RESPONSE OF SOYBEAN (*Glycine max* L. (Merr) VARIETIES TO INOCULATION IN THE SOUTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

Yield of soybean in the soils of Nigeria Savanna are often low because of inadequate effective rhizobia in the soil. The use of rhizobia inoculants may benefit the soybean plant through improved or enhanced Biological Nitrogen Fixation. The objective of this study is to determine the response of five varieties of soybean to rhizobia inoculation. A field experiment was carried out during the, 2011 and 2012 season at the Teaching and Research farm of the Federal University of Technology Gidan Kwano Minna. The experiment was laid out in a 3 x 5 factorial fitted to a randomized complete block design and replicated three times. The treatments consisted of nutrient sources and varieties (Control, Inoculated and Nitrogen in form of urea at 100 kg N/ha) and five promiscuous soybean varieties (TGX 1904-6F, TGX 1835-10E, TGX 1945-1F, TGX 1951-3F, TGX 1448-2E). The result of the experiment showed that the interaction between nitrogen sources and varieties had no significant effect on yield and yield components except for pod load and pod weight in 2011 planting season. The N-supplied treatments had similar yield and yield components as the control suggesting the effectiveness of the indigenous rhizobial population. Response to inoculation was only significant for nodule number. The main effect of varieties significantly affected plant height, pod weight, biomass dry weight and grain yield in 2011 while significantly affecting percent emergence, pod load, 100 seed weight and haulm yield in both seasons. The highest grain yield was produced by TGx 1448-2E and TGx 1951-3F suggesting the suitability of these two varieties for cultivation in the Southern Guinea savanna of Nigeria.

INTRODUCTION

Soybean is an important cash crop in Nigeria because of its rich protein and oil contents. It also plays a key role in sustaining soil fertility in agriculture through biological nitrogen fixation (Amarger, 2001). In Nigeria, this attribute is harnessed for soil fertility improvement in cereal based cropping systems in the Guinea savanna (Abaidoo *et al.,* 2006). In spite of its economic value, yields of soybean in Nigeria are often low, commonly being less than an average of 1000 kg/ha compared to world average yields (NPFS, 2009). One of the primary factors responsible for low soybean yields in Nigeria's Guinea Savanna is the inadequate number of effective rhizobia in the soil for enhanced biological nitrogen fixation (BNF) (Abaidoo *et al.,* 2013). The use of rhizobia inoculants may benefit the soybean plant through improved or enhanced BNF.

The Tropical Glycine Cross (TGx) soybean varieties that are commonly cultivated in Nigeria were developed to nodulate freely with rhizobial populations that are indigenous to tropical soils (Däshiell and Hohenberg, 1984). The aim was to obviate the need for rhizobial inoculation and reduce farmers' reliance on nitrogenous fertilizers. However, studies have shown that the TGx varieties may benefit from rhizobial inoculation in many parts of the Nigerian savanna (Osunde *et al.*, 2003; Okereke, Onochie, Onunkwo and Onyeagba, 2001). There also exist host x rhizobial interactions such that it is not in every case that an inoculant strain may effectively nodulate and enhance BNF in a host plant (O'Hara *et al*., 2002).

This study is aimed at evaluating five promiscuous soybean varieties for their response to *Bradyrhizobium* inoculation under field conditions. The specific objectives are:

(1) To determine the response of five promiscuous soybean cultivars (TGX 1904-6F, TGX 1835-10E, TGX 1945-1F, TGX 1951-3F, TGX 1448-2E) to *Bradyrhizobium* inoculation.
(2) To determine the response of these soybean cultivars to nitrogen fertilizer (urea).
(3) To establish the relationship between response of soybean varieties to inoculation and the symbiotic effectiveness of the indigenous rhizobium population

MATERIALS AND METHODS

Description of the Study Area

The field trials were carried out during 2011 and 2012 cropping season at the Teaching and Research Farm of the Federal University of Technology Minna, Niger state. The experimental has latitude 09° 32' N, longitude 06° 27' E at 232m above sea level.

Soil Sampling and Analysis

Soil samples were taken before the commencement of the trials in both 2011 and 2012 at the depth of 0-15cm. Sampling points were then randomly selected across the field and sub samples were bulked into composite sample, which was air dried and sieve through a 2 m m mesh. Routine physico-chemical analysis was carried out using standard methods (IITA, 1989). Moist soil sample obtained from the field were use in the determination of the indigenous population of rhizobia using the Most Probable

Number (MPN) method. Five-fold dilution series and three replicates were used.

Treatments and Experimental Design

The experiment consisted of 3 nitrogen sources (Control. Inoculated, Urea) and 5 promiscuous soybean varieties (TGX 1904-6F, TGX 1835-10E. TGX 1945-IF, TGX 1951-3F. TGX 1448-2E) factorially combined and replicated 3 times in a Randomised Complete Block Design (RCBD).

Agronomic Practices

Land preparation and sowing

The field was ploughed, harrowed and ridged manually with hoe each sub-plot was plots 3m x 4m containing five ridges spaced at 80cm. The soybean seeds were sown manually by drilling at an intra - row spacing of 10cm at a depth of about 1.5 - 2.0 cm. Three (3) seeds were planted per hole. Sowing was done on 7th August, 2011 and 20th July, 2012 planting season respectively.

Seeds, inoculant and fertilizers were all obtained from International Institute for Tropical Agriculture (IITA) Kano. The soybean seeds were inoculated at sowing with legume Fix a peat based inoculant containing *Bradyrhizobium japonicum* strain 532c. Single super phosphate (SSP) was also applied at sowing at the rate of 40 kg P_20_5 ha^{-1} to serve as basal application for all treatments. In 2011, the urea was applied as a single dose at the rate of 120 kg N ha^{-1} each was done at *3* and 6 weeks after planting Urea at 20 kg N ha^{-1} was also applied to all the non-nitrogen treatments as starter dose in both year. Weed control was done manually with hoes at 3 and 6 weeks after sowing

Statistical Analysis

All the data collected were subjected to analysis of variance (ANOVA) using SAS Version 9.0, 2002 statistical package. Means were compared using the Least Significant Difference (LSD) at 5% level of probability.

RESULTS

Soil Characteristics of the Study Area

The soil texture was sandy loam, pH in both year remained relatively unchanged at 6.5-6.8, while organic carbon declined from 7.42 g kg-^{1} in 2011 to 6.62 g kg^{-1} and 5.33g kg^{-1} in the uninoculated and inoculated plots, respectively in 2012. Total N content slightly improved from 0.29 g kg^{-1} in 2011 to 0.32-0.36 g kg^{-1} in 2012. Available P also remained relatively unchanged at 15-16 mg kg^{-1} in both years. Exchangeable cation content and effective CEC generally declined from 2011 to 2012.

The rhizobial population as estimated using 3 soybean varieties was much lower in the uninoculated plots of both 2011 and 2012 (93 - 465 cell g^{-1}) than the inoculated plot in 2012 (1524 – 2422 cell g^{-1}).

Table 1 Selected physico-chemical properties and rhizobial population counts of the experimental soil at the site for the trial.

	2011	2012	
Soil parameters	**Uninoculated**	**Uninoculated**	**Inoculated**
Physical properties			
% Sand	76	78	77
% Silt	12	10	14
% clay	12	12	9
Texture class	SL*	SL*	SL*
Chemical properties			
pH (Water)	6.5	6.5	6.8
pH ($CaC1_2$)	5.6	5.7	5.8
Organic Carbon (g kg^{-1})	7.42	6.62	5.33
Total Nitrogen (g kg^{-1})	0.29	0.32	0.36
Available P (mg kg^{-1})	15	16	16
Exchangeable K (cmol $^{(+)}$ kg^{-1})	0.57	0.42	0.40
Exchangeable Mg (cmol $^{(+)}$ kg^{-1})	2.72	3.04	2.56
Exchangeable Ca (cmol $^{(+)}$ kg^{-1})	3.36	2.88	2.08
ECEC (cmol $^{(+)}$ kg^{-1})	7.52	7.01	5.79
Rhizobial Population counts (cell g^{-1} of soil)			
TGX 1448-2E	93	93	2422
TGX 1835-10E	93	465	1680
TGX 1945-1F	465	298	1524

*SL – Sandy Loam

Nodule Number and Nodule Dry Weight

The main effect of nitrogen sources significantly affected nodule number only in 2012, with the inoculated plot having the highest nodule number followed by the control plot (Table 2). Nodules dry weight was not significant affected (P > 0.05) by nitrogen source nor the variety or their interaction. The main effect of variety was also had no significant effect in nodule (P> 0.05) in both 2011 and 2012.

Table 2 Effect of Nitrogen Sources and Varieties on nodule Number and Nodule Dry weight of Five Promiscuous Soya beans varieties in 2011 and 2012 Rainy Season

	Nodule Number		Nodule Dry Weight (g/plant)	
Nitrogen	**2011**	**2012**	**2011**	**2012**
Nitrogen (N)				
Control	21	28	0.1	0.4
Inoculated	21	44	0.1	0.4
Urea	17	18	0.1	0.2
LSD (0.05)	NS	12.5	NS	NS
Variety				
TGX 1904-6F	16	27	0.1	0.3
TGX 1835-10E	29	28	0.1	0.3
TGX 1945-1F	21	40	0.1	0.4
TGX 1951-3F	20	35	0.1	0.4
TGX 14458-2E	14	20	0.1	0.2
LSD (0.05)	NS	NS	NS	NS
Interaction				
N*V	NS	NS	NS	NS

NS – Not Significant

Pod Load and Pod Weight

Nitrogen sources in both seasons had no significant effect (P > 0.05) on promiscuous soybean pod load and pod weight (Table 3). The main effect of variety on pod load and pod weight was significant except for pod weight which was not significant (P > 0.05) in the 2012 season. The interaction of nutrient sources and variety significantly affected (P <0.05) pod load and pod weight in 2011 while the reverse was the case in 2012.

Table 3 Effects of Nitrogen Sources and Varieties on Pod Load and Pod Weight of Five Promiscuous Soybean Varieties in 2011 and 2012 Rainy Seasons

	Pod Load (Per Plant)		Pod Weight (g/plant)	
	2011	**2012**	**2011**	**2012**
Nitrogen Sources (N)				
Control	61	56	17.6	14.4
Inoculated	64	65	17.7	15.6
Urea	72	63	20.2	14.9
LSD (0.05)	NS	NS	NS	NS
Variety				
TGX 1904-6F	92	55	26.0	14.6
TGX 1835-10E	50	61	13.9	13.2
TGX 1945-1F	72	55	20.5	15.2
TGX 1951-3F	48	56	15.3	16.3
TGX 1448-2E	67	79	16.8	15.6
LSD (0.05)	15.3	15.2	3.7	NS
Interaction				
N*V	0.01	NS	0.02	NS

NS – Not Significant

Effect of interaction Between Treatments on Pod Load

Pod loads of control plants were marginally higher than those of the inoculated plants in TGX1945-1F and TGX 1448-2E, while those of the inoculated plants were marginally higher than the control in the TGX 1904-6F and TGX 1835-10E (Table 4). The pod load of inoculated plant of TGX 1951-3F were significantly greater (p < 0.05) than those of the control. The Urea treated plant of TGX 1835-10E, TGX 1945-1F and TGX 1951-3Fwere significantly heavier in pod load than the control.

Table 4 Interaction Effect of Nitrogen Sources and Varieties on Pod Load of Promiscuous Soybean in 2011 Rainy Season

	Nitrogen sources		
Varieties	**Control**	**Inoculated**	**Urea**
TGX 1904-6F	95.7	105.0	74.0
TGX 1835-10E	38.0	42.7	70.0
TGX 1945-IF	60.7	54.0	100.7
TGX 1951-3F	37.7	54.0	52.0
TGX 1448-2E	75.0	64.0	62.0
LSD (P = 0.05)		13.4	

Effect of Interaction between Treatments on Pod Weight

Pod weight of inoculated plant was only significantly ($p<0.05$) greater than that of the control in the TGX 1951-3F. Furthermore, the urea treatment for TGX 1945-1F and TGX 1951-3F were the only ones that had the greater pod weight than the respective control. In general, TGX 1945-1F treated with urea produces the heaviest pods.

Table 5 Interaction Effect of Nitrogen Sources and Varieties on Pod Weight of Promiscuous Soybean in 2011 Rainy Season Nitrogen Sources

	Nitrogen sources		
Varieties	**Control**	**Inoculated**	**Urea**
TGX 1904-6F	27.4	26.4	24.3
TGX 1835-10E	13.4	14.7	13.6
TGX 1945-IF	16.4	16.1	28.9
TGX 1951-3F	12.1	16.2	17.5
TGX 1448-2E	18.8	15.0	16.7
LSD (P = 0.05)		3.2	

Dry Weight of above Ground Biomass and Haulm Yield

The main effect of nitrogen sources and variety significantly ($P < 0.05$) affected biomass dry weight and Haulm yield in 2011 but not in 2012 (Table 6). The interaction between the N sources and variety was also not significant. In 2011, the urea treated plants produced the greater biomass dry weight, while those of the control and inoculated plots were similar. Haulm yield of urea plot was greater than that of the control but similar to that of the inoculated plot.

Table 6 Effect of Nitrogen Sources and Varieties on Biomass Weight and Haulm Yield of Five Promiscuous Soyabeans Varieties in 2011 and 2012 Rainy Season

	Biomass Dry Weight (g/m^2)		Haulm Yield ($kg\ ha^{-1}$)
Nitrogen	**2011**	**2012**	**2012**
Nitrogen (N)			
Control	1451.3	5112.2	1781.3
Inoculated	1403.9	5563.0	2022.3
Urea	2524.2	5598.8	2209.0
LSD (0.05)	475.4	NS	280.2
Varieties (V)			
TGX 1904-6F	1324.8	5175	2324.0
TGX 1835-10E	1725.7	5014	1783.0
TGX 1945-1F	1519.9	5014	1783.0
TGX 1951-3F	2067.0	4831	1927.8
TGX 1448-2E	2328.1	6261	2156.9
LSD (0.05)	613.7	NS	361.7
Interaction			
N*V	NS	NS	NS

NS – Not significant

One Hundred Seed Weight and Grain Yield

The main effect of nitrogen sources significantly affected ($P <0.05$) 100 seed weight and grain yield of soybean in 2011 season (Table 7). On the other hand, in 2012 the effect of nitrogen sources on 100 seed weight and grain yield was not significant ($P> 0.05$). The urea treated plot had greater seed weight than either the control or the inoculated treatment, while grain yield of the urea treatment was only significantly greater than that of the inoculated, The main effect of variety was significant (P <0.05) on 100 seed weight in both 2011 and 2012 and on grain yield in 2011. In general, the interaction between nitrogen sources and varieties did not significantly affect either the 100 seed weight or grain yield in either of the season, while TGX 1951-3F had the heaviest seed weight in 2011, this variety as well as TGX 1835-10E and the TGX 1945-1F produced the heaviest seed in 2012.

Table 7 Effect of nitrogen sources and varieties on 100 seed weight and grain yield of five promiscuous soybean varieties in 2011 and 2012 rainy seasons

	100 Seed Weight		Grain Yield (kg ha^{-1})	
	2011	**2012**	**2011**	**2012**
Nitrogen (N)				
Control	11.5	14.2	2042.7	2216.1
Inoculated	11.5	14.0	1968.1	2372.5
Urea	12.1	14.4	2244.8	2424.7
LSD (0.05)	0.4	NS	226.7	NS
Variety				
TGX 1904-6F	10.6	12.8	1956.0	2342.9
TGX 1835-10E	11.8	15.1	2004.9	2050.2
TGX 1945-1F	12.4	15.0	1895.2	2329.8
TGX 1951-3F	13.1	14.7	2336.7	2459.1
TGX 14458-2E	10.6	13.3	2233.2	2510.2
LSD (0.05)	0.6	0.8	292.7	NS
Interaction				
N*V	NS	NS	NS	NS

NS – Not Significant

DISCUSSION

Physicochemical properties and rhizobial population counts of soil.

The physical and chemical properties of the soil at the experimental site 'depict the characteristics of typical savanna soils which are generally low in organic carbon and very low in total N contents (Aliyu *et al*., 2013). On the other hand, the extractable P of the soil falls within the medium range of fertility class (Enwezor, 1990). The effective cation exchange capacity (ECEC) of the soil was low and contained low amounts of exchangeable cations which suggest low fertility status of the soil.

The indigenous rhizobial population before the first sowing in 2011 was low but eventually increased in the inoculated plot. This may be due to the introduction of *Bradyrhizobium japonicum* in the first cropping season. Three conditions were described by Giller (2001) when inoculation is necessary to establish nodulation and effective nitrogen fixation in legumes: when compatible rhizobia are absent; where populations of compatible rhizobia are low; and where indigenous populations are ineffective.

Effect of Nitrogen Sources on the Growth and Yield of Soybean

Nitrogen sources showed marginal difference in the first year between the inoculated and nitrogen treated plot. However in the second year, the inoculated plot had the highest number of nodules. This result confirms with the findings of Geeta *et al*. (2008) and Shahid *et al.* (2009) who reported that inoculating with *Bradyrhizobium* strains gave significantly higher number of nodules than those that were not inoculated. However, Okereke *et al*. (2001) in their findings also observed the presence of nodules in the uninoculated plot (control) which signifies that the soybean cultivars were promiscuous, as they were nodulated by indigenous *Bradyrhizobia* strains present in the soil. This is evident in the result of this study as the control plots had nodules on their roots. The result from this study shows that nitrogen fertilizer severely depressed nodulation.

Nodule dry weight shows no significant influence of *Bradyrhizobium* inoculation in both seasons although the inoculated and control plots had higher nodule dry weight than the nitrogen treated plots in the second year. This is consistent with the finding of Okereke *et al.* (2001) who reported that *Rhizobium* inoculation also increased nodule number and nodule dry weight in soybean.

The result of this study on Pod load and pod weight were significantly increased by inoculation in only one of the five soybean varieties although the urea treatments had greater pod load and pod weight than the control in the three varieties suggesting that although the soil N supply from the soil and BNF from indigenous population may be inadequate, the N supply from fixation due to the inoculant rhizobia was only adequate for the TGX 1951 - 3F variety. Khalid *et al*. (2009) and Elsheikh and Wood (1995) reported significant increase in pod load and pod weight respectively due to inoculation.

In contrast to the reports of other authors, 100 seed weight and grain yield was not significantly affected

by inoculation in this study. The research done by Bhuiyan, Khanam, Hossain and Ahmed (2009) clearly demonstrated that the rhizobial inoculated plants gave significantly higher stover yield and seed yield compared with uninoculated (control). However, Akpalu, Siewobr, Sekyere, and Akpalu (2014) also reported that the control and rhozobial inoculated treatments did not have any significant increase on grain yield.
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Effect of Variety on Growth and Yield of Soybean

Most of the yield parameters measured in this study were not significantly affected by the varieties used in both seasons although, in some cases there were marginal differences among the varieties used. the observed significant difference with plant among the cultivars in this study in consistent with the earlier work done by Talaka *et al.* (2013), who observed significant differences was observed among soybean cultivars for plant height. Similar to plant height, there was a significant difference in the dry weight of biomass among varieties and haulm weight differences were observed in the succeeding year. Similarly results were obtained by (Njeru, John, Richard and Gitonga 2013).

The significant difference in number of pods observed among the varieties is in agreement with earlier findings of Ngalamu *et al*. (2013) who reported differences in pod number due to varietal effect. On the other hand, Akparobi (2009) reported contrary findings on the effect of genotype on pod number per plant.

The observed effect of genotype on 100 seed weight and grain yield is consistent with other report (Akparobi, 2009; Yari *et al.,* 2013, Ikeogu and Nwofia, 2013).

CONCLUSION

This study has shown that there was no positive response to inoculation for the five varieties, suggesting that the indigenous strain performed better than the inoculant strain. In spite of lack of response to inoculation, the indigenous rhizobia could not fully meet the N_2 need of the plant. Therefore, symbiotic N_2 requirement and optimum yield potential of promiscuous soybean grown in the southern guinea savanna may not always be met by the indigenous rhizobia population. However, soybean farmers in the southern guinea savanna can derive some benefits from biological nitrogen fixation without having to inoculate their crops. Significantly increased nodulation due to inoculation did not guarantee a significant increase in economic yield. The result also shows that variety had significant positive effect on yield of soybean.

TGX 1951 -3F and TGX 1448-2E performed better in most of the parameters measured and are therefore recommended for cultivation in the southern guinea savanna of Nigeria. There is need to carry out further studies to evaluate greater number of varieties and inoculant strains to further get to the conclusion on the efficacy of inoculation on soybean varieties.

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