Maize Responses to Legume Inoculation in Legume-Maize Rotation on Three Types of Soil in Southwestern, Nigeria

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ABSTRACT

Legumes inoculation improves the ability of legume to fix N_2 and consequently soil fertility for the succeeding crop. Maize yield response to legume inoculation with indigenous rhizobial strain in a legume-maize sequence was investigated in three soil types: Nitosol, Luvisol and Alfisol. The experiment on each soil type was a randomized complete blocked design with rhizobial inoculation treatments: IDC8, R25B+IRj2180A, TRC2, O1a6(c3a) and no inoculation; maize rotation with soybean TGx1448-2E (1448-M), TGx1908-1F (1908-M) and TGx1910-2F (1910-M), cowpea IT89KD-288 (288-M) and IT97K-568-18 (568-M) and continuous maize cropping (M-M). Data were collected and analyzed on the soil characteristics, stover and grain yield and N and P uptake. Legume-maize sequence and rhizobial inoculation significantly ($P < .05$) increased grain yields of maize in the three soil types. Grain yield of 288-M, 1448-M and 1910-M under Nitosol and Luvisol were significantly higher than those of M-M. Rhizobial inoculation significantly increased maize yield. Rhizobial inoculation resulted in higher grain yield under Alfisol when IDC8- and R25B+IRj2180A- inoculated legume-maize sequence plants were compared with M-M sequence and uninoculated legume-maize sequence plants. Consequently, indigenous rhizobial strain inoculation of legume has the potentials to increase yield of maize in a legume-maize rotation system.

Keywords: Legumes, rhizobial inoculation, legume-maize sequence, maize, soil types

INTRODUCTION

Nitrogen (N) is one of the most important nutrients required in maize production. Numerous studies have proved that vitality and production of maize depend largely on the available N [1] which often comes from synthetic N fertilizers [2]. However, negative consequences on the environment and human health have been reported from the huge production and use of this synthetic N fertilizer worldwide [1]. Bloch et al. [3] reported aquatic pollution and green house emission resulting from the use of synthetic N fertilizer. More than half of the N fertilizer globally applied is lost through leaching apart from being high energy intensive, evolution of nitrous oxide in the atmosphere is also reported [4]. There are many other important processes through which nitrogen is made available to plants in the soil. One of these processes is biological nitrogen fixation, a process that involves certain prokaryotes that modulates certain group of plants (mostly legumes) and convert atmospheric N to N_2 [5].

The biological nitrogen fixation (BNF) process has been identified as an alternative source of nitrogen with lower production costs and greater use efficiency for crops [3]. Biological nitrogen fixation in root nodule symbiosis of legume has been discovered to improve soil fertility and alleviate nitrogen deficiencies problem facing small holder agriculture in Sub Sahara Africa [6, 7]. For BNF to work as an alternative source of N for crops, some biotic and abiotic factors are important for consideration such as host plant, rhizobial strain, cultivation history, drought, soil pH, salinity, mineral nutrient availability and soil organic carbon content [8]. Symbiotic association with effective rhizobia is a prerequisite to attain maximal benefits from symbiotic N_2 fixation. Symbiotic N_2 fixation can compensate for missing soil nitrogen (N) and thus potentially save costly mineral N fertilizer [9].

Central to the sustainable intensification of agriculture in sub-Saharan African, is the improvement of bacterial N fixation [10]. With the declining fertility that is experience in many parts of sub-Saharan African, incorporation of grain legumes into the cropping systems represents an opportunity to address these soil fertility concerns. Hence using BNF root nodule symbiosis of legume has been discovered to improve soil fertility and alleviate nitrogen deficiencies problem facing small holder agriculture in Sub Sahara Africa [6]. The N accrued through the BNF can be huge. Giller et al. [11] estimated nitrogen fixed by some of the grain legumes grown in the tropics as follows; soyabean 26 – 199 kg N ha-1, groundnut 68 – 206 kg N ha-1 and cowpea 47 – 201 kg N ha-1. In the West African Guinea savanna, grain legumes fix between 15 and 201 kg N ha−1 per season [12, 13].

Legume-cereal based system of farming is common in many part of West Africa and increased yields of maize (Zea mays L.) succeeding legumes relative to continuous sole maize cropping are well documented [14, 15, 16, 17]. Legumes can be incorporated through sole cropped legume-cereal rotations as predominantly practiced by farmers in the region. Biological nitrogen fixation of an effectively nodulated legume is a vital and indispensable aspect of sustainable agriculture [18], which can be harnessed further for cereal crop farming via inoculation of effective rhizobial of the legume. Lahda et al. [19] mentioned the need to incorporate a natural process such as BNF in future cereal cropping to reduce the inefficiency associated with use of synthetic nitrogen.

Incorporation of legumes into legume-cereal cropping system to supply accrued N to the cereal crop is affected by some factors such as the edaphic, host legume and rhizobia strain. Rhizobial strains differ in their capability to fixed nitrogen with different legumes and their ability to survive soil environmental factors differ [20, 21]. Compatibility of rhizobial strain with the host legume affects the amount of N fixed from the symbiosis. Franke et al. [22] stated that future research on N_2-fixation by grain legumes and residual N benefits should focus on explaining the variability observed among sites. Therefore, this study was carried out to assess the response of maize to legumes inoculated with indigenous rhizobia strain under three soil types.

MATERIAL AND METHODS

Locations and soil types

Field trials were conducted under three different soil types, nitosol, luvisol and alfisol. Nitosol is derived from metamorphic basement complex rocks [23]. The soil is predominantly Olorunda soil series [24] in Alabameji of Oluyole local government of Oyo state which lies within latitude 7º26´N and longitude 3º54´. Luvisol soil type belongs to Apomu soil series [24], it is derived from metamorphic rock and classified as Luvisols [23] in Aba-Adamo, Odeda local Gorvernment of Ogun state. It lies within latitude 7º13´N and longitude 3º31´E. While Alfisols which is derived from basement complex of rocks granite [23], within latitude 7º30´N and longitude 3º45´, it belongs to Egbeda soil series [24] in University of Ibadan Teaching and Research Farm, Ajibode Ibadan. All the sites fall within the rainforest-savanna transition zone of Nigeria. Based on the interview conducted, none of the fields had been cultivated to cowpea or soyabean in the last ten years nor had history of rhizobial inoculation

Pre-planting soil analyses

Two hundred forty (240) core top soil samples (0-15cm) were taken and bulked together **f**or each soil type for routine soil analyses and rhizobial count. The soil analyses included pH in water (1:1) [25]; soil organic matter using wet dichromate acid oxidation method [26], total nitrogen using Kjeldahl analytical method [27], available phosphorus using Bray-1 method [28], particle size using Bouyoucus hydrometer method [29] and exchangeable Mg, Ca, K and Na extracted using neutral 1M ammonium acetate and determined with spectrophotometer [29]. The rhizobial population count was determined using two soyabean varieties (TGX 1448–2E and TGX 1456-2E) and one cowpea variety (IT89KD-288) that were pre-germinated and transplanted into sterilized growth pouches. The method described by Somasegaran and Hoben [30] was used to estimate the rhizobial population of the soils.

First field trial

The first experiment was conducted to measure and compare the indigenous rhizobial isolates with the check rhizobial strains for nitrogen fixing capability by the inoculated legumes. On each soil type location, a total land area of 2,184 m^2 was cleared, marked and pegged into 4 m x 4 m (16 m^2) plots for this trial. It was a factorial combination of five 5 levels of rhizobial strains: three indigenous isolates [20] Isolate 1– OIa6(c3a), Isolate 2 – IDC8, Isolate 3 – TRC2 and check strain – R25B + IRj2180A and the control (no inoculation); five legumes- two cowpea varieties (IT89KD – 288 and IT97K– 568 – 18) three soybean varieties (TGx 1910-2F, TGx 1448-2E and TGx 1908 – IF) as well as one maize variety (TZE COMP4C2). The experiment was laid in a completely randomized design. The experiment lasted for six months of the first growing season

Second field trial

Thereafter, the fields of the three-soil types location were planted to an early maturing maize variety (TZE COMP4C2) as a follow up crop to assess the residual effect of N-fixed by the legume on the cereal crop. The trial lasted for four months of the second growing season, because TZE COMP4C2 matures at about 60-65days after planting. Planting was done at 75 cm x 25 cm using 2 seeds / hole, sown 4 – 5 cm deep and later thinned to 1 plant / stand resulting in 53,333 plants / hectare. The sequences were as follows: IT89KD – 288-Maize (288-M), IT97K– 568 – 18- Maize (568-M), TGx 1448-2E- Maize (1448-M), TGx 1908 – IF- Maize (1908-M), TGx 1910-2F- Maize (1910-M), and a maize variety TZE COMP4C2 (M-M).

The entire duration of the study was two growing seasons (two years), the study was concluded in year 2023

Data collection

The following data were collected: fresh and dry weights of stovers (t/ha), number of cobs, fresh and dried weight of cobs, grain yield/ha, %N and P in grain etc.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using PROC GLM of statistical analysis system (SAS 2003). Means were separated with Standard error and LSD.

RESULTS

Rhizobial status and physico-chemical properties of the three soil types

The most probable number counts of rhizobia in the study sites showed that indigenous rhizobial population density (cells g^{-1} soil) of Alfisol was highest. It was about two and four-fold higher than those of Luvisol and Nitosol (Table 1). The physico-chemical properties of the three soil types were different. Total N, available P, Ca, Mg and Na and soil pH were higher in Nitosol compared to other soil types. Total N and available P were two-fold higher in Nitosol when compared to those of Alfisol. Calcium in Alfisol was approximately 50 % lower compared to other soil types. The physical properties of Nitosol and Luvisol types of soil were similar, while that of Alfisol was sandier than the other soil types (Table 1)

Table 1. Rhizobial Status and Physico-Chemical Properties of the Three Types of Soil

Soil properties	Alfisol	Luvisol	Nitosol
Latitude and longitude	7º 30´N and 3º 45´E	7º 13´N and 3º 31’E	7º 26´N and 3º 54´E

Soil series	Egbeda	Apomu	Olorunda
Rhizobial count (cell g^{-1} soil)	13.54	7.81	3.8
Total N (g/kg)	0.08	0.17	0.23
Available P (mg/kg)	13.0	6.0	42.0
K (cmol/kg)	0.85	0.67	0.83
Ca (cmol/kg)	4.84	7.48	7.87
Mg (cmol/kg)	1.65	1.88	2.59
Na (cmol/kg)	0.43	0.39	0.44
Fe (mg/kg)	26.29	31.45	25.34
Mn (mg/kg)	12.38	17.41	14.74
Sand (g/kg)	812.5	675	645
Clay (g/kg)	100	185	185
Silt (g/kg)	87.5	140	170
pH (KCl)	5.76	6.09	6.55

Dry weights (t/ha) of Maize Stover from the three soil types

Alfisol generally had lower stover yield when compared to nitosol and luvisol. The stover dry weights in alfisol ranged between 7.6 – 15.8 t/ha compared to nitosol, 11.1 – 25.0 t/ha and luvisol, 11.0-23.8 t/ha. The stover dry weights of legume-maize sequence plots were significantly (p<0.05) higher than that of maize-maize sequence plots in all the three soil types **(**Table 2). The effect of rhizobial inoculation of the legumes with different strains on the stover dry weight was not significantly (P<0.05) different in all the three soil types. However, the interactive effect of the rhizobial inoculation and legume-maize sequence significantly affected the stover dry weight in all the three types of soil.

In nitosol, the stover dry weights of maize in plot 288-M inoculated with IDC8 and TRC2 isolates and plots 1448-M and 1910-M inoculated with OIa6(c3a) and IDC8 were significantly higher (P<0.05) than that of M-M plot. In luvisol, the inoculated 1910-M sequence plots had significantly higher stover dry weights than its uninoculated counterpart and M-M sequence plot. The stover dry weights of these inoculated 1910-M sequence plots were more than that of M-M sequence plot. In contrast, the stover dry weight of the inoculated 1910-M sequence plots were not significantly different (p<0.05) from the stover dry weight of M-M sequence plot in alfisol. Higher stover dry weights (P<0.05) were only observed in 288-M and 1448-M sequence plots in alfisol when compared to M-M sequence plots.

Table 2. Maize Stover Dry Weights of the Three Soil Types

Soil type	Rhizobial Inoculation	Crop Sequence								
		M-M	288-M	568-M	1448-M-	1908-M	1910-M	*Mean*		SE
Nitosol		11.1								
	OIa6(c3a)		19.6	13.6	21.1	13.9	23.9	18.42	C	1.2***
	IDC8		25.0	18.2	20.1	18.1	22.6	20.8	R	ns

	TRC2		23.3	15.7	14.7	15.6	17.9	17.44	C × R	2.8*
	R25B+		18.7	20.2	18.7	18.6	22.9	19.82		
	control		11.4	13.0	12.9	11.3	14.3	12.58		
	Mean	11.1	19.6	16.14	17.5	15.5	20.32			
Luvisol		11.0								
	OIa6(c3a)		15.3	18.4	16.6	18.2	22.4	18.18	C	0.9***
	IDC8		15.6	20.6	18.0	15.9	22.7	18.56	R	ns
	TRC2		20.1	18.0	17.6	16.0	21.2	18.58	C × R	2.1*
	R25B+		23.8	19.9	23.2	15.7	21.8	20.88		
	control		15.6	18.6	11.3	20.7	14.3	16.10		
	Mean	11.0	18.08	19.1	17.34	17.3	20.48			
Alfisol		7.6								
	OIa6(c3a)		15.8	10.3	11.9	10.9	11.8	12.14	C	0.7*
	IDC8		12.1	12.4	13.7	10.8	10.3	11.86	R	ns
	TRC2		14.0	11.2	10.7	10.4	12.1	11.68	C × R	1.5*
	R25B+		14.6	10.7	18.7	10.7	11.8	13.30		
	control		9.3	8.3	8.89	8.7	8.7	8.78		
	Mean	7.6	13.16	10.58	12.778	10.3	10.94			

SE = Standard Error; ns = not significant; ***, ** and * = p<0.001, 0.01 and 0.05 respectively †Error degree of freedom = 60 C = Crop Sequence; R = Rhizobial Inoculation

The yields of maize grain from the three soil types

The grain yields of maize in Nitosol were significantly influenced by crop sequence and rhizobial inoculation (Table 3). This was not the case in Luvisol where maize grain yields were only affected by crop sequence and no significant effect or interaction of rhizobial inoculation. Unlike Nitosol and Luvisol, crop sequence as a main effect did not significantly affect grain yields of maize in Alfisol, rather, the rhizobial inoculation and its interaction with the crop sequence (Table 3).

The grain yields of 288-M, 1448-M and 1910-M sequence plots in Nitosols were significantly higher (P<0.05) than that of M-M sequence plot (Fig 1). While the mean yields of the legume-maize sequence treatments were higher than 3 t/ha, that of M-M sequence plot was lower. The rhizobial inoculation of legumes with R25B+IRj2180A and IDC8 in 288-M, 1448-M and 1910-M sequence plots significantly increased grain yield compared to M-M and uninoculated legume-maize sequences in Nitosol. There was more than 1.5 t/ha difference when the grain yields of these treatment were compared to that M-M sequence plot. The highest yield (6 t/ha) was observed in the R25B+IRj2180A inoculated 1448-M sequence plot (Figure 1). The OIa6(c3a) and IDC8 inoculated 288-M, 1448-M and 1910-M sequence plots were significantly (p<0.05) higher in grain yield than their respective uninoculaed treatments under Nitosol.

In Luvisol, the grain yields of legume-maize sequence plots were significantly higher than that of M-M plot. Only M-M sequence plot recorded mean grain yield of less than 4 t/ha in Luvisol (Figure 2). The highest mean grain yields were observed in 288-M and 1910-M sequence plots (Figure 2). In the legume-maize sequence

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plots, there was no significant difference in the grain yield of inoculated and uninoculated treatments.

Table 3. Standard Error (P-statistics) for Grain Yield N and P Uptake

Soil Type	Source of variation	Standard Error (P-Statistics)		
		Grain Yield	Total N uptake	Total P uptake
Nitosol				
	Crop Sequence (C)	0.2***	50.4***	7.7*
	Rhizobial Inoculation (R)	0.2*	ns	ns
	C × R	0.4*	112.6*	12.2*
Luvisol				
	Crop Sequence (C)	0.1*	14*	ns
	Rhizobial Inoculation (R)	ns	ns	ns
	C × R	ns	31.3**	4.5*
Alfisol				
	Crop Sequence (C)	ns	29.6*	3.4*
	Rhizobial Inoculation (R)	0.1*	25*	2.9*
	C × R	0.3**	66.2*	7.6*

ns = not significant; ***, ** and * = p<0.001, 0.01 and 0.05 respectively †Error degree of freedom = 60

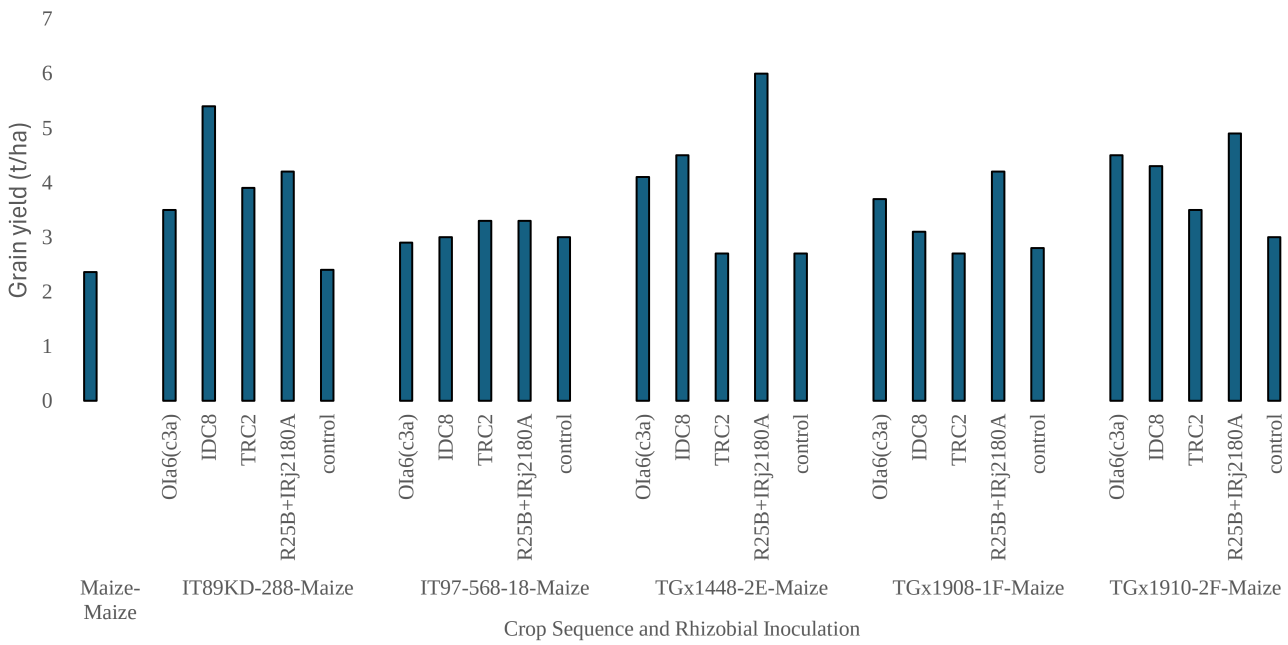

Figure 1. Grain Yield of Maize under Different Treatment in Nitosol Soil Types

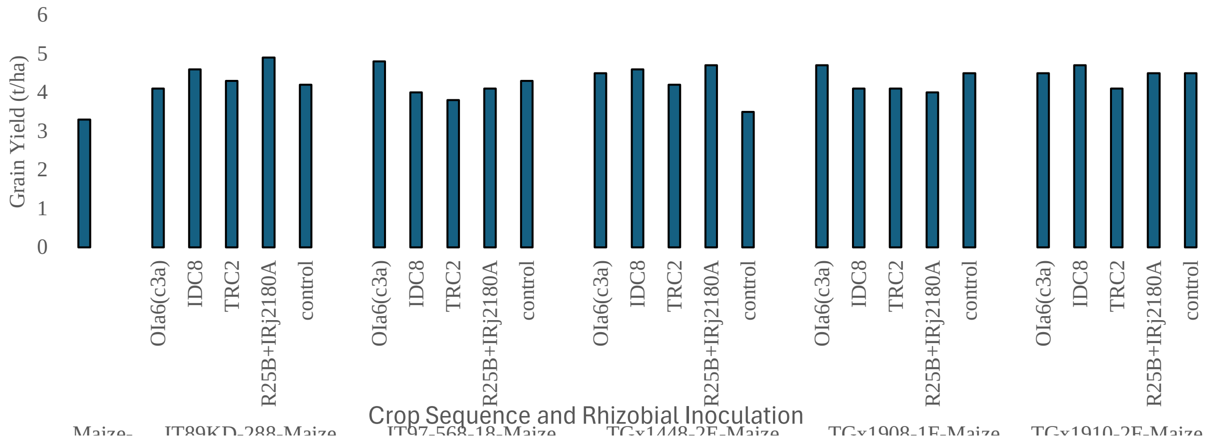

Figure 2. Grain Yield of Maize under Different Treatment in Luvisol Soil Types

In Alfisol, the grain yield of the R25B+IRj2180A inoculated 1448-M sequence plot was significantly higher than those of other treatments, about two-fold higher than that grain yields of M-M and uninoculated sequence plots (Figure 3). All the inoculated treatments of 288-M had grain yields that were significantly higher than the grain yield observed in M-M sequence plot. Also, the indigenous strain IDC8 inoculated treatments in 568-M, 1908-M and 1910-M had significantly higher grain yield than that of M-M sequence plot (Figure 3).

Total Nitrogen and Phosphorus uptake of maize grown on Nitosol, Luvisol and Alfisol

Total N and P uptake were generally higher in maize grown on Nitosol and Alfisol when compared with the Luvisol (Figure 4 and 5). In Nitosol, the N uptake in 1448-M, 1910-M and 288-M was significantly higher than that of 1908-M and 568-M. The maize in M-M sequence plot of Nitosol had significantly lower N uptake compared to any of the legume-maize sequence plot (Figure 4). Nitrogen uptake of R25B+IRj2180A inoculated plants in all legume-maize sequence was significantly higher than the M-M plants. The highest total N uptake in maize was recorded under exotic strain R25B+IRj2180A inoculated soyabean variety 1910-M plot was significantly ($p<0.05$) higher than all treatments of maize-maize, cowpea variety 568-M, soyabean variety 1908-M sequence plots. Also, IDC8 inoculated plants of 288-M and 1448-M were significantly higher. Maize plants in 288-M sequence plot had significantly higher N uptake than other treatments in Luvisol (Figure 4). Maize in IDC8 inoculated 288-M sequence plot had the highest N uptake among other treatments in Luvisol. Unlike Nitosol and Luvisol, rhizobial inoculation had significant inamong otherhe uptake of maize in alfisol. The N uptake of maize grown in R25B+IRj2180A and IDC8 inoculated 1448-M sequence plot were significantly higher other treatments except those of 288-M. N uptake of maize in uninoculated legume -maize sequence plots were not significantly different from that of M-M sequence.

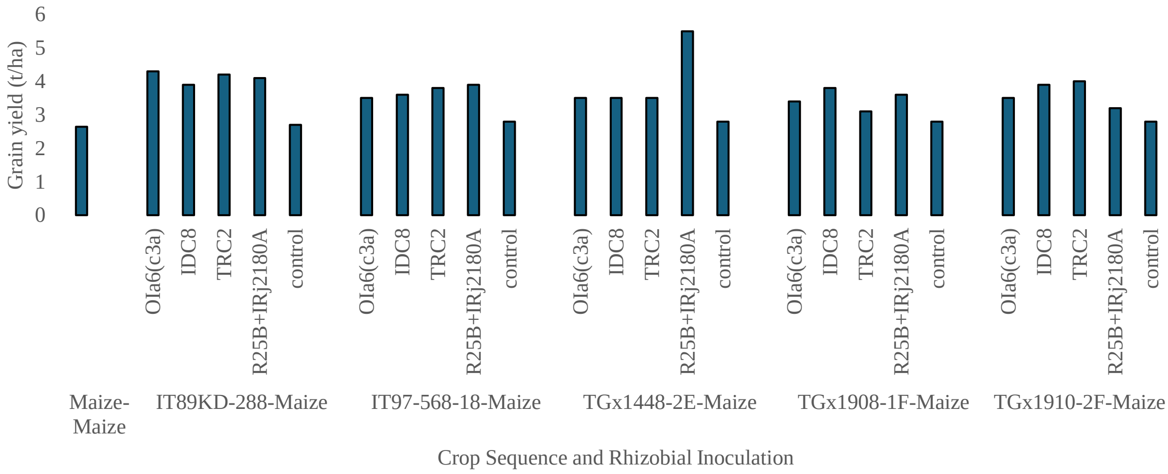

Figure 3. Grain Yield of Maize under Different Treatment in Alfisol Soil Types

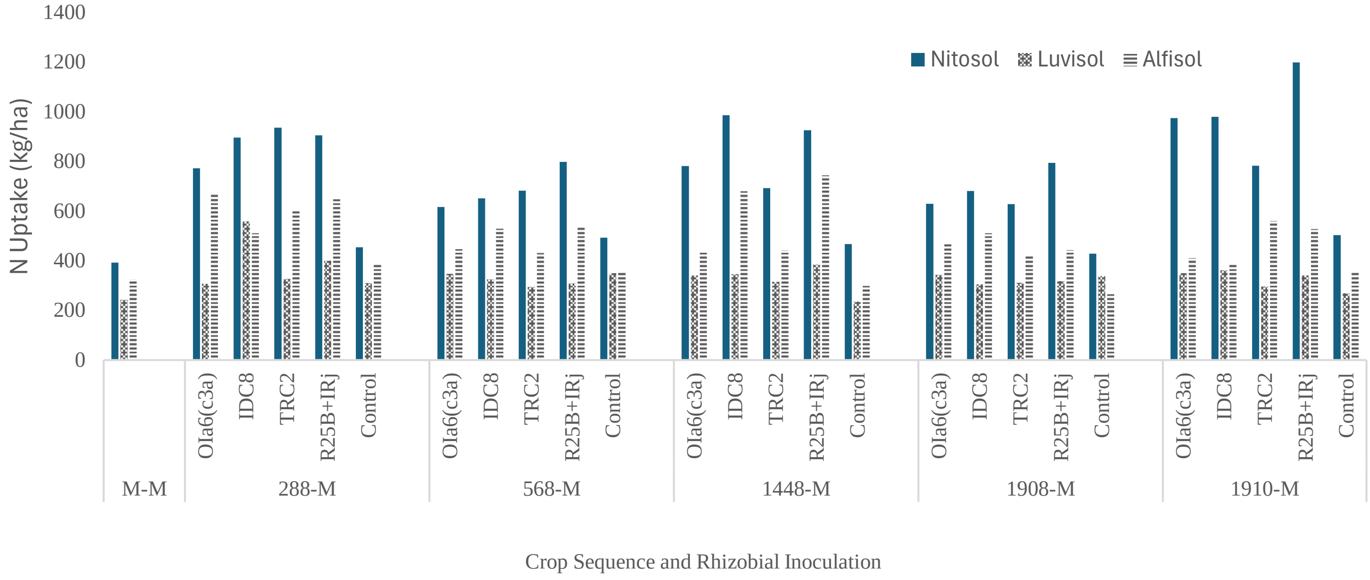

Figure 4. Total N Uptake of Maize as Affected by Treatments in Three Soil Types

The Phosphorus (P) uptake of maize was generally higher in Nitosol than other soil types (Figure 5), The P uptake of maize in 1448-M, 1910-M and 288-M sequence plot was significantly higher than other sequence plot in Nitosol and Alfisol except 1910-M (Figure 5). There was no significant difference in the P uptake of maize due to crop sequence in Luvisol (Table 3). However, the total P uptake of isolate IDC8 inoculated cowpea variety 288-M plot was significantly ($P<0.05$) higher than any other treatment under Luvisol (Figure 5). It was 100% higher than P uptake of M-M sequence plot under Luvisol. The total P uptake of maize was significantly increased under OIa6(c3a), IDC8 and R25B+IRj2180A inoculated 288-M, 1448-M and 1910-M plants when compared with the M-M sequence in Nitosol (Figure 5). The total P uptake of IDC8 inoculated 288-M and 1910-M plants in Nitosol was 100 % higher than P uptake of M-M plants in Nitosol.

In Alfisol, the P uptake was significantly influenced by the crop sequence and rhizobial inoculation and their interaction. The P uptake in 288-M plot was significantly higher ($P<0.05$) than M-M and 1908-M plots while R25B+IRj2180A and IDC8 inoculated legume-maize sequence plots had significantly higher P uptake than other rhizobial treatments. There was more than 200 % increase in P uptake when R25B+IRj2180A inoculated 1448-M plants were compared to the P uptake of M-M and uninoculated treatment of legume-maize plants.

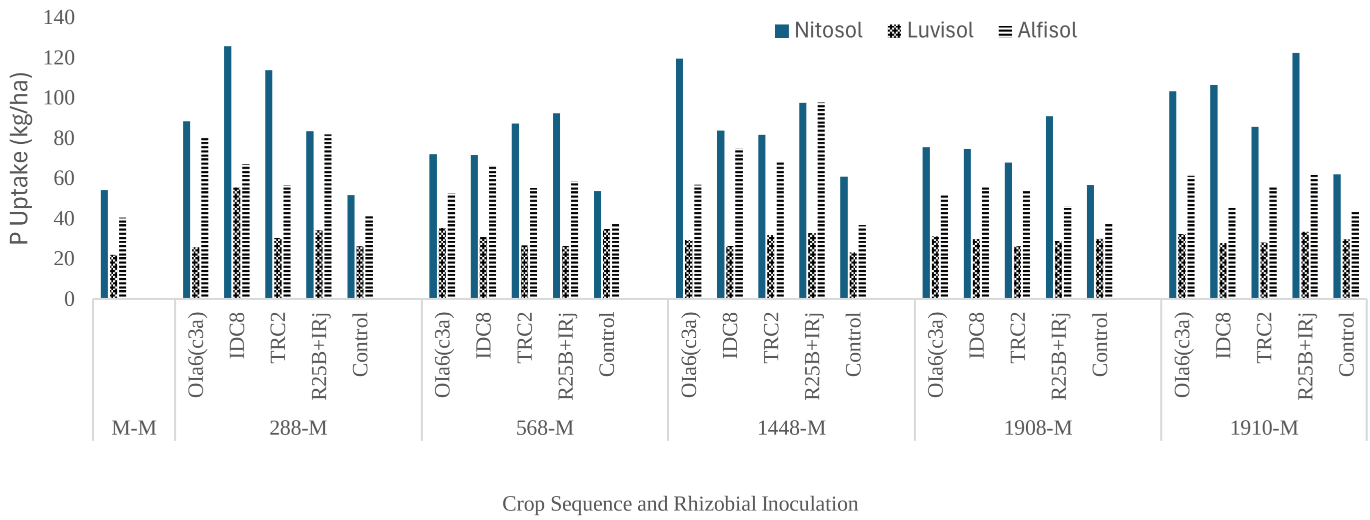

Figure 5. Total P Uptake of Maize as Affected by Treatments in Three Soil Types

DISCUSSION

Legume-maize rotation is a common practice among many farmers in the guinea savannah. Many reports have indicated increased yield of maize succeeding legumes relative to continuous sole maize cropping [15, 16, 14]. However, the contribution of inoculation to this observation has been underemphasized. In assessing the residual benefit of different legumes planted with and without inoculation in a crop rotation where maize was grown after legume (legume – maize sequence) and maize grown after maize (maize – maize sequence) under this study, the benefit of the symbiotic association between the inoculated strain and the legume planted were clearly seen and this was probably because of the N fixation from the association. Hardarson and Atkins [31] stated that the N contribution of legume–rhizobia symbiosis to total soil N is often quantified in terms of improvement in cereal yield without N fertilizer that is likely to be needed to meet up with cereal yield where cereal is planted after cereal. Success of legume cereal-rotation and subsequent maize yield increase due to succeeding legume relating to sole maize cropping was also reported by Agyare et al. [32]; Franke [14]; Yusuf et al. [17] and Kermal et al. [33]. Apart from the difference in the grain yield between legume-maize sequence and maize-maize sequence, better grain yield was also observed in inoculated treatments compared to uninoculated treatments in both soybean and cowpea varieties used for the study. It is an indication that selection of efficient indigenous rhizobial strains for inoculation of legume seeds before planting can be effective in improving legume-maize rotation cropping system. Lahda et al. [19] suggested that inclusion or incorporation of BNF which is a natural process is key to cereal cropping and indispensable aspect of sustainable agriculture.

The soils of the three experimental sites differ and the characteristics of the three soils used in the experiment indicated that the soils were generally low in fertility and rhizobia population. It has been established that the fertility of soils in the tropics are low (Vazquez et al., 2002), so also is the population of indigenous rhizobia [34]. The rhizobial population estimate of the three locations which is as follows; 13.54 cell g^{-1}soil, 7.81 cell g^{-1}soil and 3.80 cell g^{-1} soil for Alfisol, Luvisol and Nitosol respectively, which were in the range of 2 – 98 cells g^{-1}soil was an indication that seed inoculation in all the field locations is bound to be successful according to Thies et al. [35] and Brookwell et al., [36] reports that introduction of a new rhizobial strain by seed inoculation is always successful when the population of a naturalized rhizobia for a targeted legume is as low as <50 rhizobial cells g^{-1} soil. On the other hand, it has been reported that where the population of a naturalized rhizobia strains is as high as $>10^3$ rhizobial cells g^{-1} soil, inoculation often proof difficult and unsuccessful. Drew et al. [37] reported below 100 rhizobial cells g^{-1} soil threshold as a good likelihood of a response to inoculation. The effect of inoculation was more visible in Nitosol than in the other two soil types, which could be attributed to the fact that Nitosol field had the lowest rhizobial population. Moreover, the physico-chemical properties of the three soils revealed different level of nutrients and it could be significant in the interaction of the legume, rhizobia and N fixation process in benefitting the subsequent maize planted. del Rio et al. [38] listed some factors that influence amount of N fixed as follows; plant growth, rhizobial strain infecting the legume and the amount of N in the soil. Kermah et al. [39] reported that the inherent fertility of each soil type influenced the residual biomass production, N fixed, N uptake and total N contribution of legume-rhizobial symbiosis to the soil.

Rhizobial strains differ in their capability to fixed nitrogen with different legumes and their ability to survive soil environmental factors differ [20, 40]. Compatibility of rhizobial strain and legume can be a factor in N benefits derived from legume cropping by subsequent crop. Drew et al. [37] reported that the extent of nitrogen fixation is determined by the availability of effective, compatible and competitive *Rhizobium* (indigenous or exotic) in the soil, and plant genotype coupled with environmental conditions and pedo-climatic factors. Ojo et al. [20] selected indigenous rhizobial strains that were effective with soybean and cowpea in their studies, and these were used in this study. Attention was given to competitive ability and specific symbiosis that suits a wide range of soils. Despite the fact that the same inoculation treatment was applied to all the three soil types, subsequent benefit to maize was different in the three soil types. The higher grain yield observed in soybean TGx1448-2E-Maize sequence plot inoculated with R25B+IRj2180A and that of indigenous isolate IDC8-inoculated cowpea IT89KD-288-Maize sequence plot compared to other treatments in Nitosol can be attributed to the compatibility of these strains with the host varieties and the pedo-climatic conditions. Rhizobial strains differ in their sensitivity to soil conditions [41, 37] and it explains the fact that there is no rhizobial strain that is highly suitable for all soil environmental conditions, but any strain found suitable could be identified from genetic pool of isolated rhizobial strains and selected for use. The exotic strain R25B+IRj2180A and isolates IDC8 which is indigenous strains of south-western Nigeria were less hampered by the soil factors that affect biological nitrogen fixation in the three soil types for some legume-maize sequence plots.

CONCLUSION

Evaluation of maize yield in legume–maize sequence is one of the approaches to appreciate and harness the benefit of biological nitrogen fixation for sustainable agriculture in Nigeria. Legume with good genetic potential for N_2 fixation and biomass, coupled with effective and efficient rhizobial strains is also important where inoculation of legume is needed in legume-maize sequence. The indigenous rhizobial isolates in this study showed some potentials as an effective inoculum for cowpea and soybean to increase maize yield in legume-maize rotation.

RECOMMENDATION

Identification of more effective indigenous rhizobial strains are recommended to improve soil N in the absence of exotic strains where inoculation is needed in legume–maize cropping system. The study therefore recommends a legume-maize rotation system as a cropping system that increases yield of maize. Thereby making cultivation of maize cost effective and supporting food security

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