EFFECT OF METHODS OF APPLICATION OF RHIZOBACTERIA AND PHOSPHATE FERTILIZER RATES ON GROWTH AND YIELD OF SOYBEAN [GLYCINE MAX (L). Merril] IN MAKURDI

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ABSTRACT

Field experiment was carried out during the 2018 cropping season at the Teaching and Research Farm of Joseph Sarwuan Tarka University, Makurdi to determine the effect of methods of application of rhizobacteria and phosphate fertilizer rates on the growth and yield of soybean. Treatments were four rates of phosphate fertilizer (0, 20, 40, and 60 kg P2O5 ha-1) and three rhizobacteria inoculant application methods (zero, seed and soil). The crop was grown to maturity and harvested. Data collected were number of leaves, Leaf Area, Leaf Area Index, Net Assimilation Rate, Crop Growth Rate, Days to 50% flowering, Total Dry Matter, number of nodules, nodules weight, seed yield and 100 seed weight. The collected data were subjected to the analysis of variance (ANOVA) at 5 % level of probability using GenStat 17th Edition. Significant differences in means were separated using Fischers Least Significant Difference [F-LSD (0.05)].

The results from the study showed that combined application of rhizobacteria and phosphate fertilizer at 60 kg P2O5 ha-1 increased leaf area index and total dry matter yield of soybean significantly (P<0.05) with leaf area index of 10.19 and total dry matter of 72 g per plant as compared to leaf area index at 0 kg P2O5 ha-1, 20 kg P2O5 ha-1, 40 kg P2O5 ha-1 (7.97, 8.93 and 9.73) dry matter at 0 kg P2O5 ha-1, 20 kg P2O5 ha-1, 40 kg P2O5 ha-1 (16.6g, 59.4g and 65.2g) per plant. The result of this study showed combination application of rhizobacteria inoculation and phosphate significantly enhanced nodulation from 43 nodules in un-inoculated control to 156 and 175 nodules per plant in rhizobacteria inoculated and phosphate treatments. The result of the study showed that combined application method of seed inoculation of rhizobacteria at 100g per 15kg of seed at 60 kg P2O5 ha-1 phosphate was more economical and had more yield benefits than single application and therefore, stand recommended.

Keywords: Innoculant, Rhizobacteria, Phosphate, Fertilizer.

1. INTRODUCTION

Soybean [*Glycine max (*L.) Merril], is a commercial oil seed legume widely cultivated in the Southern Guinea Savanna of Nigeria (Dudje *et al.*, 2009). It is an important crop in terms of total production and international trade (Simmond *et al.,* 1999). Soybean contains about 20 % oil on dry matter basis with 30-50 % of protein (Kwarteng and Towler, 1994). Nutritionally and economically, is a good source of protein (amino acids), vitamins and minerals which are essential for human nutrition as well as for livestock. (Hartman *et al.*, 2011); thus, soybean play an important role in solving malnutrition problems (Ruhul *et al.*, 2009).

Low crop yields associated with predominantly nutrient-related soil constraints to crop production constitute an undoubted characteristic of subsistence cropping systems throughout Nigeria. Research on crop nutrition has documented nitrogen and phosphorus as the most limiting nutrient elements for crop production (Kumwenda *et al.*, 1997). However, P has been reported to be more limiting than N in tropical legumes (Hedin *et al.*, 2003; Vitousek, 2004). Maximum benefits from N2 fixation depend on soil P availability with 33 % of the world's arable land limited in P (Kennedy and Cocking, 1997). Acid-weathered soils of the tropics and subtropics are particularly prone to P deficiency (Graham and Vance, 2003). Soybean yields on growers' farms in Nigeria are often still lower than 1000 kg ha^{-1} compared to the potential yield of 2500-3000 kg ha^{-1} (FAO/STAT, 2014; Kananji *et al.*, 2013). There is therefore a wide gap between what is currently being produced and what is needed because of fertility constraints.

Heterogeneity of farmers' fields create variation in response of soybean plants to phosphorus application and *Rhizobia* inoculation. Given the same treatments, some farmers observe exceptionally vigorous soybean plants with deep green leaf colour and prolific nodulation on plants growing in inoculated plots with *Rhizobia* and applied phosphorus which translates to increases in yield. In contrast, in other farmers' fields, there is no response of soybean to inorganic P fertilizer and inoculation.

Assessment of impact of rhizobacteria inoculant and P fertilizer on soybean production would generate additional information to ameliorate acute nitrogen deficiency and enhance soybean production strategies on the optimal application method of Nodumax inoculant to P fertilizer among farmers. The information would provide an opportunity to best management practices to soybean nodulation, growth and increase grain yield that can maximize small holder farmer's return on investment. Therefore the research was carried out to determine the effect of seed and soil applied rhizobacteria inoculant application methods and phosphate rates on growth and yield of soybean.

2. MATERIALS AND METHODS

Experimental location

The experiment was carried out at the Teaching and Research Farm of Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria. The site is located at latitude 7^0 44N, longitude 8^0 35E, and 98 m above sea level in the Southern Guinea Savannah Ecological Zone of Nigeria.

Experimental Materials

TGX1904-6F variety of soybean, Nodumax Rhizobacteria Inoculant, Single super phosphate, cutlass, hoe, wooden pegs, measuring tape, meter rule, maker, rope, garden fork, some plastic sheets, bucket of water for washing, white paper and digital weighing balance.

Treatments

Treatments were four rates of phosphate fertilizer (0, 20, 40, and 60 kg P_2O_5 ha^{-1}) and three rhizobacteria inoculant application methods (zero, seed and soil).

Source of Experimental materials

The TGX1904-6F variety of soybean and the inoculant (Nodumax) were obtained from International Institute of Tropical Agriculture (IITA), Kano station.

Experimental Design

The experiment was 4 x3 factorial trial laid out in a Randomized Complete Block Design (RCBD) replicated three times. The fertilizer application was done at the time of planting by side placement at the rate of 0, 20, 40 and 60 kg P_2O_5 while seeds were inoculated at the time of planting where 100 g of rhizobacteria were inoculated per 15 kg of seeds and soil was applied by putting 10 g of rhizobacteria inoculant into planting holes before un-inoculated seeds were placed inside the holes and covered.

Preparation of Inoculant slurry

The materials used were 500 ml bottled water, wooden stirring spoon, plastic basin, Rhizobacteria inoculant (Nodumax legume inoculant manufactured by IITA business incubation platform, Ibadan Nigeria), soybean and white paper.

Seed Inoculation Procedure

The enclosed gum Arabic inside the sachet of Nodumax inoculant was dissolved into 300 ml of warm water to form a slurry. 15 kg of soybean seeds (5+5+5 kg) was put into a basin. The slurry formed was added to the seed and mixed uniformly. 100 g of Nodumax inoculant was added uniformly to the seed and covered for 10 minutes to avoid direct sunlight. The inoculated seeds were planted into a moist seed bed immediately.

Soil inoculation procedure

Planting holes at a depth of 10 cm was made on each seed bed. Inside the planting holes, 10 g of rhizobacteria inoculant was measured out and placed into each of the planting holes. Then, the un-inoculated soybean seeds were sown into the planting holes and covered with the top soil.

Planting of soybean

The soybean seeds were planted on the 15th July, 2018 with intra and inter spacing of 0.10 m and 0.75 m respectively.

Weed Control

Butaforce Pre-emergence herbicide (Butachlor 50 % EC) was applied immediately after planting and manual weeding was done 21 and 60 days after planting to maintain a weed free field.

Harvesting

Harvesting was carried out when 95 % of the soybean was physiologically matured [15 weeks after planting (WAP)] when most of the leaves turn yellow, dry pods turned brownish.

Threshing of the crop was done manually by beating the harvested dried plant with stick. Winnowing was done to separate seeds from debris and each plot was weighed using a digital balance weighing machine.

Data Collection and Analysis

Data collected were number of leaves, Leaf Area, Leaf Area Index, Net Assimilation Rate, Crop Growth Rate, Days to 50% flowering, Total Dry Matter, number of nodules, nodules weight, seed yield and 100 seed weight. Data collected were subjected to the analysis of variance (ANOVA) at 5 % level of probability using GenStat 17th Edition. Significant differences in means were separated using Fichers [F-LSD (0.05)].

3. RESULTS

The Physical and Chemical Properties of the Makurdi Experimental Soil

The physical properties of Makurdi, experimental plot presented in Table 1. The result of physical properties of the soil showed the soil belongs to sandy clay loam textural class. Chemical properties of Makurdi experimental soil presented in Table 2. The result showed that P^H of the soil was slightly acidic. The soil was low in Organic Carbon, Nitrogen, Phosphorus, Potassium and Sodium. The soil was medium in Magnesium, Calcium, Exchangeable Base and Cation Exchange Capacity and high in Exchangeable Acidity with a Base Saturation of 85.6 %

Main Effects of Phosphate, and Inoculant on Number of Leaves

The result presented in Table 3 indicated that phosphate application significantly improved the number of leaves. With higher level of phosphate application, the number of leaves improved at 55 DAP, 75 DAP and 95 DAP. Inoculant application significantly improved the number of leaves at 55 DAP, 75 DAP and 95 DAP as compare to zero application.

Interaction Effects of Inoculant and Phosphate on Number of Leaves

Significant differences ($P<0.05$) were observed with respect to interaction effects of inoculant and phosphate on the number of leaves per plant at different days after planting in 2018 cropping seasons as shown in Table 4.

Table 1: Physical Properties of the Experimental Field

		Percentage of			
Profile Depth (cm)	**Coarse sand**	**Fine sand**	**Silt**	**Clay**	**Textural Class**
0-15	69.08	21.74	12.92	18.00	Sandy loam
15-30	78.06	19.12	9.13	19.06	Sandy loam
30-45	83.04	19.03	9.06	22.74	Sandy loam

Table 2: Chemical Properties of the Experimental Field

	Profile Depth (cm)		
Parameters	**0-15**	**15-30**	**30-45**
p^H in $CaCl_2$	6.18	6.24	6.51
OC (%)	0.74	0.81	0.80
N (%)	0.079	0.096	0.093
P (mg kg^{-1})	3.33	3.80	3.50
K (cmol kg^{-1})	0.23	0.29	0.24
Na (cmol kg^{-1})	0.21	0.23	0.22
Mg (cmol kg^{-1})	2.50	3.01	2.80
Ca (cmol kg^{-1})	3.00	3.06	3.01

Exchangeable Base (cmol kg^{-1})	5.94	5.97	5.95
Exchangeable Acidity (cmol kg^{-1})	1.00	1.06	1.08
Cation Exchange Capacity (cmol kg^{-1})	6.94	6.98	6.92
Base Saturation (%)	85.60	85.70	84.31

Table 3: Main Effects Phosphate and Inoculant on Number of Leaves at Different Days After Planting in 2018 Cropping Season

.			
	Days After Planting		
	55	**75**	**95**
Phosphate			
P_0	93.85	118.30	131.10
P_1	114.26	143.00	155.55
P_2	128.22	169.33	182.81
P_3	137.63	181.81	191.67
LSD (P≤0.05)	**1.15**	**1.68**	**0.98**
Inoculant			
I_0	112.25	145.33	157.64
I_1	120.39	155.19	167.92
I_2	122.83	158.80	170.28
LSD (P≤0.05)	**0.99**	**1.46**	**1.85**

I_0 = Zero inoculant, I_1 = Seed applied inoculant, I_2 = Soil applied inoculant, P_0 = 0 %, P_1 = 20 P_2= 40, P_3 = 60, V1 = TGX 1904–6F, V2 = TGX 1987-10F, V3= TGX 1448-2E

Table 4: Interaction Effects of Inoculant and Phosphate on Number of Leaves at Different Days After Planting in 2018 Cropping Season

		Days After Planting		
		55	**75**	**95**
Inoculant	**Phosphate**			
I_0	P_0	85.56	109.22	124.33
	P_1	104.89	163.00	174.11
	P_2	123.44	163.00	174.11
	P_3	135.11	176.67	188.56
I_1	P_0	96.56	121.89	133.78
	P_1	118.00	146.22	160.56
	P_2	129.44	170.44	185.22
	P_3	137.56	182.22	192.11
I_2	P_0	99.44	123.78	135.22
	P_1	119.89	150.33	162.44
	P_2	131.78	174.56	189.11
	P_3	140.22	186.56	194.33
LSD ($P \leq 0.05$)		**1.99**	**2.91**	**1.69**

Main Effects of Phosphate and Inoculant on Leaf Area (LA)

The result presented in Table 5 showed that phosphate application significantly improved leaf area. Application of phosphate at higher level increased leaf area at 55 DAP, 75 DAP and 95 DAP in 2018 cropping seasons Inoculant application significantly improved leaf area at 55 DAP, 75 DAP and 95 DAP as compare to zero application in the two cropping seasons.

Interaction Effects of Inoculant and Phosphate on Leaf Area (LA)

Significant differences ($P<0.05$) were observed on the interaction effects of inoculant and phosphate on leaf area at different days after planting in the two cropping seasons. The

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interaction of inoculant and phosphate significantly enhanced area of leaf at 55 DAP, 75 DAP and 95 DAP as shown in Table 6

Table 5: Main Effects Phosphate and Inoculant on Leaf Area (cm^2) at Different Days After Planting in 2018 Cropping Season.

	Days After Planting		
	55	**75**	**95**
Phosphate			
P_0	36.15	73.56	84.00
P_1	42.19	87.30	97.41
P_2	49.30	94.78	102.44
P_3	53.63	105.70	112.30
LSD (P≤0.05)	**0.54**	**1.03**	**0.33**
Inoculant			
I_0	43.44	86.36	95.00
I_1	45.64	90.06	99.56
I_2	46.86	94.50	102.27
LSD (P≤0.05)	**0.47**	**0.89**	**0.91**

Table 6: Interaction Effects of Inoculant and Phosphate on Leaf Area (cm^2) at Different Days After Planting in 2018 Cropping Season.

		Days After Planting		
		55	**75**	**95**
Inoculant	**Phosphate**			
I_0	P_0	34.22	66.89	76.00
	P_1	40.89	83.89	94.11
	P_2	47.00	93.22	101.33

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	P_3	51.67	101.44	108.56
I_1	P_0	36.00	71.00	84.74
	P_1	42.44	88.22	98.22
	P_2	49.89	94.67	102.22
	P_3	54.22	106.33	113.00
I_2	P_0	38.22	82.78	92.11
	P_1	43.22	89.78	99.89
	P_2	51.00	96.44	103.78
	P_3	55.00	103.33	115.33
LSD (P≤0.05)		**0.93**	**1.79**	**1.82**

Main Effects of Phosphate and Inoculant on Leaf Area Index (IAI)

Results presented on Table 7 showed that the main effects of phosphate and inoculant on leaf area index recorded significant differences (P<0.05) at 55 DAP, 75 DAP and 95 DAP. The result also showed that phosphate application significantly improved leaf area index. Application of phosphate at higher level increased leaf area index at 55 DAP, 75 DAP and 95 DAP. The leaf area index in three varieties increased from 55 DAP to 95 DAP in the two cropping seasons. Inoculant application significantly improved leaf area index at 55 DAP, 75 DAP and 95 DAP as compare to zero application.

Interaction Effects of Inoculant and phosphate on Leaf Area Index (IAI)

The result on interaction effects of inoculant and phosphate presented in Table 8 showed no difference at 55 DAP thus, significant differences (P<0.05) were observed at 75 DAP 95 DAP in 2018 cropping season. Leaf area index were also differed significantly at 55 DAP, 75 DAP and 95 DAP in 2019 cropping season. The result indicated that the combined application of inoculant and phosphate at higher level enhanced leaf area index at 55 DAP, 75 DAP and 75 DAP.

Table 7: Main Effects of Phosphate and Inoculant on Leaf Area Index at Different days after planting in 2018 Cropping Season

	Days after Planting		
Phosphate	**55**	**75**	**95**

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P_0	2.95	5.75	6.87
P_1	3.51	6.76	8.22
P_2	4.22	7.51	8.99
P_3	4.53	7.94	9.43
LSD (P≤0.05)	**0.083**	**0.054**	**0.11**
Inoculant	**55**	**75**	**95**
I_0	3.65	6.72	7.97
I_1	3.84	7.03	8.48
I_2	3.94	7.22	8.68
LSD (P≤0.05)	**0.072**	**0.047**	**0.09**

Table 8: Interaction Effects of Inoculant and Phosphate on Leaf Area Index at Different days after planting in 2018 Cropping Season

		Days after Planting		
		55	**75**	**95**
Inoculant	**Phosphate**			
I_0	P_0	2.81	5.40	6.10
	P_1	3.30	6.44	7.81
	P_2	4.10	7.40	8.80
	P_3	4.45	7.65	9.20
I_1	P_0	2.95	5.73	7.02
	P_1	3.60	6.92	8.41
	P_2	4.25	7.49	9.01
	P_3	4.60	7.98	9.50
I_2	P_0	3.10	6.13	7.50
	P_1	3.70	6.93	8.43

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P_2	4.34	7.64	9.20
P_3	4.60	8.17	9.64
LSD (P≤0.05)	**NS**	**0.09**	**0.19**

Main Effects of Phosphate and Inoculant on Net Assimilation Rate (NAR)

The result presented in Table 9 showed significantly differences (P<0.05) with regards to phosphate application at 55 DAP, 75 DAP and 95 DAP in the cropping season. Phosphate application at higher level improved net assimilation rate at 55DAP, 75DAP and 95 DAP.

Inoculant application significantly improved net assimilation rate at 55DAP, 75DAP and 95DAP. Significant differences (P<0.05) were recorded at 75 DAP and 95 DAP as no difference observed at 55 DAP

Interaction Effects of Inoculant and Phosphate on Net Assimilation Rate (NAR)

Significant differences (P<0.05) were observed on the interaction effects of inoculant and phosphate on net assimilation rate at 75 DAP and 95 DAP as no difference observed at 55 DAP. The interaction of inoculant and phosphate significantly enhanced net assimilation rate at 55DAP, 75DAP and 95DAP (Table 10).

Table 9: Main Effects of Phosphate and Inoculant on Net Assimilation Rate [(NAR) ($g/cm^2/day$)] at Different days after planting in 2018 Cropping Seasons

	Days After Planting		
	55	**75**	**95**
Phosphate			
P_0	0.14	0.13	0.20
P_1	0.17	0.30	0.50
P_2	0.19	0.40	0.54
P_3	0.19	0.43	0.60
LSD (P≤0.05)	**0.03**	**0.02**	**0.01**
Inoculant			
I_0	0.19	0.29	0.40
I_1	0.17	0.32	0.34

I_2	0.17	0.34	0.50
LSD (P≤0.05)	**NS**	**0.01**	**0.01**

Table 10: Interaction Effects of Inoculant and Phosphate on Net Assimilation Rate [(NAR) ($g/cm^2/day$)] at Different days after planting in 2018 Cropping Season.

		Days After Planting		
		55	**75**	**95**
Inoculant	**Phosphate**			
I_0	P_0	0.15	0.13	0.15
	P_1	0.16	0.24	0.52
	P_2	0.19	0.38	0.61
	P_3	0.19	0.43	0.60
I_1	P_0	0.15	0.13	0.21
	P_1	0.15	0.30	0.41
	P_2	0.19	0.39	0.58
	P_3	0.19	0.44	0.61
I_2	P_0	0.14	0.14	0.20
	P_1	0.16	0.35	0.48
	P_2	0.19	0.42	0.60
	P_3	0.19	0.44	0.54
LSD (P≤0.05)		**NS**	**0.03**	**0.03**

Main Effects of Phosphate and Inoculant on Crop Growth Rate (CGR)

The result presented in Table 11 indicated that significantly differences were observed on the main effects of phosphate fertilizer on the crop at 55 DAP, 75 DAP and 95 DAP. Differences were recorded on inoculant at 75 DAP and 95 DAP as no difference observed at 55 DAP.

The results showed that phosphate application significantly enhanced crop growth rate. Application of phosphate at higher level increased in crop growth rate at 55 DAP, 75 DAP and

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95 DAP. Inoculant application significantly improved growth rate at 55 DAP, 75 DAP and 95 DAP as compare to zero application.

Interaction Effects of Inoculant and Phosphate on Crop Growth Rate (CGR)

Significant differences (P<0.05) were observed on the interaction effects of inoculant and phosphate on crop growth rate at 75 DAP and 95 DAP as no difference was recorded. The interaction of inoculant and phosphate significantly enhanced crop growth at 55 DAP, 75 DAP and 95 DAP cropping seasons as shown in Table 12.

Table 11: Main Effects of Phosphate and Inoculant on Crop Growth Rate (CGR) ($gcm^{-2}day^{-1}$) at Different days after planting.

	Days after planting		
	55	**75**	**95**
Phosphate			
P_0	0.0048	0.0057	0.0083
P_1	0.0048	0.0117	0.0176
P_2	0.0058	0.0153	0.0227
P_3	0.0057	0.0201	0.0262
LSD (P≤0.05)	**0.0006**	**0.0004**	**0.0007**
Inoculant			
I_0	0.0052	0.0127	0.0127
I_1	0.0053	0.0132	0.0195
I_2	0.0053	0.0137	0.0195
LSD (P≤0.05)	**NS**	**0.0004**	**0.0007**

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Table 12: Interaction Effects of Inoculant and Phosphate on Crop Growth Rate [(CGR) ($gcm^{-2}day^{-1}$)] at Different days after planting

Days after planting				
		55	**75**	**95**
Inoculant	**Phosphate**			
I_0	P_0	0.0047	0.0059	0.0087
	P_1	0.0047	0.0111	0.0157
	P_2	0.0056	0.0143	0.0217
	P_3	0.0057	0.0193	0.0239
I_1	P_0	0.0050	0.0058	0.0083
	P_1	0.0050	0.0116	0.0184
	P_2	0.0056	0.0153	0.0230
	P_3	0.0057	0.0202	0.0267
I_2	P_0	0.0050	0.0053	0.0078
	P_1	0.0050	0.0124	0.0188
	P_2	0.0058	0.0162	0.0234
	P_3	0.0058	0.0209	0.0279
LSD ($P \leq 0.05$)		**NS**	**0.0001**	**0.0014**

Main Effects of Phosphate and Inoculant on days to 50 % Flowering

Significant differences ($P<0.05$) were observed on the main effects of phosphate with respect to days to 50 % flowering. However, inoculant show no significant difference (Table 13)

Interaction Effects of inoculant and phosphate on days to 50 % Flowering

The results presented in Table 14 on the interaction effects of inoculant and phosphate on 50 % flowering showed significant differences ($P<0.05$ in the two cropping seasons.

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Table 13: Main Effects of Phosphate and Inoculant on Days to 50 % Flowering in 2018 Cropping Season.

	2018
Phosphate	**DT 50 % F**
P_0	46.22
P_1	47.00
P_2	47.20
P_3	48.10
LSD (P≤0.05)	**0.10**
Inoculant	
$I_{0\ =}$	47.11
I_1	47.00
I_2	47.12
LSD (P≤0.05)	**NS**

Table 14: Interaction Effects of Inoculant and Phosphate on Days to 50 % Flowering in 2018 Cropping Season.

Inoculant	**Phosphate**	**DT 50 % F**
I_0	P_0	46.22
	P_1	46.00
	P_2	47.00
	P_3	48.08
I_1	P_0	47.78
	P_1	46.00
	P_2	47.00

	P_3	48.00	
I_2	P_0	46.22	
	P_1	46.22	
	P_2	47.37	
	P_3	48.00	
LSD (P≤0.05)		**0.21**	

Main Effects of Phosphate and Inoculant on Total Dry Matter yield (TDM)

The result presented in Table 15 indicated that phosphate application significantly increased in total dry matter. With higher level of phosphate application total dry matter improved at 55 DAP, 75 DAP and 95 DAP. Inoculant application significantly improved in total dry matter at 55 DAP, 75 DAP and 95 DAP as compare to zero application.

Interaction Effects of Inoculant and Phosphate on Total Dry Matter yield (TDM)

Significant differences ($P<0.05$) were observed on the interaction effects of inoculant and phosphate on total dry matter at 75 DAP and 95 DAP as no difference observed at 55 DAP in 2018 cropping season. The interaction of inoculant and phosphate significantly increased in total dry matter at 55 DAP, 75 DAP and 95DAP (Table 16).

Table 15: Main Effects of Phosphate and Inoculant on Total Dry Matter (g) per plant at Different days after planting in 2018 Cropping Season.

	Days after Planting		
	55	**75**	**95**
Phosphate			
P_0	5.40	9.63	14.91
P_1	6.01	27.62	46.80
P_2	12.61	37.51	58.33
P_3	18.5	47.20	65.32
LSD (P≤0.05)	**NS**	**0.47**	**0.42**
Inoculant			
I_0	8.22	32.81	50.21

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I_1	8.11	31.71	47.32
I_2	7.70	26.93	41.60
LSD (P≤0.05)	**NS**	**0.41**	**0.40**

Table 16: Interaction Effects of Inoculant and Phosphate on Total Dry Matte (g) per Plant at Different days after planting in 2018 Cropping Season.

		Days after Planting		
Inoculant	**Phosphate**	**55**	**75**	**95**
I_0	P_0	5.00	9.24	14.44
	P_1	6.62	23.80	41.60
	P_2	9.21	36.21	56.22
	P_3	10.50	45.74	63.22
I_1	P_0	5.30	9.70	14.90
	P_1	7.00	27.50	48.43
	P_2	9.82	37.32	58.33
	P_3	10.20	47.61	65.80
I_2	P_0	5.80	10.00	15.52
	P_1	7.22	31.51	50.51
	P_2	9.92	39.11	60.53
	P_3	10.33	48.32	67.00
LSD (P≤0.05)		**NS**	**0.82**	**0.72**

3.DISCUSSION

Significant differences were observed in the growth and yield parameters as shown in the result of this research work**.** The main effects of inoculant and phosphate on physiological growth parameters showed significant difference to phosphate application and inoculant on number of leaves per plant at different day’s interval.

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The application of phosphate significantly increased number of leaves and leaf area especially at 60 kg P_2O_5 and 40 kg P_2O_5 compare to 0 kg P_2O_5 and 20 kg P_2O_5 application and this could be due to low level of phosphate (3.3) in the soil as shown by the soil analysis in Table 2.

This result agreed with the report of Vance *et al.*,(2003) who reported that phosphate is one of the most unavailable and inaccessible macronutrients in the soil and frequently limit plant growth. For this reason application of inorganic phosphate fertilizer of low fertility soil enhanced crop productivity. Significant differences were observed on the main effects of inoculant and phosphate with regards to leaf area index. The results on the main effect of inoculant and phosphate showed increment in leaf area index with increasing application of phosphate and increased growth as the number of days after planting increased.

Difference were also observed on the interaction effect of inoculant and phosphate as well as the combined interaction of inoculant and phosphate. The result showed that combined application of rhizobacteria and phosphate significantly improved growth with regards to of leaf area index at higher application of phosphate especially at 60 kg P_2O_5 and 40 kg P_2O_5 respectively as compared to 0 kg P_2O_5 and 20 kg. This result was in line with the report of Scherer *et al.*, (2008) that highly effective and competitive Rhizobium strains and supply of appropriate amount of phosphorus could markedly increase legume growth and nitrogen fixation.

Result also showed that combined application of rhizobacteria inoculant and phosphate fertilizer at higher level especially at 60 kg P_2O_5 and 40 kg P_2O_5 significantly improved crop growth rate as well as net assimilation rate as compare to 0 kg P_2O_5 and 20 kg P_2O_5 application of phosphate inoculant.

This is an indication that phosphate application have positive impact on soybean crop growth and productivity. This agreed with the report of Rao (1996) who reported that phosphate is needed most by young, fast growing and performing number of functions related to growth, development, photosynthesis and utilization of carbohydrates. It was in line with the report of Sara *et al.*, (2013) who also reported that phosphate application generally improved soybean growth and yield and phosphate fertilizer application correct major deficiencies in the soil thereby leading to optimal crop performance.

The result showed that zero application of phosphate and inoculant flowered early at 46 days after planting as compare to the combined application of rhizobacteria inoculant and phosphate which recorded 50% flowering at 47 and 48 days after planting however more flowers were recorded in rhizobacteria inoculated and phosphate treatments plots. This result agreed with Giller (2001) who reported that ATP is a source of energy for physiological processes such as biological nitrogen fixation, photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement, root development, flowering, seed formation, fruiting and improvement of crop quality. This confirmed the report of Tairo and Ndakidemi (2014) which stated that the inoculation with Rhizobium and phosphorus supplementation improved the macro-nutrient uptake (N. P.K) in different organs of the whole plant of soybean.

Total dry matter yield differed significantly with respect to main effects of inoculant and phosphate. Total dry matter yield also differed significantly at different growth stages with

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regards to interaction effects of inoculant and phosphate, as well as the combined interaction of inoculant and phosphate.

The result actually showed that increased in the application of phosphate significantly improved dry matter accumulation at different days after planting and the interactions of inoculant and phosphate both significantly enhanced total dry matter yield at different days interval after planting.

The combined application of rhizobacteria and phosphate fertilizer at 60 kg P_2O_5 produced the highest total dry matter of 72 g. This result agreed with the findings of Wabekwa *et al*., (2014) and Ikenganyia (2017) both reported that total dry matter production increased with increasing phosphorus application. Main effect of inoculant and phosphate on soybean nodulation. The study result showed that significant differences were observed on main effect of phosphate and inoculant indicating significant influence of phosphate and inoculant on nodulation of soybean. Report of interaction effect of inoculant and phosphate as well as the two way interaction of inoculant and phosphate showed significant effect on the growth and yield of the crop.

Combined application of phosphate fertilizer and rhizobia significantly increased nodules number suggesting that combined application of phosphate fertilizer and rhizobacteria has a positive impact on the initiation and development of soybean root nodules signifying the positive contribution to the quantity of biology fixed nitrogen in the soybean farming system. This finding is in agreement with the report of Tahir *et al.*, (2009) who reported that application of rhizobacteria inoculation and phosphate fertilizer significantly increased nodules number from 73 in un-inoculated control (no inoculant and phosphate application) to 95 and 125 in rhizobia inoculated and phosphate treatments. Also, Fatima *et al.*, (2006) reported that combined application of phosphate and rhizobia inoculation increased nitrogenease activity, growth and grain yield as well as improved soil fertility for sustainable agriculture.

Main effect of inoculant and phosphate on nodules weight showed significant effect on nodulation of soybean in terms of nodules number, nodule size significantly influence the weight of nodules however, significant differences were recorded on the main effect of phosphate and inoculant with respect to nodules weight. The result indicated that higher nodules weight were obtained from higher number of nodules with bigger sizes. This result is in agreement with the findings of Pommereche and Hansen (2017) which reported that after successful inoculation of soybean seed, nodules number increased as well as size and nodule weight.

4. CONCLUSION

It was therefore concluded that application of 60 kg P_2O_5 phosphate and rhizobacteria inoculant significantly increased nodulation (175 nodules per plant) as well as N–Fixation especially when the same strain of inoculant was repeatedly applied and cultivated.

Based on the result it is therefore, recommended that application of 60 kg P_2O_5 phosphate be used for increased growth and yield of soybean. Seed inoculated method of rhizobacteria at 100 g per 15 kg of seed should be adopted and combined application of rhizobacteria inoculation and phosphate fertilizer has more yield benefits than single application (yield and nodulation as well as N-fixation) is therefore recommended.

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REFERENCES

Dugje I.Y., Omoigui, L.O., Ekeleme, F., Bandyopadhyay, R., Kumar, P.L., Kamara, A.Y. (2009). Farmers Guide to Soybean Production in Northern Nigeria. International Institute of Tropical Agriculture, Ibadan, Nigeria. 21 pp.

Fatima, Z., Zia, M. and Chaudhary, M.F. (2006). Effect of *Rhizobium* strains and phosphorus on growth of soybean (*Glycine max*) and survival of *Rhizobium* and P solubilizing bacteria. *Pakistan Journal of Botany* 38: 459-464.

Food and Agricultural Organization (FAO) (2014). Sustainable crop production intensification.Rome,http//*www.fao.org/agriculture/crop/thematic-sitemap/theme/spi/scpi-home/framework/en/.*

Giller, K. E. 2001. Nitrogen fixation in tropical cropping systems. 2nd ed. Biddles Ltd, Guildford and King's Lynn. UK. 243 pp

Graham, P.H. and Vance, C.P. 2003. Legumes: Importance and constraints to greater use. Plant Physiology 131: 872-877.

Hartman G.L; E.D West, T.K. Herman (2011). Crops that feed the world 2. Soybean-worldwide production, use, and constraints caused by pathogens and pests.Food Sec3:5-17

Hedin, L.O., Vitousek, P.M and Matson, P.A. 2003. Nutrient losses over four million years of tropical forest development. Ecology 84:2231–2255.

Ikenganyia EE, Anikwe MAN, Ngwu OE (2017) Influence of Rhizobacteria Inoculant Application Methods and Phosphate Fertilizer Rates on Dry Matter Accumulation, Yield of Bambara Groundnut [*Vigna subterranea* (L.) Verdc] and Soil Total Nitrogen Content in a Degraded Ultisol in Southeast Nigeria. Agrotechnology 6: 165.

Kananji, G.A.D., Siyeni, D., Yohane, E. Mtambo, L., Kachulu, L. Chisama, B.F., Malaidza, H., Tchuwa, F. and Mulekano, O. 2013. A Guide to Soybean Production in Malawi. Lilongwe: Department of Agricultural Research Services, Ministry of Agriculture, Irrigation and Water Development

Kennedy, I.R. and Cocking, E.C. 1997. Biological Nitrogen Fixation: The Global Challenge and Future Needs. Rockefeller Foundation Bellagio Conference Proceedings. Sydney: SUN Fix Press.

Kumwenda JDT, Waddington S, Snapp SS, Jones JB, Blackie MJ (1997) Soil fertility management in the smallholder maize based cropping systems of eastern and southern Africa. In Eisher C (eds) The Emerging Maize Revolution. Michigan State University E. Lansing, MI, USA, pp 153–172

Kwarteng JA, Towler MJ (1994) West Africa Agriculture. A textbook for schools and colleges, by Macmillan Publication Press Limited, pp 144-116.

ISSN: 2456-8643

Pommeresche & Hansen (2017). Examining root nodule activity on legumes. Ferti. Crop Technical Note. Download at www.fertilcrop.net.

Rao, I.M. (1996). The role of phosphorus in photosynthesis. *In:* M. Pessarakli, (ed.) *Handbook of Photosynthesis.* New York: Marcel Dekker. pp 173–194.

Ruhul AAKM, Jahan SRA, Karim MF, Hasanuzzaman M (2009) Growth Dynamics of Soybean (*Glycine max* L.) As Affected by Varieties and Timing of Irrigation. American-Eurasian Journal of Agronomy 2: 95-103.

Sara, S., Morad, M. and Reza, C.M. (2013). Effects of seed inoculation by *Rhizobium* strains on chlorophyll content and protein percentage in common bean cultivars (*Phaseolus vulgaris L*.). *International Journal of Biosciences* 3: 1-8.

Scherer, H. W., S. Pacyna, K. Spoth and M. Schulz (2008) Low levels of ferredoxin, ATP and leghemoglobin contribute to limited N2 fixation of peas (Pisumsativum L.) and alfalfa (Medicago sativa L.) under S deficiency conditions. Biol. Fert. Soils. 44: 909-916.

Simmonds, N.W., Smartt, J., Millen, S., Spoor, W. (1999). Principles of crop improvement, 2nd edition. Published Longman Group Ltd. Pp 252-256.

Tahir, M.M, Abbasi, M.K., Rahim, N., Khaliq, A. and Kazmi, M.H. (2009). Effect of *Rhizobium* inoculation and NP fertilization on growth, yield and nodulation of soybean (*Glycine max* L.) in the sub-humid hilly region of Rawalakot Azad, Jammu and Kashmir, Pakistan. *African Journal of Biotechnology* 8 (22), 6191-6200.

Tairo, E. V. and P. A. Ndakidemi (2014). Macronutrients Uptake in Soybean as Affected by Bradyrhizobium japonicum inoculation and phosphorus (P) supplements. Am. J. Plant. Sc. 5: 488-496.

Vance, C.P., Uhde-Stone, C. and Allan, D.L. (2003). Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. *New Phytologist* 157: 423–447

Vitousek, P. M. (2004). *Nutrient cycling and limitation: Hawai'i as a model system.* Princeton, New Jersey: Princeton University Press.

Wabekwa J. W., Odion E. C. & Aminu D. (2010). Effects of poultry manure rates on yield and yield attributes of sunflower (Helianthus annuus L.) at Samaru, Nigeria. Int. J Food Agric Res. 7(1):182-190.