphorous. Application of phosphorus fertilizer generally increased total dry weight in both years and in both agro-ecologies. The increases in dry weight due to phosphorus application may be due to the fact that phosphorus is known to help in the development of more extensive root system (Sharma and Yaday, 1997; Gobarah et al., 2006; Kamara et al., 2011) and thus enables plants absorb more water and nutrients from depth of the soil. This in turn could enhance the plant's ability to produce more assimilates which are reflected in the high biomass production.

The response of Samnut 23 was not statistically significant within the variety at the rate of application of phosphorous in the experiment. The most pronounced effect of phosphorous addition on biomass production was in Samnut 22 which showed a very significant increase in biomass production. The effect of phosphorous on biomass production was variously reported by Kamara et al. (2010), Kausale et al. (2007) and Anil et al. (2008)

Conclusions

This study found that agro-ecology of cultivation had significant effect on groundnut seed yield, haulm production and stover yield; and that the response of groundnut to phosphorous application was steady in the two agro-ecologies, which validates the importance of P for production of groundnut in Sierra Leone. It was also found that the effect of phosphorous was influenced by the variety with some varieties showing higher response either in terms of grain yield, haulm production, and nodulation or biomass production. The variety 'Samnut 23' which is early to medium maturing produced higher grain yields than the other varieties Samnut 22 and Slinut 1. The late maturing Samnut 22, however, produced higher fodder yields than 'Samnut 23'. Both varieties (Samnut 23 and Samnut 22) are less susceptible to the prevalent *Cercospora* leaf spot disease. The variety 'Samnut 23' which is of a similar duration to maturity as most of the local varieties but is higher yielding in terms of seed yield and relatively disease resistant is recommended for farmers in Sierra Leone. However, for farmers interested in fodder for their livestock in addition to grain, the variety Samnut 22' is recommended. The transitional rainforest ecology is found more productive for groundnut production than the savanna woodland ecology especially for seed yield.

Conflict of Interests

The authors have not declared any conflict of interests.

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