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Interactive Effect of Plant Spacing and Phosphorus Concentration on Yield and Yield Components of Soybean (Glycine max. L.)

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Abstract

Determination of the optimum plant population necessary for optimum yield is a major agronomic goal. Phosphorus nutrition is the main and most common constraint behind poor soybean productivity. A field experiment was conducted at Ibadan Nigeria (transition between Rain forest and Guinea savannah zone)during 2015 cropping season to evaluate the effect of Phosphorus application and soybean plant population on the productivity of soybean The trial was laid out in a Randomized Complete Block Design (RCBD) with split plot arrangement, replicated three times. The main plots consisted of four Phosphorus (P) levels (0, 20, 40 and 60 kg/ha) while four soybean populations (666700, 333333, 222200 and 166700 plants/ha) were the sub plots. Data collected include: number of branches, number of pods produced per plant, actual grain yield, seed weight, number of seed per pod, pod length and threshing percentage. Data collected were subjected to analysis of variance and significant means separated using Least Significant Difference ($p<0.05$). It was discovered that application of 60kg P/ha produced significantly ($p=0.05$) higher soybean yield (1103. kg/ha) with a yield advantage of 53.33% over Zero kg P /ha. also, plant population of 222200 plants/ha had significantly ($p=0.05$) higher soybean yield (1,188kg/ha) with a yield advantage of 33.33% and 18.01% over 666700 and 333333 plants/ha respectively. It was concluded that combination of 60kg P/ ha planted at 15 cm spacing produced optimum soybean yield and yield components. Hence, application of 60kg/ha of Phosphorus to soybean planted at15 cm is recommended for optimum yield and yield components of soybean.

***Key words**: phosphorus, soybean, yield, spacing, population.*

Introduction

Soybean requires phosphorus for attaining high yield especially under low available soil P status. However, it's response to phosphorus fertilizer application is dependent on the crop environment and management factors (Mallarino and Reuben, 2005). Shanker Lai Khaswa *et al.* (2014) also reported that inadequate phosphorus nutrition is the main and most common constraint behind poor soybean productivity. Many studies have confirmed that the use of P is essential for the increasing soybean seed yield (Nimje and Potkile, 1998; Ogoke 2006). However, there is a need to ascertain the level of phosphorus that is needed for the optimum yield of soybean before diminishing returns sets in. Determination of the optimum plant population necessary for optimum yield is a major agronomic goal. This can be achieved through sowing at a correct seed rate which reduces seed cost, lodging and also ameliorate disease problems (Hosseini *et al.*, 2001). Plant population is a production factor which affects light interception by plant canopy (Board, 2001). Increase plant population decrease number of side branches (Ibrahim and Hala, 2007, Caliskan *et al.*, 2007), pod number per plant (Shafshak *et al.*, 1989) seed yield per plant (Shafshak *et al.*, 1989, Pawlowski *et al.*, 1993), harvest index (Spaeth *et al.*, 1984) while seed yield per hectare is increased (Caliskan *et al.*, 2007).

Two general concepts are frequently used to explain the relationship between row spacing, plant densities and yield. Firstly, maximum yield can be obtained only if the plant community produces enough leaf area to provide maximum interception of the photo-synthetically active radiation during reproductive stage. Secondarily, equidistant spacing between plants will maximize yield because it minimizes interplant competition Egli, (2011). Looking at these two factors that are important in determining the yield of soybean becomes imperative so as to know their relationship for optimum performance of soybean.

Materials and Method

Field experiments was conducted at the Teaching and Research Farm of the Federal College of Agriculture, Moor Plantation, Ibadan (Latitude 7^o 22N and Longitude 3^o 58^{I}E) . The soil of the experimental site was sandy loam. Pre cropping soil samples were randomly collected from the experimental plots at both sites with a soil auger from a depth of 0-30cm prior to fertilizer treatment application. The collected samples were bulked into a composite sample, air dried, grounded and passed through 2mm sieve. The sieved samples were subject to routine analysis at the soil laboratory of Federal College of Agriculture, Ibadan.

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Field Procedures

The land of the experimental plot was ploughed and harrowed using tractor. Planting was done on the flat after marking out the plots using a tape rule. The whole experimental plot was 11.1x35m^2 which was marked out into 12 plots of 11x2 m^2 separated by 1m alley way. The plot was sub divided into plots of 2.4x2.0 m^2 . The treatments consisted of four levels of phosphorus application (0, 20, 40 and 60kg P/ha) in the main plot and four soybean population densities of 166700, 222200, 333333, and 666700 plants/ha, derived by varying intra row spacing in each sub-plot. The various intra row spacing were 20cm, 15cm, 10cm and 5cm respectively while the inter row spacing was 60cm. The treatments were fitted to randomized complete block design and laid out in split plot arrangement with three replications. Each replicate was separated by 1m alley way. The four phosphorus rates were assigned to the main plots, while the four population densities were allocated to the sub- plots. The main plot was 11.1 x 2.0 m (22.2m^2) while the sub plot was 2.4 x 2.0 m (4.8m^2). The main plots were separated by 1m apart while the sub plots were separated by 0.5m apart. Two seeds of were sown manually per hole using a meter tape to achieve the desired spacing. Phosphorus fertilizer application was done as single super phosphate ((18%P) at the treatment rates by uniform broadcast and mixed with the soil a week before planting. Nitrogen in form of urea was applied to the crop as a basal dose at the rate of 20 kg/ha at 2 weeks after planting. Weeds were controlled by using metaphox pre-emergence herbicide with glyphosate as an active ingredient at the rate of 3 litres/ha immediately after sowing and manually using traditional hoe at six (6) and nine (9) weeks after emergence.

Data collection and analysis

Crop measurements and data collection were taken from five (5) randomly selected and tagged plants within the net plot measuring 2.4 m^2 for computations. The data taken were number of branches/ plant at 6, 8 and 10 WAS, number of harvested pods per plant, pod length, number of seeds per pod, threshing percentage, final grain yield and 100 seed weight. All data collected were subjected to analysis of variance (ANOVA) using Genstat Discovery Edition 4 (2011) and significant means were separated using the Least Significant Difference at 5% level of probability ($LSD_{0.05}$) Steel *et al.* (1997).

Results and Discussion

The results of laboratory analyses of the pre-cropping soil samples of the experimental site is presented in Table 1. The physical and chemical properties shows that the soil is moderately acidic. The nitrogen content was low (0.96 g/kg) while the available phosphorus contents was moderately okay. The textural class was sandy loam. The values of exchangeable bases (calcium, magnesium and sodium) are moderate.

Treatment effect on soybean number of branches and number of pod per plant is presented in table 2. Application of P had no significant effect on soybean branching but significantly influenced pod production where P at 60 kg/ha had significantly ($\rho < 0.05$) higher pod number than all the other levelsof 40, 20 and 0 kg P / ha by 13.84, 21.77 and 51.87% respectively.

Application of P was observed to promote production of more pods significantly because of the importance of Phosphorus in legumes to be able promote nodule formation, flower and fruit or pod development. This agrees with the work of Elliot *et al.* (2014) who observed that application of phosphorus to legumes aids nodule formation, flower and fruit development.

Table 1. Physical and chemical properties of pre cropping soil of experimental sites (2015 season).

Soil properties	Value
pH	6.05
Organic carbon (g/kg)	9.6
Total Nitrogen (g/kg)	0.96
Available phosphorus (mg/kg)	7.62
Exchangeable cation (cmol/kg)	
Na^{2+}	0.52
Ca^{2+}	1.34
Mg^{2+}	1.87
K^{2+}	0.23
Exchangeable acidity	0.11
Effective cation exchangeable capacity	4.06
Particle size distribution (g/kg)	
Sand	863
Silt	72
Clay	65
Textural class	Loamy sand

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The effect of spacing was significant (ρ < 0.05) at 8 WAS for number of branches/plant with soybean planted at 20 cm spacing having higher number of branches than either 5 or 10 cm spacing but at par with those planted at 15 cm spacing . This could be due to less interplant competition hence they were able to utilize the available space for more horizontal growth. This result underscores the report of other authors like Liu *et al., (*2010); and Kobrace and Shamsi, (2011) who observed that increased in plant density reduced the number of branches of individual plants and vice versa. Wider spacing (20cm) was also observed to contribute to more pod production, this could be because wider spacing encouraged more lateral growth and since pod bearing pedicels are located on branches this could lead to production of more pods. Researchers like Ball *et al.* (2000), also concluded that increased plant density reduced number of branches, pods and seed per plant and yield of individual plants. Also, Epler and Staggenborg (2008) reported that as plant density increased, number of pods/plant steadily decreased.

Table 2. Effect of phosphorus rate (kg ha^{-1}) and plant spacing (cm) on soybean number of branches and number of pods per plant

	NOB			NOP
Treatments	6WAS	8WAS	10WAS	
Phosphorus (P)				
0	0.80	4.10	4.91	51.13b
20	1.49	4.50	5.20	60.04b
40	1.75	4.59	8.35	66.13b
60	1.61	4.64	7.28	76.75a
$LSD_{0.05}$	ns	ns	ns	10.32
Spacing(S)				
5	1.23	3.59c	5.63	48.79c
10	1.50	4.25b	7.04	63.46b
15	1.52	4.89a	6.66	63.88b
20	1.42	5.07a	6.40	78.67a
$LSD_{0.05}$	ns	0.62	ns	11.07
Interaction				
P × S	ns	ns	ns	**

WAS = weeks after planting; NOB = Number of branches; NOP = number of Pods; ns = not significant; ** = Significant at 1% probability level

There was also an interaction of phosphorus and soybean spacing on the production of pods by soybean. The interactive table is shown in table 3 where it was observed that, Comparing effect of phosphorus at each spacing, more pod production was favoured with the application of 60 kg P/ ha at wider spacing of 20 cm. Also, soybean planted at spacing 10 cm and 15 cm with zero application of phosphorus was also observed to produced more pods significantly than those of 5 cm spacing under zero application of phosphorus. This result obtained could be the effect of Phosphorus on legumes which promotes pod development coupled with the fact that wider spacing encouraged lateral growth or production more branches and since pod bearing pedicels are located on the nodes of branches, more pod production is encouraged. This result agrees with the work of Elliot *et al.* (2014) who opined that phosphorus promotes nodule formation, flower and fruit or pod development. Also, Ball *et al.* (2000), Liu *et al.,* (2010) and Kobrace and Shamsi (2011) concluded that increased plant density reduced number of branches, pods and seed per plant and yield of individual plants.

Effect of phosphorus concentration and spacing on soybean yield and yield component is shown in table 4. Application of P significantly influenced soybean yield and number of seeds per pod. The yield of soybean was significantly ($p<0.05$) higher with the application of 60 kg P/ha than other levels of P with a yield difference of 34.3 and 47.7% for 40 and 20 P respectively. This could be due to the response of the crop to available phosphorus in the soil. More P was needed to produce high yield because the soil P was lower. Mallarino and Reuben, (2015) reported that soybean utilizes applied P more when available soil P was low for attaining high yield. Significantly high yield ($p<0.05$) was also recorded with 15cm spacing probably due to the effect of less interplant competition among the crops which promotes more lateral growth hence more pods were produced which translates to more yield. This corroborate the work of Kobrace and Shamsi (2011) who concluded that increased plant density reduce number of branches, pods and seed per plant and yield of individual plants.

Application of P at 60 kg/ha gave significantly (ρ < 0.05) higher seed number per pod than other P levels (table 4) this could be as a result of the fact that phosphorus is needed by legumes for seed formation. Gyaneswar *et al.*, (2002) had earlier reported that root improvement, stalk and stem vigor, flower and seed formation, crop production, crop maturity and resistance to plant pests and diseases are the attributes associated with phosphorus availability.

There was also an interaction between phosphorus application and soybean spacing on the production of seeds per pod. The interaction table (Table 5) showed that number of seeds per pod of soybean with application of P at all the spacing were more this reveals the importance of phosphorus and spacingin soybean being a legume and a crop with branches. Phosphorus has been noted to be needed for seed formation hence soybean responded to application of P by producing more seeds compare to when P was not applied. This is in agreement with (Gyaneswar *et al.*, 2002) who reported that Phosphorus is a major factor in many plant processes such as energy transfer, stimulation of root growth, flowering, fruiting and seed formation. Also, Liu *et al. (*2008) had observed less interplant competition when crops are planted at wider spacing hence maximizing yield and yield components.

Table 3. Interactive effect of phosphorus (kg ha^{-1}) and spacing (cm) on soybean number of pods during the 2015 cropping season

Phosphorus	Spacing			
	5	10	15	20
0	73.00^{ab}	118.67^{a}	108.67^{a}	101.67^{bc}
20	77.33^{a}	55.00^{c}	73.67^{b}	117.67^{b}
40	45.00^{b}	82.33^{bc}	83.33^{ab}	78.67c
60	54.33^{ab}	108.33^{ab}	84.00^{ab}	188.67^{a}
$LSD_{0.05}$	30.11			

Means followed by the same letter(s) are not significantly different from each other at 5 % level of probability $LSD_{0.05}$;

Table 4. Effect of phosphorus rate (kg ha^{-1}) and plant spacing (cm) on soybean yield and yield components during the 2015 and 2016 cropping seasons

Treatment					
	GY (kg/ha)	*PL*	*NSPP*	*100 SW (g)*	*TP*
Phosphorus(P)					
0	514.8c	3.09	1.95b	15.00	36.27
20	576.4c	3.13	2.08b	16.00	37.05
40	724.9b	3.15	2.14b	17.00	35.46
60	1103a	3.19	2.43a	18.00	41.15
$LSD_{0.05}$	180.60	ns	0.24	ns	ns
spacing					
5 cm	792.0c	3.04	2.00b	15.00	37.78
10 cm	974.1b	3.15	2.09ab	18.00	40.02
15 cm	1188a	3.25	2.30a	17.00	36.75
20 cm	1110a	3.12	2.23a	17.00	35.38
$LSD_{0.05}$	120.2	ns	0.14	1.00	ns
PxS	ns	ns	**	*	ns

Means followed by the same letter(s) are not significantly different from each other at 5 % level of probability $LSD_{0.05}$; *, ** = Significant at5% and 1% probability levels respectively; GY = grain yield; PL =pod length; NSPP = number of seeds per pod; 100SW = 100 seeds weight; TP = threshing Percentage.

Effect of spacing was also observed to be significant on 100 seed weight of soybean. The seeds obtained from soybean planted at 10 cm spacing had more weight (18.00g) than other spacing followed by 15 and 20 cm (17.00g) while those of 5 cm spacing had the least weight (15.00g). The interactive means for 100 seed weight of soybeans at the different combinations of spacing and phosphorus fertilizer are presented in Table 5. It was observed that at wider spacing (20 cm),100 seed weight was significantly high at high rate of P application (60 kg P/ha) this could be due to the fact that because P was relatively low during the cropping season, hence soybean was able to utilize the applied P for better seed formation and since P is important for seed production in soybean coupled with space advantage, weightier seeds were produced.

(Ibrahim and Hala, 2007; Caliskan *et al.,* 2007), Also, plants with more branches have the tendency of producing more pods which in this experiment translates to morre number of seeds with more weights. This is because according to Abimiku *et al.* (2009) branching is an important yield component since the flower bearing pedicels are produced on branch nodes.

The result obtained for soybean threshing percentage shows no significant effect of either P nor spacing on the parameter.

Conclusion and Reccomendation:

The findings from this study showed that application of 60kg/ha of phosphorus to soybean planted at15 cm produced optimum yield soybean with more number and weightier seeds. Hence, application of P at 60kg/ha with soybean planted at 15cm spacing is recommended for optimum yield and yield components of soybean.

Table 5. Interactive effect phosphorus (kg ha^{-1}) and spacing (cm) on soybean number of seed per pod and 100 seed weight (g)

Spacing	5	10	15	20
Phosphorus		Seed per pod		
0	1.55^{c}	1.82^{b}	2.33^{ab}	2.12^{b}
20	2.00^{b}	2.23^{a}	2.08^{b}	2.00^{b}
40	2.00^{b}	2.08^{ab}	2.25^{ab}	2.23^{b}
60	2.43^{a}	2.22^{a}	2.52^{a}	2.56^{a}
$LSD_{0.05}$	0.33			
100 Seed Weight (g)				
Phosphorus				
0	20.00^{a}	20.00^{a}	20.00^{a}	14.30^{b}
20	20.00^{a}	20.00^{a}	20.00^{a}	19.53^{b}
40	20.00^{a}	20.00^{a}	20.00^{a}	19.53^{a}
60	20.00^{a}	20.00^{a}	20.00^{a}	20.00^{a}
$LSD_{0.05}$	5.00			

Means followed by the same letter(s) are not significantly different from each other at 5 % level of probability $LSD_{0.05}$

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