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Influence of Phosphorus Sources on Soybean Growth and Nodulation in Typic Plinthustalfs of Southern Guinea Savanna, Nigeria.

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ABSTRACT

Phosphorus is one of the most limiting plant nutrient in tropical soils. A pot trial was conducted using soils from three locations (Maikunkele, Maitunbi and Gidan Kwanu) of Bosso local government area in Minna, Niger State, Nigeria. The trial was set up in the screen house of the School of Agriculture and Agricultural Technology, Soil Science and Land Management, Federal University of Technology, Minna, in the Southern Guinea Savanna of Nigeria. The treatments include three phosphorus sources; inorganic phosphorus as single superphosphate (SSP), organic phosphorus as bone meal (BM) and bio–phosphorus as "*Glomus intaradices*" (Arbuscular Mycorrhizal Fungi) and a control, laid out in a Completely Randomized Design (CRD), replicated three times. The observed parameters includes plant height, number of branches, number of leaves, number of nodule, nodule and root dry weights. Analysis of variance was done using Genstat statistical package. Significant means were further separated using Least Significant Difference (LSD) at $P < 0.05$, soybean (TGX 1988-5F) was the test crop. The results shows that soybean responded to the treatments positively. The observed parameters (plant height, number of branches, number of leaves, number of nodule, nodule and root dry weights) were all enhanced as a result of the various sources of phosphorus applied as compared to the control. The application of inorganic–P (SSP), organic-P and bio–P (AMF) were significant at the three locations for leaf area, shoot weight (except at Gidan Kwanu where only the inorganic-P (SSP) was significant for shoot weight). The nodule number was also significant at Maikunkele and Maitunbi with the use of inorganic-P (SSP) and bio-P (AMF), while the nodule and root dry weight recorded substantial increase in weight to the application of the P-sources as compared to the control. Hence, the application of the various sources of phosphorus is worthwhile for soybean growth and grain yield improvement on Typic Plinthustalfs soil in the study area.

Key words: Bone meal, *Glomus intaradices,* Nodulation, Soybean, Typic Plinthustalfs,

INTRODUCTION

Soybean (*Glycine max* (L) Merril) is an important economic crop among grain legumes, mostly grown in a wide range of environments all over the world. It plays very important function in the natural ecosystem and agriculture, where its ability to fix atmospheric N_2 in symbiosis with *Bradyhizobium* spp. makes it a very good colonizer of low-N environment (Graham and Vance, 2003). Soybean has an average protein content of 40%, richer in protein than any of the common vegetables or animal feed sources in Nigeria. Soybean seeds also contain about 20% oil on a dry matter basis with 85% unsaturated fatty acid that is cholesterol-free (IITA, 2009). Increase in demand for this crop by the day is due to its numerous importance. Yet low soybean yield in Nigeria is alarming (Makinde *et al*., 2001 and Adeyemo *et al*., 2002). This low yield has been attributed to many factors which include; declining soil fertility, use of blanket rate of inorganic phosphorus fertilizer, low population density and use of low yielding soybean varieties (IITA, 2000). The ability of soybean to fix atmospheric nitrogen has resulted in very low usage of nitrogen for its cultivation, some farmers don't even consider it a necessity, however for soybean N–fixing ability to be efficient Ezekiel-Adewoyin (2014) reported the need for phosphorus. In Nigeria, some legume farmers do not receive any form of mineral phosphorus fertilizer, they therefore entirely rely on the natural available soil phosphorus and other nutrients for nitrogen fixation and growth and this has resulted in lower yields (Smith *et al*., 2011). When legumes dependent on symbiotic nitrogen receive an inadequate supply of phosphorus, they may suffer from nitrogen deficiency. Weisaney *et al.,* (2013) reported that the deficiency of phosphorous supply and availability remains a severe limitation to nitrogen fixation and symbiotic interactions. Phosphorus, in particular, is highly required for soybean production because the process of symbiosis (N_2 fixation) is a high energy demanding process; it also enhances energy metabolism, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation (Raghothama, 1999; Ezekiel-Adewoyin *et al.,* 2017). Despite the substantial amount of total phosphorus in tropical soils, phosphorus availability for plants is still often problematic due to binding of phosphorus by Al or Fe (Mamo *et al*., 2002). Mallarino and Reuben (2005) observed that soybean response to phosphorus (P) is dependent on soil available P, while Ferguson *et al*. (2006) reported that P concentration above 12 ppm might hinder seed yield. Many studies have confirmed that the use of P is essential for increasing soybean seed yield (Kakar, *et al*., 2002; Ogoke 2004)

Phosphorus (P) is a plant growth-limiting nutrient despite being naturally available in soils, because it is immobile in the soil and its deficiency can limit nodulation in legumes. Many soils are phosphorus deficient because available phosphorus concentration even in fertile soil is generally not sufficient (Gyaneshwar *et al*., 2002; Darryl *et al*., 2004). Therefore, application of the right form of phosphorus at optimum level and at the right time is essential for soybean production. In developing countries such as Nigeria, the use of chemical fertilizer is limited by its high cost and long-term degradation of soil and environment. Likewise, organic inputs generally do not provide sufficient P for optimum crop growth due to their low P concentration (Aulakh *et al*., 2003). However, the use of organic materials as soil amendments has been identified as an alternative approach to application of chemical fertilizers for improved soil fertility and crop productivity in the tropics, where most soils are relatively low in fertility (Aulakh *et al*., 2003). Arbuscular Myccorhiza Fungi association commonly described as the result of co-evolution events between fungi and plants, where both partners benefit from the reciprocal nutrient exchange, is another alternative. It colonizes most agricultural crops and also play important role in phosphorus supply to plants in phosphorus deficient farming systems (Smith and Read, 2004), this symbiotic association is gradually becoming an explorable option. Phosphorus is necessary for efficient growth, nodulation and optimum yield of soybean, hence, research on the influence of phosphorus sources is timely, since previous researches have shown that inadequate phosphorus fertilizer hinders soybean growth and nodulation. In Niger state of Nigeria, several researchers have reported the effect of phosphorus on soybean growth with recommendation's made, however there have been few reports comparing the effect of phosphorus sources on soybean in Typic plinthustalfs soils in the state. This study was conducted with the objective of investigating the effect of organic-P (bone meal), inorganic-P (single superphosphate) and bio-P source {(*Glomus intaradices*) Arbuscular Mycorrhizal Fungi} on the growth and nodulation of soybean in a Typic plinthustalfs

MATERIALS AND METHODS

Study site

The experiment was conducted in the Soil Science and Land Management Screen house at the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna in Niger state. The soil has been classified as Typic plinthustalfs (Lawal *et al*., 2012). Minna lies within the Southern Guinea Savannah zone of Nigeria with longitude 9° 31' E and latitude 6°30' N and an elevation of 258.5 m above sea level.

Soil sampling and analysis

Soil samples were collected for routine analysis and pot filling (2 kg) randomly from 15 points at three different locations (Maikunkele, Maitunbi, and Gidan kwanu) in Bosso local government area of Minna, Niger state, at 0-20 cm depth using sterilized soil auger and shovel. The collected soil samples were packed into different sacks and labelled properly at different locations. A composite sample was generated from the collected bulked soil samples for each location and the initial soil routine analysis was carried out in the Federal University of Technology Soil Science Laboratory, in accordance with ISRIC/FAO, (2002) method. The soil samples for the screen house trial was filled into polythene pots (2 kg each) and labelled according to location and treatments.

Treatments and experimental design

The treatments were applied as 30 kg P ha^{-1} of organic-P (Bone meal), inorganic-P (Single superphosphate), bio-P (Arbuscular Mycorrhizal Fungi (*Glomus intaradices*) 4 g pot^{-1}) and Control at each location. The experiment was laid out in three (3) replicates fitted into a Completely Randomized Design (CRD).

Agronomic Practices

Soybean (TGX1988-5F) was the test crop, four (4) seeds were sown per pot and thinned after one (1) week of emergence to two (2) stands per pot. The various treatments were applied at sowing per pot according to the requirement, except for the control pot where no treatment was added. Based on the field capacity determination, 100 ml of water was used to water the soil for three weeks, after which it was increased as required, manual weeding of the pots were done as at when necessary.

Growth parameters determined

Plants height was measured from their base to the tip using meter rule, the number of leaves were determined by counting at 2, 4 and 6 weeks after sowing. Soybean nodule counts were determined after 6 weeks, by careful removal and washing soil off the roots through a sieve, detaching the nodules from the root and counting the nodules per plant. Nodule and shoot fresh weight was taken at harvest while the dry weights were determined after oven drying at 75 ^{0}C for 48 hrs in the laboratory using the electronic weighing balance.

Statistical Analyses

Data collected were subjected to analysis of variance (ANOVA) using GenStat statistical package 11th edition (2008). Significant treatment means were separated using Least Significant Difference (LSD) at 5% level of significance.

RESULTS

The physical and chemical properties of the experimental soils before planting

The soil texture was sandy loam; with relatively high sand and fairly low clay and silt content across locations. At Maikunkele the soil was moderately acidic and suitable for plant growth at pH 5.6 according to (Brandy and Weil, 2002), while soil from Maitunbi and Gidan Kwanu were strongly acidic with pH of 5.0 and 4.8 respectively based on the rating of (Esu, 1991). The organic carbon content, exchangeable acidity, total nitrogen levels were very low across location however, total nitrogen in soil collected from Maikunkele was moderately low, available phosphorus was also moderately low across location. Furthermore, the exchangeable bases were low indicating low fertility status below the critical minimum for Nigeria soils according to Chude, *et al*., (2011). Hence, the need for soil fertility amendments.

Effect of phosphorus sources on soybean leaf number

The highest number of leaves at 2 WAS at Maikunkele was obtained from pots treated with bio-P (AMF) which was not significantly different from inorganic-P (SSP) but were both significantly higher than the organic-P (BM) and the untreated pot (control) which had the lowest value. At 4 WAS bio-P (AMF) still recorded the highest number of leaves (17.83) but was not significantly different from the other treatments, however was 25% higher than the control. At 6 WAS all treated plants recorded similar number of leaves which were significantly ($P < 0.05$) higher than that of the control. At Maitunbi and Gidan kwanu the trend of soybean leaf number count was similar to that observed at Maikunkele, in that the treated plants recorded higher leaf number which were at par with one another but significantly higher than that of the untreated (control) plants (Table 2).

Effect of phosphorus sources on soybean number of branches

The soybean plants treated with bio–P (AMF) and the inorganic-P (SSP) recorded same number of branches followed by the plants treated with organic-P (BM) and control at 2 WAS at Maikunkele, (Table 3). At 4 WAS the pattern was the same with the initial week while at 6 WAS the organic-P (BM) had the highest number of branches, followed by the pot treated with inorganic-P (SSP), which were significantly different from pots treated with bio-P (AMF) and the control which recorded the lowest value. The number of branches recorded at Maitunbi (2 WAS)

Table 1. Soils Initial physical and chemical analysis

Parameters	Maikunkele	Maitunbi	Gidan Kwanu
Sand (g kg^{-1})	768	778	798
Silt	120	100	80
Clay	112	122	122
Textural class	SL	SL	SL
pH in H_20	5.6	5.0	4.8
O.C g kg^{-1}	3.5	3.4	1.4
Ex. Acidity (c mol kg^{-1})	0.07	0.09	0.11
Total N (g kg^{-1})	1.29	0.06	0.08
Available P (mg kg^{-1})	18.55	17.73	13.87
Ex. Bases (c mol kg^{-1})			
Ca	4.43	1.81	2.32
Mg	1.22	1.88	0.42
K	0.32	0.23	0.27
Na	0.12	0.07	0.09

were at par amongst the treated pots, while the control recorded the lowest, the treated pots were 20% higher than the control. At 4 WAS pot treated with inorganic-P (SSP) had the highest number of branches followed by the pots treated with bio-P (AMF) which were higher than the control. At 6 WAS the highest number of branches were obtained from pots treated with the organic-P (BM) which was not significantly different (P > 0.05) from the pots treated with bio–P (AMF) followed by the pots treated with inorganic-P (SSP) and then the control. While at Gidan Kwanu pots treated with the organic-P (BM) and the inorganic-P (SSP) recorded the highest plant branches which were significantly different (P < 0.05) from pots treated with bio-P (AMF) and the control. The highest number of branches were recorded at 4 WAS on pots treated with bio–P (AMF) which was 23% higher than pots treated with organic-P (BM) and control followed by pots treated with inorganic-P (SSP) which was significantly different (P < 0.05) from the pots treated with Organic-P (BM) and the control. At 6 WAS pots treated with Organic-P (BM) and inorganic-P (SSP) had the highest number of branches, which were not significantly different from the pots treated with bio-P (AMF), followed by pots treated with the control which had the lowest value (Table 3).

Effect of phosphorus sources on soybean plant height

The pots treated with bio–P (AMF) and organic-P (BM) had the highest plant height values (14.63 and 14.15 cm) respectively, at Maikunkele (2 WAS) which were not significantly different (P > 0.05) from the pots treated with the inorganic-P (SSP) and control. At 4 WAS bio–P (AMF) still had the highest value (36.02 cm) at Maikunkele, which was significantly different (P < 0.05) from the pots treated with inorganic-P (SSP) which had a value of (33.40 cm), followed by the pots treated with the organic-P (BM) and then the control. Also at 6 WAS pots treated with bio-P (AMF) still maintained the highest value of (48.69 cm) which was significantly different (P < 0.05) from pots treated with organic-P (BM) and inorganic-P (SSP) then the control.

At 2 WAS the highest height was obtained from pots treated with inorganic-P (SSP) at Maitunbi which had a value of (17.65 cm) which was not significantly different (P > 0.05) from the pots treated with organic-P (BM) which had a value of (16.67 cm) and bio–P (AMF) which had a value of (15.60 cm), followed by the control which recorded the lowest value of (14.57 cm). At four weeks (4 WAS) the highest plant height was obtained from pots treated with the inorganic-P (SSP) which had a value of (43.17 cm), which was significantly different (P < 0.05) from the pots treated with organic-P (BM) which had plant height of (36.57 cm) followed by pots treated with bio-P (AMF) and control which had values of (35.11 and 33.48 cm) respectively. At 6 WAS the highest plant height was

Table 2. Effect of phosphorus sources on soybean leaf number

TREATMENTS	LOCATIONS								
	Maikunkele (WAS)			Maitunbi (WAS)			Gidan Kwanu (WAS)		
	2	4	6	2	4	6	2	4	6
Control	9.00	14.23	20.83	8.33	12.33	20.50	8.00	13.30	22.50
Bio-P (AMF)	10.00	17.83	25.50	8.83	17.83	27.00	8.83	16.67	26.50
Inorganic-P (SSP)	9.50	17.50	26.67	9.67	18.67	26.00	9.00	17.17	25.67
Organic-P (BM)	9.17	17.43	25.33	9.67	17.83	25.67	9.83	17.33	27.67
LSD	0.77	2.39	2.68	0.77	2.39	2.68	0.77	2.39	2.68

AMF = Arbuscular Myccorhizal Fungi, SSP= Single Superphosphate, BM= Bone Meal, LSD= Least Significance Difference, WAS = Week After Sowing.

Table 3: Effect of phosphorus sources on soybean number of plant branches

TREATMENTS	LOCATIONS Maikunkele (WAS)			Maitunbi (WAS)			Gidan Kwanu (WAS)		
	2	4	6	2	4	6	2	4	6
Control	1.83	5.33	7.50	1.67	5.00	8.33	1.83	5.00	7.83
Bio-P (AMF)	2.00	5.83	8.00	2.00	5.67	9.00	1.83	6.17	8.33
Inorganic-P (SSP)	2.00	5.83	8.83	2.00	6.00	8.83	2.00	5.17	8.50
Organic-P (BM)	1.83	5.67	9.17	2.00	5.50	9.17	2.00	5.00	8.50
LSD	0.23	0.76	0.76	0.23	0.76	0.76	0.23	0.76	0.76

AMF= Arbuscular Myccorhizal Fungi, SSP= Single Superphosphate, BM= Bone Meal, LSD= Least Significance Difference, WAS= Week After Sowing.

obtained from pots treated with inorganic-P (SSP) at Maitunbi which had a value of (54.57 cm) which was significantly at par with pots treated with the organic-P (BM) which had a value of (51.72 cm) and were significantly different ($P < 0.05$) from pots treated with bio-P (AMF) which had a value of (50.42 cm) and the control pots recorded the shortest plant height (48.37 cm). The plant heights obtained from soils collected from Gidan Kwanu at 2 WAS treated with the inorganic-P (SSP) had the highest value (16.53 cm), followed by pots treated with bio-P (AMF) which had a height of (15.37 cm) which was significantly different ($P < 0.05$) from the pots treated with the organic-P (BM) and the control (14.67 and 14.00 cm) respectively. Also, at 4 WAS the pots treated with inorganic-P (SSP) had the highest value (31.28 cm) which was significantly different ($P < 0.05$), followed by pots treated with organic-P (BM) with a value of (28.23 cm) which was also significantly different from pots treated with bio-P (AMF) which had a value of (27.77 cm) as shown on Table 4. At 6 WAS the highest plant height was obtained from pots treated with inorganic-P (SSP) which was not significantly different from pots treated with organic-P, followed by pots treated with bio-P (AMF) and then the control as shown on Table 4.

Effect of phosphorus fertilizer on soybean shoot growth

The pots treated with bio-P (AMF) on soils from Maikunkele had the highest value of shoot weight (6.18 g) which was not significantly different ($P > 0.05$) from pots treated with organic-P (BM) which had a value of (5.33 g), followed by pots treated with inorganic-P (SSP) which had a value of (4.95 g) and was slightly significantly different ($P < 0.05$) from the control which had the lowest value of (4.00 g). The highest shoot weight was obtained from soil treated with inorganic-P (SSP) on soils collected from Maitunbi which was not significantly ($P > 0.05$) different from soil treated with organic-P (BM) which was not significantly different from bio-P (AMF) treated plants followed by the control which had the lowest value, the pots treated with inorganic-P (SSP) was 38 % more than the control. While at Gidan Kwanu pots treated with the inorganic-P (SSP) had the highest value which was not significantly different from pots treated with the organic-P (BM) and was not significantly different from soils treated with bio-P (AMF), followed by the control which recorded the lowest value.

Effect of phosphorus fertilizer on soybean number of nodules

The highest number of nodules was obtained on soil from Maikunkele in pots treated with bio-P (AMF) which was not significantly different ($P > 0.05$) from pots treated with inorganic-P (SSP), followed by pot treated with organic-P (BM) then the control which recorded the lowest number of nodules, the pot treated with bio-P (AMF) was 61% higher than the control. On soil collected from Maitunbi the pot treated with inorganic-P (SSP) had the highest number of nodules (14.50), which was not significantly different from pots treated with bio-P (AMF) but different from the organic-P (BM), followed by the control which had the lowest number. The inorganic-P (SSP) at Gidan Kwanu had the highest number of nodules in pots treated with inorganic-P (SSP), followed by bio-P (AMF) and organic-P (BM) which was significantly different ($P < 0.05$) from the control with the lowest value Table 5.

Effect of phosphorus fertilizer on soybean nodule dry weight

The highest value of nodule dry weight was obtained on soil from Maikunkele in the pots treated with organic-P (BM) which had the highest dry weight of (0.38 g), which was 73% weightier than the control. The pots treated with the inorganic-P (SSP) at Maitunbi recorded the highest weight followed by bio-P (AMF) which had a dry weight of (0.32 g) and organic–P (BM) with a dry weight of (0.27 g), resulting in 100, 88 and 59% increase in weight over the control respectively. The inorganic-P (SSP) at Gidan Kwanu had the highest nodule dry weight followed by bio-P (AMF) and organic-P (BM) then the control which recorded the lowest.

Effect of phosphorus fertilizer on soybean root dry weight

Soil collected from Maikunkele treated with organic-P (BM) had the highest value of root dry weight (1.69 g), followed by pots treated with bio-P (AMF) which had a dry weight of (1.34 g) while soybean in pots treated with inorganic-P (SSP) and the control had dry weights of (1.23 and 1.21 g) respectively, in fact the organic-P (BM) was 40% higher than the control. Also, the highest root weight in all was obtained from soil collected from Maitunbi treated with organic-P (BM) which had the value of (2.83 g), followed by pots treated with inorganic-P (SSP) which had a dry weight of (2.01 g) which were significantly different from pots treated with bio-P (AMF) which had dry weight of (1.85 g), the plants treated with the organic-P (BM) was 76% higher than the control. Also at Gidan Kwanu, soybean in pots treated with organic-P (BM) had the highest dry weight (2.07 g) which was significantly different from pots treated with inorganic-P (SSP) which had a dry weight of 1.90 g, followed by soybean treated with bio-P (AMF) and were significantly different ($P < 0.05$) from the control which had a dry weight of (1.36 g), the organic-P (BM) recorded 52% increase in root dry weight than the control on soil from Gidan Kwanu.

Table 4. Effect of phosphorus sources on soybean plant height

TREATMENTS	LOCATIONS Maikunkele (WAS)			Maitunbi (WAS)			Gidan Kwanu (WAS)		
	2	4	6	2	4	6	2	4	6
Control	13.15	32.69	44.45	14.57	33.48	48.32	14.00	27.32	42.48
Bio-P (AMF)	14.63	36.02	48.69	15.60	35.11	50.42	15.37	27.77	42.93
Inorganic-P (SSP)	13.72	33.40	45.50	17.65	43.17	54.57	16.53	31.28	48.20
Organic-P (BM)	14.15	33.10	46.35	16.67	36.57	51.72	14.62	28.23	44.97
LSD	2.08	4.43	3.72	2.08	4.43	3.72	2.08	4.43	3.72

AMF= Arbuscular Myccorhizal Fungi, SSP= Single Superphosphate, BM= Bone Meal, LSD= Least Significance Difference, WAS= Week After Sowing.

Table 5: Effect of sources of phosphorus on soybean shoot, nodule and root growth

	LOCATIONS Maikunkele ($g\ plant^{-1}$)				Maitunbi ($g\ plant^{-1}$)				Gidan kwanu ($g\ plant^{-1}$)			
TREATMENT	SHW	NN	NDW	RDW	SHW	NN	NDW	RDW	SHW	NN	NDW	RD W
Control	4.00	25.50	0.15	1.21	4.67	6.17	0.17	1.61	4.97	1.67	0.01	1.36
Bio-P (AMF)	6.18	41.00	0.21	1.34	5.90	14.17	0.32	1.85	5.61	4.67	0.07	1.49
Inorganic-P (SSP)	4.95	33.83	0.21	1.23	6.80	14.50	0.34	2.01	6.14	8.00	0.10	1.90
Organic-P (BM)	5.33	29.83	0.38	1.69	6.43	10.83	0.27	2.83	5.83	3.40	0.02	2.07
LSD	0.94	7.58	0.19	0.33	0.94	7.58	0.19	0.33	0.94	7.58	0.19	0.33

SHW= Shoot weight, NN= Nodule number, NDW= Nodule Dry Weight, RDW= Root Dry Weight, LSD= Least Significant Difference.

DISCUSSION

Low phosphorus release observed in phosphorus fertilizers is associated with tropical soils dominated by low activity kaolinitic clay minerals and high sesquoxides of Al and Fe (Hellal *et al*., 2013). In view of the inherent acidic nature of the studied soils, the moderately available phosphorus in the soil is likely not available in the plant available form, hence the need to determine which source will facilitate the release of phosphorus in the form suitable for soybean growth, nodule and seed development.

The systematic significant increase observed in almost all the soybean parameters measured in this study is attributed to the various phosphorus sources evaluated. The study revealed that soybean leaf and number of branches were similar across locations revealing that pots treated with Bio-P (AMF), Inorganic-P (Single superphosphate) and Organic-P (BM) had better growth performance than the control. Likewise, the soybean shoot accumulated in response to the phosphorus sources were 24, 26 and 13% and above at Maikunkele, Maitunbi and Gidan Kwanu respectively, as compared to the control. This is an indication that phosphorus serves as an energy source during the physiological processes taking place in the plant (Better Crops, 1999). Phosphorus is confirmed required in a large quantity in the shoot and root tips where metabolism is high and cell division rapid according to Ndakidemi and Dakora, (2007). Hence, soybean requires phosphorus for attaining high yield especially under low available soil phosphorus status.

The same trend of growth observed on the control producing the shortest plant height, lightest shoot weight, lowest nodule number, lightest nodule and root dry weight in the study, indicates the importance of phosphorus to soybean development, as earlier reported by Ibekwe *et al*., (1997) and Nkaa *et al*. (2014) that low availability of phosphorus depresses rhizobium survival and persistence, resulting in overall reduction in growth and yield parameters in aluminum toxic soils. The phosphorus sources used were positively responded to as against the control, as buttressed by Bekere *et al*. (2012) in a report that omission of phosphorus from soybean nutrition can drastically reduce shoot dry matter yield of soybean.

The pattern of soybean response at Maikunkele remains the same as bio-P (AMF) recorded higher values than the other phosphorus sources. This is possibly because of the huge network of mycorrhizal hyphae, which spread into the surrounding soils influencing the fertility and plant nutrition by changing the physical and chemical characteristics of soils, by acting as stabilizing agents in the formation and maintenance of soil structure. Increase in growth of plants on application of *Glomus intraradices was* reported by Al-Hmoud and Al-Momany, (2017). The better response of soybean to inorganic–P (SSP) at Maitunbi and Gidan Kwanu compared to bio-P (AMF) and organic-P (BM) with regards to plant height, shoot weight and nodule number, could be due to the acidity nature of the soil which fix P and not allowing mycorrhiza survival, hence the high response to inorganic P. Though the responses were at par in some cases.

The Arbuscular mycorrhizal fungi (*Glomus intaradices*), the inorganic-P (single superphosphate) and the organic-P played important role in enhancing soybean growth and nodulation and expectedly the yield as against the control. High response of soybean to bio-P (AMF), as seen in the results is similar to Dora *et al*., (2021) observation on pineapple field where mycorrhiza was referred to as a reasonable source of phosphorus for plant which supplements chemical fertilizers. Mycorrhizal fungi produce powerful phosphate-solubilizing enzymes that are released into the soil, increasing phosphate solubility. These "digested" phosphate minerals are sent to the host by fungal hyphae transporters, reducing the metabolic energy needed by plants Sally *et al.,* (2011). Similarly, the response to organic manure according to (Ezekiel-Adewoyin, 2017) significantly reduced the fixation of added P as well as native P availability, making P more available to plant. Organic acids released during decomposition of organic materials also influences pH, forming stable complexes or chalates with cations responsible for P- fixation. This in turn increases P availability for uptake and is in line with the report of Oyeyiola *et al*., (2019) that positive response of cowpea root length, dry shoot and root weights which aside compost ability to stimulate substances responsible for presenting toxic Al^{3+} to a non-toxic form, Ancuta *et al*., (2013), also attributed the response to the tendency for bone meal to act as a liming material by increasing soil pH through proton consumption during the bone meal dissolution (Tan, 2011). These reactions might not be visible with respect to the use of inorganic-P (SSP) being a chemical fertilizer.

CONCLUSION

The study indicates that phosphorus from different sources (organic, inorganic and bio-fertilizer) positively enhanced soybean growth and nodulation, compared to the control. This shows that soybean cultivation on Typic plinthustalfs requires phosphorus application regardless of the source. However, for farmers at Maikunkele, the use of bio-P (AMF) which significantly enhanced most of the parameters observed resulting in 55%, 61% 40% increment in shoot weight, nodule number and weight respectively as compared to control is a good option. While at Maitunbi and Gidan Kwanu, the three phosphorus sources were positively responded to than the control. But inorganic-P and organic-P seems to be better off. Therefore, the evaluated phosphorus sources depending on the choice of the farmers are required for better performance of soybean (TGX 1998-5F variety). However, there is need for further study to affirm the observations so as to make affirmative recommendation.

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