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Research Article

Effect of Phosphorus and Zinc on the Growth, Nodulation and Yield of Soybean (*Glycine Max* (L.) Merrill)

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An investigation was carried out at Kogi State University Student Research and Demonstration farm Anyigba during the 2019 wet season to observe the effect of phosphorus and zinc on the growth, nodulation and yield of soybean. The treatments comprised three levels: phosphorus and zinc (0, 30 and 60 kg P_2O_5/ha; 0, 5 and 10kg Zn/ha) and two varieties TGX 536 – 02D and Samsoy 2. The investigation revealed that application of phosphorus affected growth, nodulation, yield and some yield components of soybean while zinc application, apart from the plant height, which is reduced significantly, had no significant effect on other growth characters, nodulation, yield and yield components. However, it was generally found to decrease most of the characters. Application of 60 kg P_2O_5/ha gave the highest growth and yield, while 30 kg P_2O_5/ha gave the highest nodulation. Application of 60 kg P_2O_5/ha significantly increased yield to 1.9t/ha, which was significantly higher over the control plots, which gave 1.7t/ha. Crude protein and oil contents of the seeds were not significantly affected by phosphorus application but were significantly affected by zinc application, which significantly decreased protein content as its amount an increase from 0 to 10 kg/ha, and significantly increased oil content from 0 to 5kg/ha and decreased it below 5kg/ha. It was also revealed that the two varieties responded similarly to phosphorus and zinc in terms of growth, grain yield and crude protein content of the seeds.

Keywords: *Glycine max (L.) Merrill, Nodulation, yield, yield characters, percentage effective nodule, dry matter accumulation, oil content, correlation.*

INTRODUCTION

Soybean originated in the Northern China plains around the eleventh century B.C., and later was introduced into Manchuria; it has been recognized as a former crop plant since the origin of agriculture (Jandong *et al.* 2011). Soybean, a temperature-sensitive crop, belongs to Papilionaceae, a leguminous family and it is an annual herbaceous legume (oilseed), normally erect, bushy and leafy. It provides approximately 50% edible oil of the world's total oil production (Akparobi, 2009). It is usually grown in environments with temperatures between 10 and 4^0C during the growing season. It is grown on nearly all well-drained soil types. Soybean is a two-dimensional crop as it contains 20-22% oil and 42-46% protein (Aulakh *et al.* 1990). Continuous soil nutrient mining, resulting from increasing population pressure on the land resource is one of the major causes of soil fertility declining in most regions of sub-Saharan Africa; its consequences on crop production is quite depressing, as crop yielding potential is severely affected by soil nutrients deficiencies (Okogun *et al.* 2004). Phosphorus and Zinc, being one of the most important nutrient element requirements in soybean, is, however, lacking or in very minimal quantity in many regions of sub-Saharan Africa. Phosphorus is needed in relatively large amounts by legumes for growth and nitrogen fixation and has been reported to promote leaf area, biomass, yield, nodule number, nodule mass, etc., in a number of legumes (Kasturikrishna and Ahlawat, 1999). While Phosphorus deficiency can limit nodulation by legumes and P fertilizer application can overcome the deficiency (Carsky *et al.*, 2001), the microbial community does inf1uences soil fertility through soil processes viz. decomposition, mineralization, and storage/release of nutrients. Microorganisms enhance the P availability to plants by mineralizing organic P in soil and solubilizing precipitated phosphates (Chen *et al.,* 2006; Kang *et al.,* 2002; Pradhan and Sukla, 2005). Phosphorus is an important plant nutrient involved in several energy transformations and biochemical reactions, including biological nitrogen fixation. A large amount of P applied as fertilizer enters into the immobile pools through a precipitation reaction with highly reactive aluminum (Al+) and iron (Fe3+) in acidic, and calcium (Ca2+) in calcareous or normal soils (Gyaneshwar *et al.,* 2002; Hao *et al.,* 2002). Isherword (1998) found 10-25% efficiency of P around the world with the concentration of bioavailable P in soil reaching a low level of 1.0 mg kg-1 soil (Goldstein, 1994), hence the need to augment soil nutrient with phosphate fertilizers.

Soybean is sensitive to zinc deficiency, which is needed for protein metabolism and involved in the chlorophyll formation, growth hormone stimulation, enzymatic activity and reproductive processes (Thenua *et al.* 2014). Zn is considered the most limiting factor in producing crops in different parts of the world. Babaeian *et al.* (2011) indicated that Zn deficiencies are common in 30% of the global soils. The low solubility of Zn in soils rather than the low total amount of Zn is the major reason for the widespread occurrence of Zn deficiency problems in crop plants (Raof, 2016). It has also been reported that P decreases the concentration of Zn mostly in leaves and least in roots, suggesting that the effect of P on Zn originates in roots, which retards translocation of Zn to the upper plant parts, probably due to the formation of a compound that is either less mobile or has a lower solubility product (Chiezey, 1999). Zn foliar application and seed inoculation with bio fertilizers such as Plant Growth Promoting Rhizobacteria (PGPR) and *Bradyrhizobium has been reported to be an* important effective factor in increasing soybean yield and nodulation. (Oscar *et al.,* 2014; Heidarian *et al.,* 2011). Therefore, this research was carried out to investigate;

1. The effect of different doses of phosphorus and zinc on the growth, nodulation and yield of soybeans.
2. Their effects on other agronomic characters of the crop and;
3. To obtain the best doses suitable for this location.

MATERIALS AND METHODS

Experimental Materials and Procedures

Experiments were conducted at Kogi State University Student Research and Demonstration Farm Anyigba, (Lat 7^{o} 29^{1} and Long 7^{0} 11^{1}E) in the Guinea savanna agro-ecological zone rainy season of 2019 to determine the response of soybean to different levels of phosphorus and zinc.

Table 1: Laboratory result of soil analysis of the experimental site at 2019 cropping season.

Physical properties (%)	**Depth (0-30cm)**
Clay	11.15
Silt	2.61
Sand	86.24
Textural Class	Sandy clay-loam
Chemical properties (%)	
pH (H_2O)	6.13
Organic carbon	0.15
Organic matter	0.88
Total Nitrogen (%)	0.03
Available phosphorus (ppm)	9.00
Exchangeable cations	
Calcium Ca^{2+} (Cmol/kg)	4.16
Magnesium Mg^{2+} (Cmol/kg)	1.97
Potassium k^{+} (Cmol/kg)	2.75
Sodium Na^{+} (Cmol/kg)	0.95
Extractable Zn^{2+} (ppm)	1.85
Cation Exchange Capacity (CEC)	9.83

The two varieties evaluated were TGX 536 – 2D and Samsoy 2, both of which mature in about 110 days from sowing. Treatment comprises of a factorial combination of two soybean varieties aforementioned with three phosphorus levels (0, 30 and 60 kg P_2O_5/ha) and three zinc levels (0, 5 and 10 kg Zn/ha), which were arranged in a Randomized Complete Block Design with four replications. Each plot was 4.5m wide, containing 6 rows of 4m in length. All sowing was done manually on 75cm ridges. The gross and net plot sizes were $18m^2$ and $12m^2$, respectively.

Cultural Practices

The experimental site was disc-ploughed and harrowed with a notched disc harrow. Ridges of 75cm apart were made.

Planting
Seeds were sown at a spacing of 5cm on ridges 75cm apart to achieve a plant population of 266,666 plants/ha.

Fertilizer Application
There was a uniform application of 25kgN/ha in Calcium Ammonium Nitrate (CAN) to all plots as a starter dose. The nitrogen was applied at the same time with phosphorus and zinc. Phosphorus was applied as P_2O_5 using a Single Superphosphate fertilizer (SSP), while Zinc was applied in the form of Zinc Sulphate Heptahydrate ($ZNSO_4.7H_2O$). These fertilizers were soil-applied and placed about 5cm to the side and below the seed, just before sowing.

Weed and Pest Control
The use of hoe only controlled weeds; this was done twice, first at 3 weeks after sowing and second at 6WAS. After that, the crop canopy closed and weed growth was minimized. No disease and pest attack/infestation was observed. Plants maintained a healthy appearance throughout their growth.

Harvesting
This was done when the leaves of the soybean plants turned yellow and eventually dried in the field. The four inner rows of $12m^2$ were used as the not plot. The harvested soybean was allowed to dry for about two weeks before threshing thoroughly.

Threshing
This was manually done; chaff was separated from the seeds by means of winnowing with trays. Clean seeds from each plot were immediately weighed to determine yield, while haulms were also weighed to determine haulms yield.

Determination of Soil Nutrient Status
Soil samples were taken to a depth of 30cm before fertilizer application and analyzed for physical and chemical properties. The texture was analyzed by the Hydrometer method (Boyoucos, 1951) and the texture class was determined by the soil texture triangle.

Soil Nitrogen
Total nitrogen was determined by the macro-kjeldhal procedure (Bremmer, 1965).
Available Phosphorus

Available phosphorus was determined by the method described by Troug (1930). The extracted
phosphorus was determined by the Molybdate blue colour (Bray and Kurtz, 1945).

Extractable Zinc
Extractable zinc was determined by using extracting solution DPTA, known as DPTA method.

Exchangeable Cations
Exchangeable cations were determined by the acetic acid method (Reith, 1967). Magnesium, calcium and potassium were determined by the atomic absorption spectrophotometry, using Perkin Elmer Model 403.

Observation

Beginning from 4 weeks after sowing, and at 4weeks intervals until 12weeks after sowing and at harvesting, five plants per plot were sampled to determine the effect of the treatments on various characters. The following plant characters were measured; plant height, total dry matter per plant, number of days to 50% flowering, nodule count of five plants, nodule weight of five plants, percentage of effective nodules, number of days to physiological maturity from 50% flowering, number of days to physiological maturity from the time of sowing, number of pods per plant, number of branches per plant at harvesting, 100-seed weight, grain yield per hectare, haulm yield per hectare, oil and crude protein contents of the seed. Other measurement made was the Leaf Area Index (LAI) (Watson, 1947 and 1952).

Statistical Analysis

The data collected was subjected to Analysis of Variance (Snedercor and Cochran, 1967), and a significant difference amongst treatment means were evaluated using the Duncan' Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

Soil test reveals a textural class of Sandy clay-loam and Available phosphorus (9.00ppm), which is low compared to 15mg kg^{-1} considered the critical level for soybean production (Staton and Darry, 2007). The soil is deficient in extractable Zn, with about 25% of the critical level established for some soils in South-Western Nigeria. (Osiname *et al.,* 1973; Adeoye and Agboola, 1985). The pH of 6.13 indicates that the soil is slightly alkaline (Table 1).

Effect of Phosphorus, Zinc and Variety on growth characters of Soybeans at Anyigba, Kogi state.

Results from this study is presented in table 2. The variety was found to have no significant effect on the LAI at 4 and 8WAS. However, leaves of Samsoy 2 had a higher area at 12WAS, while Zn fertilizer application had no significant differences at all sampling periods; this supports Heidarian *et al.* (2011), who found LAI decreased at different growth stages. However, SeifiNadergholi *et al.* (2011) also found that Zinc foliar application increases tryptophan amino acid and indol-acetic acid hormone, which were the two main factors in leaf area expansion in *P. vulgaris*. P application greatly influenced LAI, at 4WAS with 60kg P_2O_5 producing consistently higher leaf area but not at the later sampling period (8 and 12 WAS); this may have resulted from P and Zn to the leaves. The antagonism between Zn and P has already been reported in other crops like maize and wheat (Zhimini *et al.,* 1999).

There were no significant differences in the nodules produced by the two varieties examined and none of the sampling periods had variety any significant effect on nodule weight as well, due probably to the fact that they are both promiscuous. P application was significant on the number of nodules produced only at 4 and 8WAS while nodule weight responded to P application just in the same manner as the number of nodules produces by the varieties. 30kg P_2O_5/ha application increased nodules while continuous increase up to 60kg P_2O_5/ha decreases nodules below 30kg P_2O_5/ha application rate; this corresponds with Devi *et al.* (2012) who attributed the increase in nodule number with P to a diluting effect, as P is known to stimulate nodulation. Zn had no significant influence on the weight of nodules; this result is in opposition to Thenuna *et al.* (2014) findings, who discovered that zinc levels significantly increased the number of nodules per plant and nodule dry weight per plant. This opposition might be attributed to the high concentration of available phosphorus in the soil (9.00ppm), which might have held up the absorption of Zn. A high concentration of phosphorus in the soil, according to Sharma *et al.* (1968), tend to reduce the availability of extractable Zn to plants.

At 8WAS, effective percentage nodules varied significantly with TGX 536 – 02D producing higher effective nodules than Samsoy 2 while Zn had no such influence at all sampling stages, P application had a significant influence on PEN, only at 4WAS, the higher PEN was obtained when 30kg P/ha was used this was however not statistically significant from other application. This corroborates with Odoh *et al.* (2016) finding, who discovered that P Omission in the applied fertilizer significantly reduced the shoot dry weight, % effective nodules number and dry weight while combined application of NPK, Mo and Zn significantly decreased the root colonization. V x P x Zn interaction was significant at 4WAS (table 5); the highest effective nodules was produced by TG x 536-02D at 60kg/ha of P_2O_5 and 0 kg/ha of Zn. This was significantly higher than all other treatments, which were not significantly different from each other. The improved performance of the treatment combination of Pha^{-1} and $Znha^{-1}$ showed Zn-P synergy, which had been reported by Shittu *et al.* (2012). Some authors claimed that applied P affects the absorption of Zn by roots in some way other than precipitation of an insoluble Zinc phosphate (Ogoke *et al.,* 2004). This assertion has been validated by the interaction effect exhibited by V x P x Zn, which the two varieties in the study responded to. Plant height was significantly influenced by variety, zinc and phosphorus application, TGX 536-02D produced consistently taller plants (20.0, 46.58 and 65.35cm) than its counterpart Samsoy 2 at 5, 10WAS and at harvest, respectively. Zn application had significant differences only at harvest.

Increasing the level of Zn reduced plant height. Increasing the level from 0 to 5 kg/ha did not reduce plant height significantly, but further increase to 10 kg/ha had a significant reduction in plant height from zero levels. At 10 WAS and at harvest, application of 60kg/ha of P_2O_5 significantly produced taller plants than 0 and 30 kg/ha of P_2O_5 applications. At both stages of growth, there were no significant differences between 0 and 30 kg/ha applications. This corroborates with Shittu *et al.* (2012) findings. V x Zn interaction showed significant differences in plant height (Table 6). On TG x 536-02D, it was observed that increasing the amount of Zn from 0 to 5kg/ha significantly reduced plant height and further increase to 10kg/ha still reduced it, even though the reduction was not statistically significant, this results from the fact that a lot of soil phosphorus, reduces the growth of plant roots and mycorrhiza volume, which also reduce the absorption of zinc by plants. In plants, the presence of high phosphorus concentrations will reduce the solubility of zinc and decreases its transmission from the roots to the rest of the plant's organs (Malakouti *et al.,* 2006). On Samsoy 2, there was no significant change in plant height as the amount of Zn was altered from 0 to 10kg/ha. There were also significant differences at each level of Zn between the two varieties.

Variety only responded to numbers of branches (table 3), with Samsoy 2 producing the highest number of branches. P and Zn application had no significant effect on branches. These results agree with the findings of Lamera and Para (1983).

Varieties and Zn application had no significant differences in the number of days to 50% flowering. Application of P, on the other hand, significantly affected the number of days to 50% flowering. Increasing the P level from 0 to 30kg/ha significantly increased the number of days to 50% flowering, a further increase to 60kg/ha also increased it; however, the increase was not statistically significant, this means that high rates of P can prolong flowering. A similar result was obtained by Chiezey (1989). Physiological maturity from 50% flowering was observed Samsoy 2 significantly exhibit longer days to physiological maturity than TG x 536-02D. An increasing amount of P from 0 to 30kg/ha significantly reduced the number of days to physiological maturity from 50% flowering. This conforms with the findings of Jacob and Uexkiill (1963), who reported that the liberal application of P accelerates ripening. However, a further increase to 60kg/ha had no significant effect again. However, there was still a reduction.

Physiological maturity from the sowing date took the same pattern as “from 50% flowering” for variety (Table 3). Increasing Zn application rate from 0-5kg/ha extends physiological maturity from sowing time. Physiological maturity does not respond to P application.

All growth characters that showed significant variation among varieties may be attributed to varietal differences in several energy transformation processes and biochemical reactions such as the ability to utilize and maximize absorbed cations from the soil for Root development stalk and stem strength, nitrogen fixation, among other potentials which are attributed to phosphorus fertilization (Devi *et al.,* 2012). Also, the non-response of growth characters to Zn application in its entirety across sampling periods result from the fact that it was soil-applied. Therefore, Zn^{2+} is extremely slowly released for plant use. However, foliar application of Zn could curb this situation as Foliar application of microelements is more beneficial than soil application (Heidarian *et al.,* 2011). Since application rates are lesser than soil application, the same application could be obtained easily and the crop reacts to the nutrient application immediately (Zayed *et al.,* 2011). Also, Foliar spraying of microelements has been very helpful when the plant roots cannot provide the necessary nutrients (Kinaci and Gulmezoglu, 2007; Babaeian *et al.,* 2011).

Effect of Phosphorus, Zinc and Variety on Yield and Yield characters of Soybeans at Anyigba, Kogi state.

Table 4 presents the effect of Zn, P and Variety on yield /yield characters. Although TG x 536-02D produced slightly higher grain and haulm yields than Samsoy 2, these differences were not statistically significant.

Grain yield was influenced by P application, 60kg P_2O_5/ha gave higher grain yield, as haulm yield followed the same pattern, there were no significant differences in grain and haulm yields between 0 and 30kg/ha of P_2O_5 applications. High yields from P application has been reported by Devi *et al., (2012).* The low yield of soybean grain at lower phosphorus levels was probably due to the lesser magnitude of phosphorus response. Stefanescu and Palanciuc (2000); Landge *et al.* (2002); Umale *et al.* (2002); Ilbas and Sahn (2005); Tapas and Gupta (2005) and Jain and Trivedi (2005) also reported that seed yield of soybean increase with inoculation and applying higher levels of phosphorus. Other treatments showed no significant effect on grain and haulm yield. Variety varied significantly with 100seed weight as Samsoy 2 produced the highest value (14.51kg) than TGx 536-02D (13.13kg), while the reverse became the case with reference to matured pods, TGx 536-02D was discovered to have more matured pods (172) than Samsoy 2 (129.06).

Table 2: Effect of Phosphorus, Zinc and Variety on growth characters of Soybeans at Anyigba, Kogi state.

	Growth characters														
Treatment	Leaf Area Index			Nodule Count/plant			Nodule weight/plant			% Effective nodule			Plant height (cm)		
	Weeks after sowing														
Variety	4	8	12	4	8	12	4	8	12	4	8	12	5	10	16 (Harvest)
TGX 536-02D	0.79	4.12	8.33$_b$	0.73	6.29	20.39	0.004	0.21	20.39	41.25	82.50$_a$	67.53	20.00$_a$	46.58$_a$	65.35$_a$
Samsoy 2	0.79	4.50	9.69$_a$	0.36	5.82	26.92	0.003	0.19	26.92	16.19	75.00$_b$	69.33	17.76$_b$	36.98$_b$	49.71$_b$
SE ($\pm$)	0.04	0.17	0.33	0.14	0.82	2.92	0.001	0.02	2.92	5.7	1.71	1.84	0.34	0.86	0.85
Zinc (kg ha^{-1})															
0	0.88	4.48	9.28	0.34	6.53	27.92	0.002	0.23	27.92	30.33	77.92	68.33	19.64	34.03	59.85$_a$
5	0.74	4.03	8.42	0.84	5.88	25.46	0.005	0.16	25.46	25.67	81.46	68.54	18.85	41.72	56.90$_{ab}$
10	0.74	4.43	9.34	0.45	5.76	17.58	0.005	0.20	17.58	30.17	76.88	68.41	18.14	40.58	55.85$_b$
SE ($\pm$)	0.05	0.21	0.43	0.18	1.00	3.58	0.002	0.03		6.98	2.10	2.26	0.42	1.05	1.04
P_2O_5 (kg ha^{-1})															
0	0.78$_b$	4.36	8.70	0.22$_b$	3.73$_b$	18.33	0.002$_b$	0.12$_c$	18.33	16.88$_b$	77.17	68.21	18.90	40.90$_b$	57.24$_b$
30	1.67$_c$	4.10	8.59	1.07$_a$	9.26$_a$	24.29	0.008$_a$	0.27$_a$	24.29	44.54$_a$	80.67	66.50	18.32	40.19$_b$	54.62$_b$
60	0.92$_a$	4.46	9.75	0.33$_b$	5.1$_b$	28.33	0.002$_b$	0.20$_b$	28.33	24.75$_{ab}$	78.42	70.58	16.82	44.24$_a$	60.73$_a$
SE ($\pm$)	0.05	0.21	0.43	0.18	1.00	3.58	0.002	0.03	3.58	6.98	2.10	2.26	0.42	1.05	1.04
Interactions															
V x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
V x Zn	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
Zn x P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

V x Zn x P	NS	NS	NS	*	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.
*NS Not Significant * Significant*

Table 3: Effect of Phosphorus, Zinc and Variety on Number of Branches, days to 50% flowering and physiological maturity of Soybeans at Anyigba, Kogi State.

	Growth characters			
Treatment			Physiological maturity from;	
	Number of Branches/plant	Days to 50% flowering	50% flowering	Sowing date
Variety				
TGx 536-02D	7.71b	76.44	32.42$_{b}$	109.00$_{b}$
Samsoy 2	17.87$_{a}$	76.03	37.53$_{a}$	113.44$_{a}$
SE ($\pm$)	0.68	1.13	1.12	0.22
Zinc (kg ha $^{-1}$)				
0	12.54	74.38	34.03	59.85$_{b}$
5	11.88	76.58	35.00	111.50$_{a}$
10	13.95	77.75	33.75	111.42$_{a}$
SE ($\pm$)	0.84	1.38	1.37	0.26
P_2O_5 (kg ha $^{-1}$)				
0	13.08	73.17$_{b}$	38.13$_{a}$	111.42
30	11.50	77.67$_{a}$	33.67$_{b}$	111.13
60	13.78	77.88$_{a}$	33.21$_{b}$	111.13
SE ($\pm$)	0.84	1.38	1.37	0.26
Interactions				
V x P	NS	NS	NS	NS
V x Zn	NS	NS	NS	NS
Zn x P	NS	NS	NS	NS
Y x Zn x P	NS	NS	NS	NS

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.
*NS Not Significant * Significant*

Table 4: Effect of Phosphorus, Zinc and Variety on Yield and Yield characters of Soybeans at Anyigba, Kogi state.

Treatment						
	Yield	Yield characters				
Variety	Grain yield (kg)	100seed weight	Matured pods/plant	Haulm Yield	Crude Protein content (%)	Oil content (%)
TGx 536-02D	1787	13.13$_{b}$	172.0$_{a}$	1171	39.20	20.45$_{a}$
Samsoy 2	1757	14.51$_{a}$	129.06$_{b}$	1111	38.96	18.93$_{b}$
SE ($\pm$)	61.2	0.12	5.60	49.4	0.45	0.21
Zinc (kg ha $^{-1}$)						
0	1809	13.95	149.6	1170	40.85$_{a}$	19.58$_{b}$
5	1833	13.96	143.6	1229	38.49$_{b}$	20.55$_{a}$
10	1673	13.54	159.5	1024	37.90$_{b}$	18.93$_{b}$
SE ($\pm$)	73.6	0.15	6.86	60.6	0.56	0.26
P_2O_5 (kg ha $^{-1}$)						
0	1715$_{b}$	13.78	150.7	1118$_{b}$	39.23	19.87
30	1667$_{b}$	13.71	140.3	997$_{b}$	39.11	19.74
60	1934$_{a}$	13.96	161.7	1309$_{a}$	38.90	19.45
SE ($\pm$)	73.6	0.15	6.86	60.6	0.56	0.26
Interactions						
V x P	NS	NS	NS	NS	NS	NS
V x Zn	NS	NS	NS	NS	NS	NS

Zn x P	NS	NS	NS	NS	*	*
V x Zn x P	NS	NS	NS	NS	NS	*

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.
*NS Not Significant * Significance*

Table 5: Interaction between Variety, Zinc and Phosphorus fertilizers on the PEN of soybean at 4 WAS at Anyigba, Kogi state.

Variety	P_2O_5 (kg /ha)	Zinc (kg /ha)		
		0	5	10
TGx 536-02D	0	0_{c}	18.75_{bc}	57.50_{abc}
	30	25.00_{abc}	0_{c}	0_{c}
	60	79.50_{a}	46.00_{abc}	61.00_{ab}
Samsoy 2	0	16.75_{bc}	39.00_{abc}	25.00_{abc}
	30	35.75_{abc}	50.25_{abc}	12.50_{bc}
	60	15.00_{bc}	0_{c}	25.00_{abc}
SE ($\pm$)	17.09			

Table 6: Interaction between Variety and Zinc fertilizers on the plant heights of soybean at 4 WAS at Anyigba, Kogi state.

	Variety	
Zinc (kg /ha)	TGX 536-02D	Samsoy 2
0	69.84_{a}	49.85_{c}
5	63.45_{b}	50.34c
10	62.77_{b}	48.93c
SE ($\pm$)	1.47	

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.

Table 7: Interaction between Zinc and Phosphorus fertilizers on the crude protein content of soybean at Anyigba, Kogi state.

	Zinc (kg/ha)		
P_2O_5 (kg /ha)	0	5	10
0	39.32_{bcd}	39.11_{bcd}	40.71_{ab}
30	40.03_{bc}	40.53_{ab}	36.77_{d}
60	43.18_{a}	37.28_{cd}	36.23_{d}
SE ($\pm$)	0.96		

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.

Table 8: Interaction between Zinc and Phosphorus fertilizers on the % Oil content of soybean at Anyigba, Kogi state.

	Zinc (kg/ha)		
P_2O_5 (kg /ha)	0	5	10
0	20.77_{ac}	19.50_{bcd}	19.33_{cd}
30	18.74_{d}	21.74_{a}	18.74_{d}
60	19.24_{cd}	20.42_{abc}	18.71_{d}
SE ($\pm$)	0.45		

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.

Table 9: Interaction between Variety, Zinc and Phosphorus fertilizers on the % oil content of soybean at Anyigba, Kogi state

		Zinc (kg /ha)		
Variety	P_2O_5 (kg /ha)	0	5	10
TGX 536-02D	0	22.32_{bc}	19.49_{def}	28.48_{a}
	30	19.22_{def}	19.52_{def}	18.18_{ef}
	60	19.77_{de}	24.21_{b}	18.03_{ef}
Samsoy 2	0	17.51_{f}	19.26_{def}	19.44_{def}
	30	19.70_{def}	20.38_{cd}	19.46_{def}
	60	18.77_{def}	20.46_{cd}	17.96_{ef}
SE ($\pm$)	0.64			

Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability.

This result from the variation among the different genetic lines examined, while other treatments showed no significant effect on 100seed weight and number of matured pods.

Effect of Phosphorus, Zinc and Variety on Crude Protein and Oil Content of Soybeans at Anyigba, Kogi state.

Zn application significantly affected protein content. Increasing the amount of Zn from 0 to 5kg/ha significantly reduced the crude protein content of the seeds. A further increase to 10kg/ha of Zn reduced it further, but the reduction was not significant statistically (Table 4). This corroborates with Namvar *et al.* (2011), who reported that seed inoculation with *Rhizobium* increases nodulation, nitrogen uptake and could be a possible reason for increasing protein content and yield parameters of legume crops. Zn x P interaction was also found to be significantly different (table 7). 60kg P and 0kg Zn application respectively gave the highest crude protein content; however, increasing Zn application to 5kg and 10kg/ha, while holding P application at 60kg/ha, shows no significant differences in the crude protein content. The least crude protein content was obtained when 0kg/ha of both P and Zn was applied; this shows that P is more essential than Zn in increasing crude protein content in soybean. Variety responded to oil content with TGX 536-02D giving a higher percentage of oil than Samsoy 2. While P application had no significant differences among sampling periods, 5kg Zn application gave the highest oil content; however, increasing Zn application from 10kg/ha reduces oil content. There was no significant difference between oil content at 0kg and 10kg Zn application. Zn x P and V x Zn x P interactions was significant in the cause of the examination (tables 8 & 9). In the Zn x P interaction for oil content, 5kg Zn + 30kg P_2O_5/ha gave the highest oil content, increasing P application to 60kg/ha while keeping Zn at 5kg/ha reduces oil content. Increasing Zn from 5kg/ha further also decreases oil content. 10kg Zn + 60kg P application gave the lowest oil content (Table 8). In the V x Zn x P, 0kg P_2O_5 + 10kg Zn application on TGX 536-02D gave the highest oil content, which was significantly higher than all other treatments. The above result opposes Tomar *et al.* (2004) finding, who observed that inoculation and phosphorus application increased the oil contents of soybean. Mehasen *et al.* (2002) and Bardan (2003) also reported that more oil yield was produced when inoculation and higher phosphorus doses were applied. This opposition may result from the Zn x P x V interactions. The lowest oil content was, however, obtained from 0kg Zn + 0kg P application on Samsoy 2.

Correlation Coefficient between Grain yield and Yield characteristics in soybean at Anyigba, Kogi state.

Table 10 shows the result of the correlation analysis conducted to determine the relationship between the grain yields and yield characters assessed. There was a positive and significant correlation between grain yield and LAI, number of nodules per plant, plant height, number of branches per plant, number of pods per plant and 100-seed weight. However, these characters significantly contribute immensely to the yield. They can as well be considered in further breeding programs in soybean improvement.

Table 10: Correlation Coefficient between Grain yield and yield characteristics in soybean at Anyigba, Kogi state.

Variables		Variables 1	2	3	4	5	6	7	8	9	10	11
	Grain yield	1.00										
	Leaf Area Index	0.399*	1.00									
	Number of Nodule/ plant	0.440**	0.226	1.00								
	Nodule Weight/plant	0.267	0.036	0.598**	1.00							
	Effecitve Nodules (%)	0.090	-0.058	0.396**	0.277*	1.00						
	Dry Matter accumulation	0.169	0.363**	-0.053	-0.046	-0.164	1.00					
	Plant height	0.518**	0.060	0.020	0.031	-0.039	0.444**	1.00				
	Number of Days to 50% flowering	-0.046	0.137	0.150	-0.024	-0.021	0.092	-0.018	1.00			
	Number of Branches/plant	0.283**	0.501**	0.195	-0.008	0.104	-0.133	-0.355*	-0.112	1.00		
	Number of Pods/plant	0.357*	0.186	-0.048	-0.080	-0.003	0.494*	0.652**	-0.117	0.074	1.00	
	100-Seed Weight	0.457*	0.362**	0.390**	0.144	0.001	-0.073	-0.188	-0.041	0.595**	-0.064	1.00

**significant at 5% level of significance ** significant at 1% level of signicance*

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