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Effects of variety and phosphorus application on soybean (*Glycine max* L.) yield

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ABSTRACT

There has been a decline in soybean production owing to poor adaptable variety and low soil fertility, especially phosphorus among other factors. A field and screen house experiments were conducted in National Center for Agricultural Mechanization (NCAM), Idofian and Kwara State University, Malete both in southern Guinea savannah environment to evaluate the response of five soybean varieties to different rates (0, 20, 40, and 60 kg SSP/ha) of phosphorus fertilizer application. The field experiment was laid out in a 5 x 4 split-plot arrangement fitted into randomized complete block design (RCBD) with each treatment replicated three times. The screenhouse experiment was arranged in a complete randomized design (CRD) with three replications too. Soil samples were collected from both experimental sites and analyzed for physical and chemical characteristics. Plant data collected on the vegetative and yield component characteristics. The pre-planting soil analysis showed that the soil of the experiential sites was low in soil essential nutrients. Having both studies, the coefficient of variation from the two studies showed that the data from the field study is more reliable due to the low coefficient of variation ranging from (19.33 and 53.09) for hundred seed weight and seed weight per plant compared to the screen house (138.43 and 75.25). Across both studies, variety recorded significant ($p<0.05$) variation on all yield parameters. Phosphorus application had a significant effect in the number of seeds per plant. While in the field, pair-wise interaction of (variety and phosphorus application) showed a significant difference ($p<0.05$) in the number of pods, the number of seeds per pod, the number of seeds per plant, pod weight, seed weight per plant, and hundred seed weight. In screen house phosphorus, there was a significant difference in the number of seeds per pod. The interaction between variety and phosphorus, on the other hand, revealed no significant differences in these yield characteristics. The number of pods recorded a highly positive and significant correlation with the number of seeds per plant. TGX 1740-1E performs better under phosphorus application than SOYA with no phosphorus application. The best performance was observed on TGX 1740-1E variety treated with 20kgSSP/ha.

Keywords: Phosphorus fertilizer application; low soil fertility status; variety

INTRODUCTION

Soybean (*Glycine max* L) is an important grain legume crop farmed all over the world as a source of animal feed, human food, soil fertility improvement, and as an industrial raw material for candles, and paints (Hartman *et al*., 2011; Adjei-Nsiah *et al*., 2019). Soybean is

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the crop of choice for improving human diets in underdeveloped nations with its high protein content (40%) of acceptable nutritional quality and high oil content (20%) (Murithiab *et al*., 2016). Soybeans fix nitrogen from the atmosphere into the soil, improving soil fertility dramatically. This is particularly advantageous in Africa, where soil nutrients are deficient, and fertilizers are either unavailable or too expensive (IITA, 2009). Despite the numerous advantages of soybeans, grain production in Africa is relatively low, accounting for about 0.4–1% of total global production owing low productivity (USDA, 2017). Kolawole (2012) has identified phosphorus deficiency as a major factor limiting yields in Africa's soybean-producing countries. In legumes, a lack of phosphorus inadequacy had restricted root growth, photosynthesis, and sugar translocation, all of which affected biological nitrogen fixing (Zarrin *et al*., 2007; diCenzo *et al*., 2019). The amount of nitrates taken from the atmosphere by the soybean-rhizobium symbiotic system is increased when phosphorus fertilizer is added to the soybean (Zhou *et al*., 2016). Phosphorus is also a crucial nutrient for rhizobium bacteria, which is known to give energy to transform atmospheric nitrogen (N_2) into an ammonium (NH4) form that is readily available to plants (Zarrin *et al*., 2007). Malik *et al*. (2006) reported improved soybean yield with phosphorus fertilization. Hence, this study aimed to investigate the best adaptable variety with high seed yield and interacting effects of phosphorus on some soybean varieties in order to determine the most adaptable variety under optimal phosphorus treatments.

MATERIALS AND METHODS

The Study Area

The field study was carried out on the experimental field of the National Center for Agricultural Mechanization (NCAM), Idofian, Kwara State in the Southern Guinea Savannah agro-ecology of Nigeria. NCAM has an altitude of 327 m above sea level, between latitudes 08°13'N and 08°23'N and longitudes 04°25'E and 04°43'E of the equator with an annual rainfall of 1154.15 mm. The temperature and relative humidity range from 34 to 35.5 ºC and 75 - 88% during rainy season (Ajadi and Adeniyi, 2017). The field experiment started in September 2020 and was terminated in December 2020, while the screen house study was carried out during dry season in the screen house of Kwara State University (KWASU), Malete located in the Southern Guinea Savannah agroecology of Nigeria, on an altitude of 316.37 m. a. s. l. within latitude 08°42'N to 08°43'N and longitude 04°282'E to 4°283'E of the equator. The climate is tropical with annual rainfall, maximum temperature, maximum relative humidity and a daily photoperiod of 1500 mm, 38 ºC, 75 % and 7.1 hours, respectively (Olarenwaju, 2009). This screen house experiment started in November 2020 and was terminated in February 2021.

Treatments and Experimental Design

The treatments tested were phosphorus rates (0, 20, 40 and 60 kg SSP/ha) as the sub-plot applied two weeks after sowing and soybean varieties: Sam soy-2, TGX-1448-2E, TGX-1479, Local, and TGX-1740 as the main-plot in a randomized complete block design with a 5 x 4 split-plot arrangement with three replications. The plot size was 1 by 1.5 m, spacing between plots and blocks were 1 and 2 m, respectively. Soil samples were collected before planting for chemical and physical analyses using the procedure described by Okalebo *et al*. (2002).

TGX 1448-2E and TGX 1740-1E were obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan while SAM SOY-2, TGX 1479 and SOYA were purchased from reputable seed shop. The land was ploughed and harrowed. Two (2) seeds were sowed per hole at a spacing of 75 by 5 cm to give 533,333 plants per hectare (pph) and later thinned down to one seedling/stand at second week after planting. The experimental plots were weeded regularly with hoe. Cypermethrin at the rate of 2ml/l was sprayed every fortnightly until pod maturity due to the prevalence of insect pest attack on soybean in this locality.

In the screen house, perforated pots of 10 liter were filled with 5 kg of sterilized topsoil. Four (4) seeds were sowed per hole and later thinned to two seedlings at two weeks after planting. The plants were irrigated as and when due to the field capacity of the pots.

Data Collection and Analysis

Data were collected on nine yield components: average number of nodules per plant, average of weight of nodules (g), average shoot dry weight (g), average number of pods per plant, average pod weight per plant (g), number of seeds per pod, number of seeds per plant, seed weight at harvest (g), hundred seed weight (g) and yield per hectare (t/ha).

All data collected were summarized, computed and analyzed using descriptive statistics (mean, range, standard deviation and coefficient of variation), Analysis of variance (combined), Duncan Multiple Range Test, AMMI and Correlation Coefficient Analysis using GENSTAT statistical software 17th edition VSNI,2006.

RESULTS

Results of Soil Analysis

The physical and chemical analyses of the soil of NCAM site showed that the soil was loamy-sand and moderate acidic in reaction with low organic carbon, total nitrogen and available phosphorus contents. Potassium was high (Table 1). While the screen house site was sandy loam with moderate acidic reaction with low organic carbon, total nitrogen, available phosphorus and potassium contents

Results of Yield Components of Five Soybean Varieties in the Field

The analysis of variance (ANOVA) for yield components of five soybean varieties is presented in Table 2. It shows that varieties, interaction between varieties and phosphorus had significant effect ($p < 0.05$) on number of pods, pod weight, number of seeds per pod, number of seeds per plant, seed weight and 100 seed weight. Phosphorus had significant variation on all yield characters except on number of seeds per pod.

Results of Yield Components of Five Soybean Varieties in the Screen House

The analysis of variance (ANOVA) for yield components of the five soybean varieties is shown in Table 3. It shows that varieties had significant variation on all yield parameters (number of pods, pod weight, number of seeds per pod, number of seeds per plant, seed weight and 100 seed weight). While phosphorus had significant differences in the number of seeds per pod and number of seeds per plant. However, interaction between variety and phosphorus recorded no significant ($p < 0.05$) variations for these yield characters.

Table 1: Soil characteristics of the study areas

Soil parameters	Experimental Site/Location	
	Field (NCAM)	Screen house (Malete)
Sand (%)	79.0	77.0
Silt (%)	13.0	15.0
Clay (%)	8.0	8.0
Textural class	Loamy sand	Sandy loam
Organic carbon (%)	1.21	0.72
Total nitrogen (%)	0.14	0.08
Available phosphorus (mg/kg)	6.68	5.12
Ph	6.90	6.70
Exch. Mg (cmol/kg)	1.38	1.31
Exch. K (mg/kg)	0.24	0.41
Exch. Ca (mg/kg)	1.98	5.46
Exch. Na(cmol/kg)	0.70	0.79
Exch. Acidity(cmol/kg)	0.30	0.30
Mn (mg/kg)	110.00	121.00
Fe (mg/kg)	98.00	120.00
Cu (mg/kg)	1.04	1.10
Zn (mg/kg)	0.92	0.88

Mg: Magnesium, K: Potassium, Ca: Calcium, Na: Sodium, Mn: Manganese, Fe: Iron, Cu: Copper, Zn: Zinc

Table 2: ANOVA results of yield components of five soybean varieties evaluated under different phosphorus in the field in 2020 season

SV	Degree of freedom	No. pods per plant	Pods weight (g)	No. of seeds per pod	No. of seeds per plant	Seed weight (g)	Hundred seed weight (g)
Replication	2	56.99	2.86	0.15	166.98	1.30	0.45
V	4	222.01***	36.28***	1.05***	1763.49***	33.40***	34.57***
Error	8	10.24	0.48	0.04	24.62	0.32	1.15
P	3	443.39***	39.92***	0.42ns	3384.32***	29.71***	11.16***
VxP	12	34.41*	6.02***	0.61***	307.10***	3.29***	5.86**
Error	30	11.12	0.74	0.09	46.49	0.44	1.51
Range		3-33.3	1.1-13.6	1.16-3	7.3-88.4	0.8-10.2	5.08-15.06
Mean		13.81	3.92	2.27	31.68	2.90	9.40
SD		5.68	1.79	0.47	15.40	1.54	1.81
CV (%)		41.18	45.74	20.73	48.63	53.09	19.33

*, **, *** and ns mean significant p<0.05, 0.01, 0.001 and not significant, respectively. CV: Coefficient of variation. SV: Source of variation. SD: Standard deviation, V: Variety, P: Phosphorus.

Table 3: ANOVA results of yield components of five soybean varieties evaluated under different phosphorus in the screen house in 2020 season

SV	Degree of freedom	No. pods per plants	Pods weight (g)	No. of seeds per pod	No. of seeds per plant	Seed weight (g)	Hundred seed weight (g)
Replication	2	33.50	3.47	7.17	82.29	0.41	101.61
V	4	111.19***	16.73***	14.75*	395.37***	3.61**	261.13**
Error	8	6.95	1.13	1.74	19.16	0.39	29.49
P	3	60.08ns	3.37ns	9.15***	265.37*	0.51ns	60.11ns
VxP	12	7.87ns	1.13ns	0.70ns	21.51ns	0.35ns	16.44ns
Error	30	14.93	1.26	0.93	52.21	0.24	14.92
Range		0-27	0-7.6	0-4.3	0-42	0-5.5	0-16.6
Mean		2.3	0.76	0.85	4.41	0.35	3.29
SD		3.90	1.26	1.13	6.95	0.63	4.56
CV (%)		169.90	165.61	131.64	157.44	175.25	138.43

*, **, *** and ns mean significant p<0.05, 0.01, 0.001 and not significant, respectively. CV: Coefficient of variation. SV: Source of variation. SD: Standard deviation, V: Variety, P: Phosphorus

Mean for the Interaction between Variety and Phosphorus in the Fields

The mean value of the yield character for the interactions between variety and phosphorus are shown in Figures 1 - 6. Results from the interaction between variety and phosphorus showed that most of the soybeans recorded the best significant performance at 20kg SPP/ha. TGX 1740-1E recorded the highest number of pods per plant, highest number of seeds per plant and with the values of 18.94, 48.83 whereas, TGX 1479 has the highest pod weight, number of seeds per pods, seeds weight per plant and yield per hectare (6.76, 5.25, 2.69g and 70458.03t/ha, respectively) at 20kgSSP/ha compared to other varieties.

For the number of pods per plant TGX 1740-1E recorded the highest at 0, 40, and 60kgSSP/ha (13.12, 18.94, 16.27 and 16.35 respectively). While, for the pod weight TGX 1479 has the highest at 40kgSSP/ha (5.13g). SOYA recorded highest at 0kgSSP/ha (4.30g) and TGX 1740-1E recorded highest at 60kgSSP/ha (4.89g). For the number of seeds per plant SOYA recorded highest at 0kgSSP/ha (43.08) and TGX 1479 has the highest at 40kgSSP/ha (37.38). For number of seeds per pod, TGX 1740-1E recorded the highest at 0kgSSP/ha (2.30), SOYA recorded the highest at 20kgSSP/ha (2.48) and TGX 1448-E recorded the highest at 60kgSSP/ha (2.65). For seed weight TGX 1740-1E recorded highest at 0kgSSP/ha, 60kgSSP/ha (3.05g, 3.75g) and TGX 1479 has the highest at 40kgSSP/ha (3.89g). Whereas, for yield per hectare TGX 1740-1E recorded highest at 20kgSSP/ha and 60kgSSP/ha (24,969.98t/ha, 32,372.97t/ha) and TGX 1479 has the highest at 40kgSSP/ha (37,932.45t/ha).

However, SAMSOY-2 recorded lowest number of pod per plant, pods weight, number of seeds per plant, number of seeds per pods, seed weight per plant and yield per hectare (6.42, 1.72g, 12.30, 1.97, 1.0g and 3406.36t/ha respectively) at 0kgSSP/ha compared to other varieties.

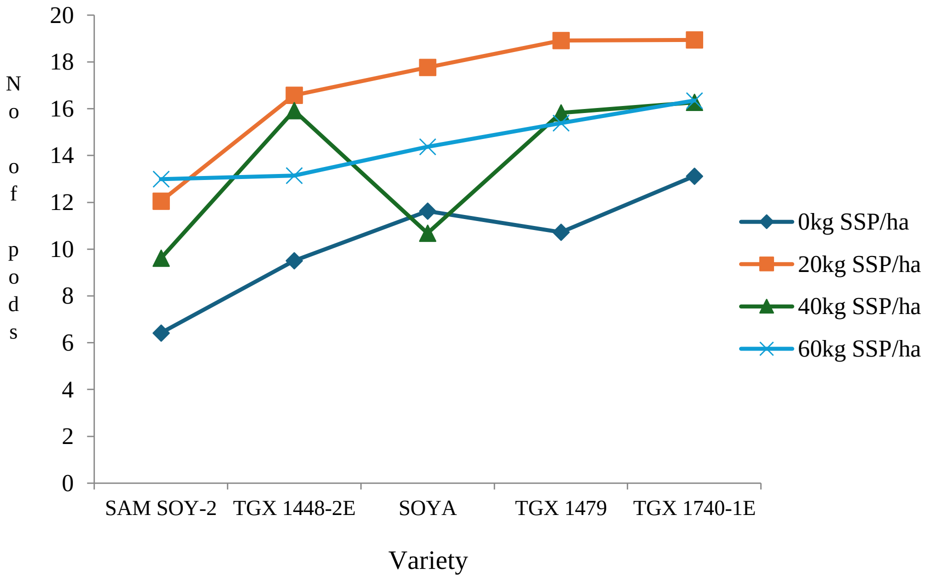

Fig.1: Interactive between variety and phosphorus for number of pods

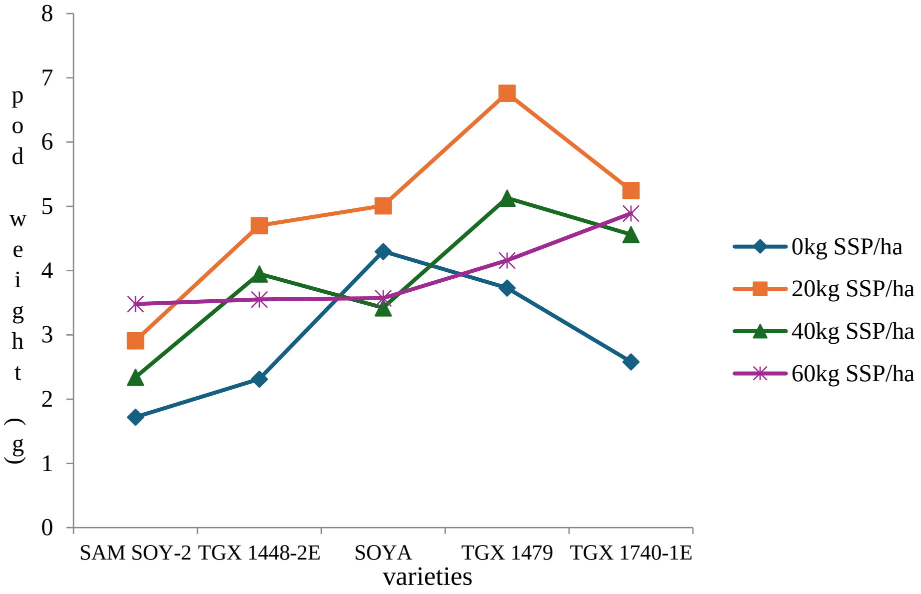

Fig. 2: Interactive between variety and phosphorus for pod weight

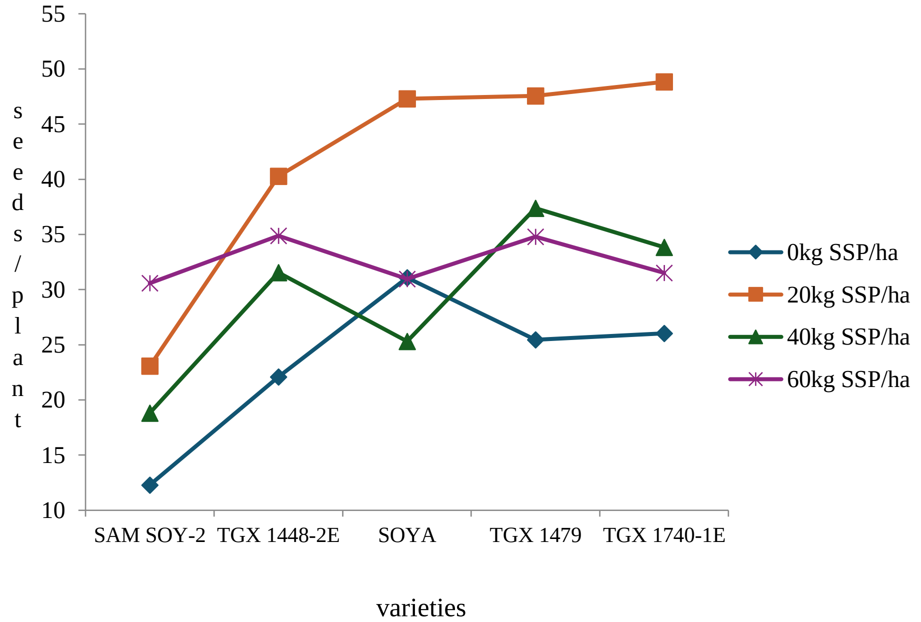

Fig. 3: Interactive between variety and phosphorus for number of seeds per plant

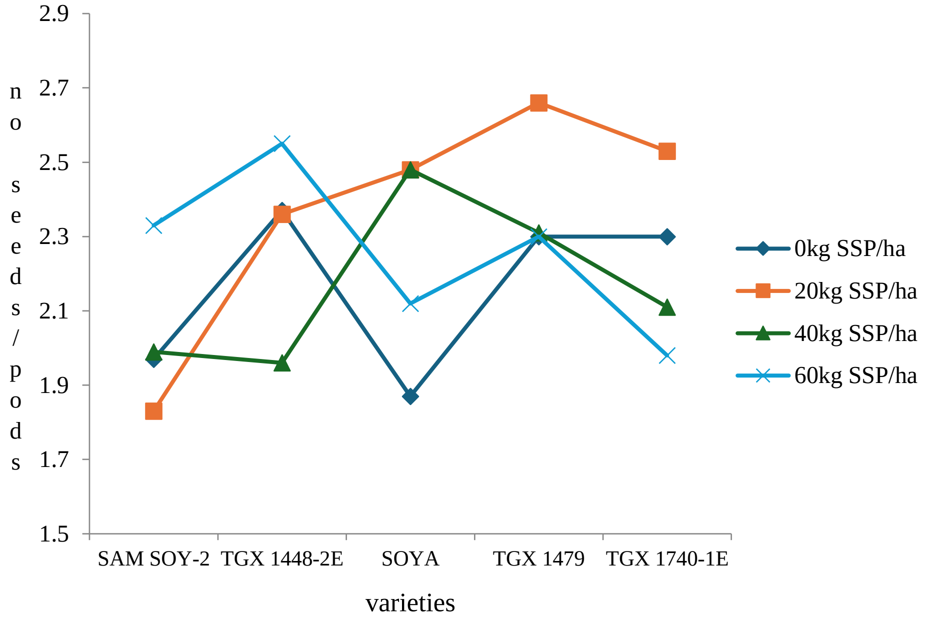

Fig. 4: Interactive between variety and phosphorus for number of seeds per pods

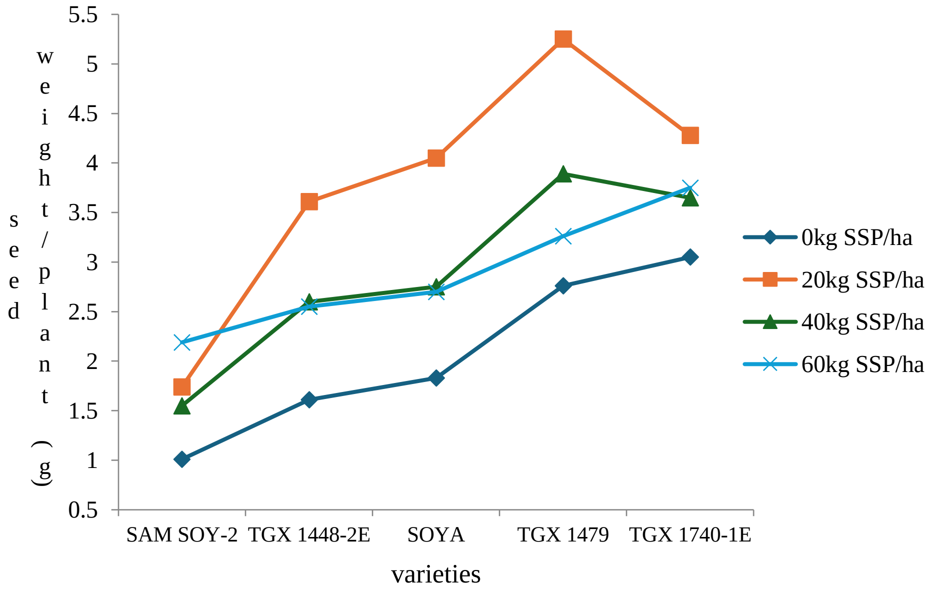

Fig. 5: Interactive between variety and phosphorus for seed weight per plant

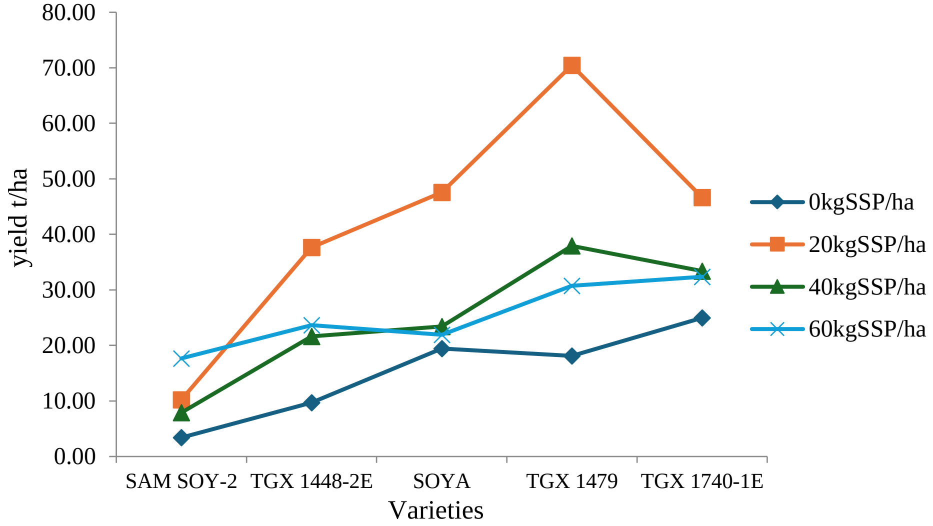

Fig. 6: Interactive between variety and phosphorus for yield per hectare

Correlation analysis for seed yield and soybean components character in the field and screenhouse

A hexagonal phenotypic correlation analysis for the yield components on the field and screenhouse is presented in Table 4. There was a positive significant correlation between parameters observed which included number of nodules, nodules dry weight, numbers of pods per plant, pod weight, and number of seeds per pod, number of seed per plant were all positively with seed weight and among themselves. The strongest correlation (0.95) was recorded between the number of pods and number of seeds per plant. More so, in the screen house Number of nodules, nodules dry weight, numbers of pods, pod weight, and number of seeds per pod, pod weight not only significantly correlated to seed weight but positively correlated with among themselves. The number of pods seeds per plant recording the strongest correlation (0.93).

AMMI Analysis for Varieties and Environments (phosphorus) Interaction in the Field

AMMI analysis for the interaction between the varieties and environment (phosphorus application) on yield components showed significant effect (Table 5). Between 16.82 and 45.50 % of total variation was due to the phosphorus application. The AMMI analysis showed the level of variation that signifies the degree of influence of each component factor. The effect of genotype (explained %) ranged from about 7.96 to about 23.43% for the number of seeds per pod and seed weight. The influence of environment was between 2.39% for 100 seed weight and 17.89% for number of seed per plant. The genotypic variation among the genotypes was influenced by the environmental factors (phosphorus application) for number of pod and number of seed per plant.

Table 4: A hexagonal correlation analysis for seed yield and soybean components character in the field (under the diagonal) and the screen house (above the diagonal).

		NND	NDW	NPD	PDW Screen	NSPD House	NSPT	SDW	100SDW
Field Experiment	NND	1.00	0.57***	0.13**	0.10*	0.05ns	0.12***	0.10*	0.05ns
	NDW	0.44***	1.00	0.16***	0.18***	0.09ns	0.14**	0.18***	0.14**
	NPDP	0.27***	0.45***	1.00	0.79***	0.55***	0.93***	0.83***	0.64***
	PDW	0.32***	0.45***	0.87***	1.00	0.63***	0.83***	0.88***	0.78***
	NSDPD	0.11*	0.14**	0.09ns	0.18***	1.00	0.70***	0.62***	0.79***
	NSPLT	0.29***	0.46***	0.95***	0.83***	0.48***	1.00	0.88***	0.67***
	SDW	0.32***	0.47***	0.85***	0.90***	0.26***	0.85***	1.00	0.77***
	100SDW	0.10*	0.18***	0.09*	0.33***	0.27***	-0.03ns	0.32***	1.00

NND: Number of nodules, NDW: Nodules weight, NPD: Number of pods, NSPD: Number of seed per pod, NSPT: Number of seed per plant, SDW: Seed weight, 100SDW: 100 seed weight, PDW: Pod weight.

Table 5: AMMI Analysis for varieties and environment (phosphorus) interaction in the field

		NPD		PDW (g)		NSP		NST		SWP (g)		HSW (g)	
SV	DF	SS	% E	SS	% E	SS	% E	SS	% E	SS	% E	SS	% E
Total	239	7732		768.7		52.99		5674		570.0		790.9	
TRT	19	2631	34.02	337.3	4.36	12.92	24.43	2089	36.81	262.3	46.00	242.2	30.62
VAR	4	888	11.48	145.2	18.90	4.22	7.96	7054	12.43	133.6	23.43	138.3	17.50
ENV (p)	3	1330	17.20	119.8	15.58	1.27	2.39	1015	17.89	89.21	15.65	33.5	4.23
Blocks	8	207	2.67	14.1	1.83	1.18	2.22	682	0.00	7.1	1.24	6.2	0.78
Interactions	12	413	5.34	72.3	9.40	7.43	14.02	3685	6.49	39.5	6.92	70.4	8.90
IPCA1	6	301	3.89	39.3	5.11	6.07	11.44	2654	4.67	20.4	3.57	58.1	7.34
IPCA2	4	99	1.28	32.4	0.17	1.32	2.49	1029	1.81	19.0	3.33	10.8	1.36
Residual	2	13	0.01	0.6	0.07	0.03	0.05	2	0.00	0.1	0.00	1.41	0.17
Error	212	4894		417.3		38.90		3517		300.6		542.4	

SV: Source of variation, DF: Degree of freedom. SS: Sum of squares. %E: Explained % of sum of square. TRT: Treatment. VAR: Variety. ENV (P): Environment (phosphorus). NPD: Number of pods, NSP: Number of seed per pod, NST: Number of seed per plant, SWP: Seed weight, HSW: Hundred seed weight, PDW: Pod weight.

Ranking of Soybean Varieties under Different Rates of Phosphorus (GxE) on the Field

The performance of the varieties in each environment (phosphorus) ranked by AMMI analysis for the yield characters are presented in Table 6. At 0kgSSP/ha SOYA was best for the number of pods per plant (13.04) and number of seeds per plant (31.05). While at 20kgSSP/ha and TGX 1740-1E was best for number of pods per plant and number of seed per plant (18.76 and 48.75) compared to other rates of P application. The rate of 40kgSSP/ha TGX 1479 was best for the number of seeds per plant (37.26) and TGX 1740-1E was best for number of pods per plant (16.34). Whereas at 60kgSSP/ha and TGX 1740-1E was best for number of pods per plant (16.30) and TGX 1479 was best for number of seed per plant (34.91).

Table 6: Ranking of soyabean varieties under different rates of phosphorus (GXE) that are influenced by environment (phosphorus) in the field

Environment	Rank	No. Seed/plant		No. of pods per plant	
		Variety	Mean	Variety	Mean
0kgSSP/ha	1st	SOYA	31.05	SOYA	13.04
	2nd	TGX 1740-1E	26.14	TGX 1740-1E	11.77
	3rd	TGX 1479	25.31	TGX 1479	11.15
	4th	TGX 1448-2E	22.22	TGX 1448-2E	9.10
	5th	SAM SOY-2	12.27	SAM SOY-2	6.32
	Mean		23.40		10.28
20kgSSP/ha	1st	TGX 1740-1E	48.75	TGX 1740-1E	18.76
	2nd	TGX 1479	47.69	TGX 1479	18.40
	3rd	SOYA	47.33	SOYA	17.86
	4th	TGX 1448-2E	40.15	TGX 1448-2E	17.07
	5th	SAM SOY-2	23.10	SAM SOY-2	12.7
	Mean		41.40		16.85
40kgSSP/ha	1st	TGX 1479	37.26	TGX 1740-1E	16.34
	2nd	TGX 1740-1E	33.90	TGX 1479	16.06
	3rd	SOYA	31.65	TGX 1448-2E	15.72
	4th	TGX 1448-2E	25.28	SOYA	10.64
	5th	SAM SOY-2	18.79	SAM SOY-2	9.56
	Mean		29.38		13.66
60kgSSP/ha	1st	TGX 1479	34.91	TGX 1740-1E	16.30
	2nd	TGX 1448-2E	34.78	TGX 1479	15.26
	3rd	TGX 1740-1E	31.45	SOYA	14.41
	4th	SOYA	31.01	TGX 1448-2E	13.27
	5th	SAM SOY-2	30.60	SAM SOY-2	13.02
	Mean		32.55		14.45

AMMI Analysis for Varieties and Environment (Phosphorus) Interaction in the Screen House

The total variation of between 20.06 and 50.30% was due to phosphorus application while the effect of variety (explained %) ranged from 12.18 to 20.98% for the number of pod and 100 seed weight (Table 7). The influence of environment was between 1.63% for seed weight and 8.96% for number of seed per pod.

Table 7: AMMI Analysis for varieties and environment (phosphorus) interaction in the screen house

SV		NPD		PDW (g)		NSP		NST		SWP (g)		HSW (g)	
	DF	SS	% E	SS	% E	SS	% E	SS	% E	SS	% E	SS	% E
Total	239	3649.9		380.70		306.06		11563		94.92		4980	
TRT	19	719.5	19.71	90.69	23.82	94.94	31.02	2636	22.79	29.25	21.33	1422	28.55
VAR	4	444.8	12.18	66.92	17.57	59.02	19.28	1581	13.67	14.45	15.22	1045	20.98
ENV (p)	3	180.2	4.93	10.11	2.65	27.45	8.96	796	6.88	1.55	1.63	180	3.61
Blocks	8	115.0	3.16	14.92	3.91	23.47	7.66	527	4.55	2.62	2.76	284	5.70
Interactions	12	94.5	2.58	13.66	3.58	8.47	2.76	258	2.23	4.24	4.46	197	3.95
IPCA1	6	69.5	1.90	10.10	2.65	6.50	2.12	197	1.70	2.75	2.89	161	3.23
IPCA2	4	18.6	0.50	3.55	0.93	1.88	0.61	57	0.49	1.49	1.56	33	0.66
Residual	2	6.4	0.17	0.01	0.01	0.09	0.03	4	0.03	0.01	0.01	3	0.66
Error	212	2815.4		275.09		187.65		8400		72.05		3273	

DF: Degree of freedom. SS: Sum of squares. %E: Explained % of sum of square. TRT: Treatment. VAR: Variety. ENV (P): Environment (phosphorus). NPD: Number of pods, NSP: Number of seed per pod, NST: Number of seed per plant, SWP: Seed weight, HSW: Hundred seed weight, PDW: Pod weight.

DISCUSSION

The pre-planting soil analysis showed that the soils of the experiential sites were low in soil nutrient status. The values of total nitrogen and available phosphorus, and potassium of the experimental soil were below the critical level as recorded by Olowoake, (2014). This necessitated the need for the application of soil amendment in the form of inorganic or organic fertilizers.

This study demonstrated that yield component characters were better in all phosphorus-treated soybean varieties compared to the un-treated varieties both on the field and in the screen house. This implies that the treatment of soybean variety with single super phosphate fertilization increased yield components in soybean. This observation is in agreement with Kolawole (2012) who had earlier postulated that phosphorus is known to be a major drawback hindering soybean yield in the producing countries in Africa. Kakar *et al*. (2002) had shown phosphorous application to be important for growth, development and yield of soybean.

On the field, the grand mean value for interaction between variety and phosphorus indicated that across the treatments, there was significant increase among yield component characters of phosphorus-treated varieties compared to untreated, which in agreement with the report of FMARD (2012) which reported had recommended Phosphorus rate in the range of 20 – 40 kg/ha for soybean in soils of the Nigerian savanna. TGX 1740-1E recorded highest number of pods per plant, number of seeds per plant and nodules dry weight. Whereas TGX 1479 has the highest pods weight, number of seeds per pods, seed weight per plant and yield per hectare at 20kg SPP/ha compared to other variety. This agreed with the report of Singleton *et al.* (1984) which reported that improved phosphorus nutrition significantly increased dry matter, grain yield and weight. Darwesh *et al*. (2013) also confirmed that treatment with phosphate increased production in an experiment conducted on soybean. Lobo *et al*. (2019), also notes that P is essential in energy metabolism especially in BNF, a process that requires energy process. For good nodulation, P is required in high amounts (Hc and Aa, 2019). 20kg SPP/ha is efficient for soybean varieties for sustainable Phosphorus management strategy for enhancing yield and Phosphorus use efficiency. However, in this study, excessive phosphorus rate (40 and 60kgSSP/ha) only increased biomass at the expensive. There was a trade-off between biomass and yield. Phosphorus application at a higher rate is not only wasteful but also increased production cost. Demeterio *et al.* (1972) had shown that excess phosphorus application decreased yield of soybean.

The correlation between most of the yield components and 100 seed weight are positively significant ($p > 0.001$, 0.01, and 0.005). There was no linear relationship between the movements of the variables as observed through non-significantly and negatively correlated between the numbers of seed per pod and 100 seed weight. A perfect significant correlation between pod weight and seed weight implied that for a positive increase in one variable, there will be an increase in the second variable. However, significant positive correlation between yield components (number of seeds per pod and seed weight, number of pods and pod weight, number of seeds and hundred seed weight) recorded in this study is consistent with previous studies (Aliyu and Makinde 2016), which suggest plausible faster genetic of seed yield the cowpea variety.

On the field, the performance of the varieties in each environment (phosphorus application) ranked by AMMI analysis for the yield characters shows that at 0kgSSP/ha SOYA ranked first and TGX 1740-1E ranked second for number of pods per plant and number of seeds per plant respectively and at 0g of phosphorus TGX 1740-1E ranked first and TGX 1479 ranked second for number of seed per plant and number of pod. This implies that farmers who do not have access to fertilizer can adopt SOYA and TGX 1740-1E due to their availability and cost in this locality. However, at 20kgSSP/ha TGX 1740-1E ranked first and TGX 1479 ranked second for number of pods per plant and number of seeds per plant compared to other rates. While at 40kgSSP/ha TGX 1479 ranked first and TGX 1740-1E ranked second for number of seeds per plant and TGX 1740-1E ranked first and TGX 1479 ranked second for number of pods per plant. Whereas at 60kgSSP/ha TGX 1740-1E ranked first and TGX 1479 ranked second for number of pods per plant and TGX 1479 ranked first and TGX 1448-2E ranked second for number of seeds per plant. Similarly, when there is availability of phosphorus it is preferable to cultivate the listed above variety at their best treatment level.

CONCLUSION

There was a synergistic effect between phosphorus fertilizer applications on soybean varieties as the positive effects of phosphorus fertilizer application on the soybean yield were significantly boosted.

The soybean component characters enhancements observed in this study may also be attributed to an increased symbiotic relationship of rhizobia (bacteria) with the root of leguminous crops resulting in the possible fixation of atmospheric nitrogen into the root of soybean which was favoured by phosphorus fertilizer. Among the five soybean varieties, TGX 1740-1E and TGX1479 are the highest yielding both on the field and screen house. The number of pods had highest contribution to the seed yield and should be a major selection index during breeding and improvement of soybean.

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REFERENCES

Adjei-Nsiah, S., Kumah, J., Owusu-Bennoah, E., and Kanampiu F. (2019). Influence of P sources and rhizobium inoculation on growth and yield of soybean genotypes on Ferric Lixisols of Northern Guinea savanna zone of Ghana. *Communication in Soil Science and Plant Analysis, 1532-2416.*

Ajadi BS, Adeniyi A. (2017). Trends analysis of agricultural productivity in Kwara State, Nigeria. *Journal of Research and Development Studies*. 5 (1), 205-214.

Aliyu, O.M., and Makinde, B.O. (2016). Phenotypic analysis of seed yield and yield components in cowpea (*Vigna unguiculata* L., Walp). *Plant Breeding and Biotechnology*, 4:252-261.

Darwesh, D.A., Amin, S.A., Maulood, P.M. (2013). Effect of Phosphorus Fertilizers on Growth and Physiological Phosphorus Use Efficiency of Three Soybean Cultivars. *IOSR Journal of Agriculture and Veterinary Science*, 3(6), 32–36.

Demeterio, J.L., Ellis, R. & Paulsen, G.M. (1972). Nodulation and nitrogen fixation by two soybean varieties as affected by phosphorus and zinc nutrition. *Agronomy Journal*.64:566-568.

diCenzo, G.C., Zamani, M., Checcucci, A., Fondi, M., Griffitts, J.S., Finan, T.M., and Mengoni, A. (2019). Multidisciplinary approaches for studying rhizobium–legume symbioses. *Canadian Journal of Microbiology*, 65, 1-33.

Zarrin, F., Zia, M. and Chaudhary, M.F. (2007). 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.

FMARD (2012) Fertilizer Use and Management practices for Crops in Nigeria. Federal Ministry of Agriculture and Rural Development, Abuja. Pg 215.

Hartman, G. L., West, E. D., and Herman, T. K. (2011). Crops that feed the World 2. Soybean—worldwide production, use, and constraints caused by pathogens and pests. *Food Security*, 3, 5-17.

Hc, O. & Aa, U. (2019). Influence of Nodumax Inoculant on Nodulation, Root Growth Parameters of Soybean and Soil Physico-Chemical Properties. EC Agriculture 5(10), 619-627. https://www.ecronicon.com/ecag/pdf/ECAG-05-00208.pdf

IITA (2009). Farmers' Guide to Soybean Production in Northern Nigeria.1 - 5pp

Kakar, K.M., Tariq, M., Taj, F.H., Nawab, K. (2002). "Phosphorous use efficiency of soybean as affected by phosphorous application and inoculation," *Pakistan Journal of Agronomy*, vol. 1, no. 1, pp. 49–50.

Kolawole, G.O. (2012). Effect of phosphorus fertilizer application on the performance of maize/soybean intercrop in the southern Guinea savanna of Nigeria., 58(2), 189-198.

Lobo, C.B., Juárez Tomás, M.S., Viruel, E., Ferrero, M.A. and Lucca, M.E. (2019). Development of low-cost formulations of plant growth-promoting bacteria to be used as inoculants in beneficial agricultural technologies. *Microbiological Research*, 219, 12–25. https://doi.org/10.1016/j.micres.2018.10.012

Malik, M.A., Cheema, M. A., Khan, H. Z., & Ashfaq, M. W. (2006) Growth and yield response of soybean (*Glycine max* L.) to seed inoculation and varying phosphorus levels. *J. Agric. Res*., 44, 47-53

Murithiab, H. M., Beedc, F., Tukamuhabwad, P., Thommab, B. P. and Joosten M. H. (2016). Soybean production in eastern and southern Africa and threat of yield loss due to soybean rust caused by Phakopsorapachyrhizi. *Plant Pathology*, 65., 176–188.

Okalebo, JR, KW. Githua. P.L.J., Woomer. (2002). Laboratory methods of soil and plant analysis: A working manual, 2nd ed. TSBF-CIAT and SACRED Africa. Nairobi.

Olanrewaju, R.M. (2009). Climate and the Growth Cycle of Yam Plant in the Guinea Savannah

Olowoake, A.A. (2014). Influence of organic, mineral and organomineral fertilizers on growth, yield and soil properties in grain amaranth (*Amaranthus cruentus.* L). *Journal of Organics*,1 (1): 39-47.

Singleton, PW., HM, AbdelMagid., and JW, Tavares. (1984). Effect of Phosphorus on the Effectiveness of Strains of Rhizobium japonicum. *Soil Science Society of America Journal* 49:613-616.

USDA (2017). Soybeans and oil crops. Economic Research Outlook, 1.

Zhou, Q.H., Chen, Q., Y., Tong, Y.L. and Wang, Y. (2016). Light-induced ambient degradation of Few-layer black phosphorus: Mechanism and protection. *Angewandte chemie*, (128), 11609-11613.