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Effect of Phosphorus Fertilizer on Soyabean Pod Yield in the Guinea Savanna

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ABSTRACT
A replicated trial was conducted at four sites in the Guinea savanna ecological zone to study the effect of P fertilizer on soyabean pod yield especially for the new soyabean varieties which have been released to farmers in this zone where P deficiency is common. Results show that grain dry weight was significantly increased by P application at sites where initial soil test P was = 6.2 mg kg^{-1}. Where initial soil test P was high, the application of P depressed grain yield. At sites where responses were observed due to low initial soil test P, the effect of P application at the rate of 30 kg P ha^{-1} on pod number, pod dry weight and grain weight was not different from when 60 kg P ha^{-1} was applied. At sites where positive responses to P application were observed, grain dry weight increased by 56 to 156% when P was applied compared to no P treatment. These results show that applying P at rates above 30 kg P ha^{-1} may not be desirable for soyabean even when soil test P is low. Grain dry weight averaged 99 g m^{-2} in this study and was 22% lower in the early and medium varieties than in the late varieties. Although an average of 501 pods m^{-2} were produced, number of pods in the early variety was at least 34-44% lower than in the medium or late varieties. Number of pods was also increased by up to 29% with P treatment. Significant increases of at least 53% were observed in the late varieties as result of P application.

INTRODUCTION

The savanna zone of Nigeria is extensive, occupying an area of approximately 730,000 Km^2. In this area, there are variations in climate, vegetation, soil types and fertility (Kowal and Knabe, 1972). Five ecological zones including the derived savanna (a transition zone occurring between the rain forest and the southern Guinea savanna), southern Guinea savanna, northern Guinea, sudan and sahel savannas have been delineated (Keay, 1959; Jagtap, 1995; Tian *et al.,* 1995). Apart from the sudan and sahel savannas, the others make up what is referred to as the moist savanna.

Compared with the humid zone, the higher levels of insolation, low incidence of diseases and pests, and dry weather at the end of the growing season make the moist savanna a more favourable environment for the production of annual crops of medium duration such as groundnut, maize and soyabean (Jagtap, 1995). Leguminous grain crops such as groundnut, cowpea and soyabean are grown primarily for their grains with the residues from harvest being fed to livestock. They have the potential to contribute significantly to maintain N levels, organic matter and physical properties of soils for intensifying cereal-based cropping system (Danso, 1992; COMBS, 1993).

Tropical savannas are characterised by low effective cation-exchange-capacity, and N and P deficiencies (Jones and Wild, 1975; Ker, 1995). Under low available soil P status, P fertilizer application to legume and its management are of importance in attaining high yields in soyabean. Phosphorus is not only essential for plant growth, its availability has been noted to affect the functioning of the BNF system (McLaughlin *et al.*, 1990; Chein *et al.*, 1993). Studies on soyabean fertilization in the Nigerian savanna date back to 1957 when Goldsworthy and Heathcote (1964) using a locally adapted low-yielding Malayan variety in more than 40 experiments recommended 30 kg P ha^{-1} and 20 to 60kg N ha^{-1} application for optimum yield. In research involving high yielding cultivars responses have been obtained at 40 - 80 kg P ha^{-1} (Chiezey *et al.*, 1992; Shannon *et al.*, 1992). There is increased cultivation of soyabean in the moist savannas of Nigeria but increases in national yield is mainly due to the increased hectarage cultivated rather than increased output per hectare. Increase in output per hactare is limited by P deficiency. Because soyabean grain yield is dependent on pod yield, it is important to know the effect of P on the yield of pod especially for the new soyabean varieties which have been released to farmers in the moist savanna ecological zone where P deficiency is common.

MATERIALS AND METHODS

Four soybean varieties of different days to maturity including: the early variety (TGx1485-1D) which matures in about 95 days after planting (DAP), the medium variety (TGx536-02D) which matures in about 100 (DAP), two late varieties (TGx923-2E and TGx1670-1F) which mature in about 115-120 DAP were sown in 1996 at four sites in the moist savanna in Nigeria. The sites were Mokwa (9°18'N, 5°04'E), Gidan Waya (9°28'N, 8°22'E), Kasuwan Magani (10°24'N, 7°42'E), and Fashola (7°56'N 3°45'E). Some of the chemical and physical characteristics of the soils at these sites are shown in Table 1. According to the soil fertility status classification by Enwezor *et al.* (1989), available soil P was low at three sites and adequate at one site (Mokwa) with a value of 16.2 mg kg^{-1}. Rainfall distributions in the year of study at the different sites are presented in Table 2. The amount of rainfall from the sowing of soybean to harvest ranged from 623-1089 mm at the sites, and this was evenly distributed through the period of study at each site. This provided adequate moisture for the soyabeans whose water requirement have been reported to be in the range of 450-825 mm (Doorenbos and Pruit, 1977).

The study was laid out as a split-plot in randomized complete block with three replications. While the soyabean varieties were assigned to the main plot treatments, P rates of 0, 30, and 60 kg P ha^{-1} as triple superphosphate (TSP, 20% P) were randomly allocated to the sub-plots. In order to obtain a localized P fertilizer effect, TSP was drilled and mixed with the soil in furrows made at the top of ridges 75 cm apart to the depth of 6-8 cm. Soybean seeds were then drilled along these furrows and the seedlings thinned to about 8cm between stands three weeks after planting. The late varieties were sown three weeks before the medium and early varieties so that grain was ready for harvest at the same time. At harvest, plants within a 2 m length of three central rows in each plot were cut at the base just above ground. The pods were separated from the haulms and grains from pods. The pods harvested per plot were counted. Pods were oven-drying at 65°C for 48 h and weighed. After shelling the dry weight of soyabean grain was also measured.

The analysis of variance (ANOVA) for all sites combined was carried out on the number of pods m^{-2}, pod dry weight m^{-2}, grain weight m^{-2}, and shelling percentage using the General Linear Model (GLM) procedure of Statistical Analystical System Inc. (SAS) (1992).

RESULTS

Number of Soyabean Pods

The number of pods produced in the soybean varieties averaged 501 m^{-2} and was significantly ($p = 0.01$) affected by sites x P rate interaction (Table 3). Table 4 shows that the significant site x P rate interaction effect on number of soyabean pods was accounted for only by the effect at Gidan Waya and Kasuwan Magani. At these sites pod number in soyabean was significantly least with no P treatment and P application significantly increased number of pods by 32 to 208%. However, the effects of 30 and 60 kg P ha^{-1} on number of pods were not significantly different. Averaged over varieties and P rates, the effect of site on number of pods was significant ($p = 0.01$). The higher number of pods (607 pods m^{-2}) was produced at Mokwa although this was not significantly different from the number of pods at Kasuwan Magani. The number of pods produced at Fashola was significantly lower by at least 28% compared to any other site. Number of pods was also significantly ($p = 0.01$) affected by soyabean variety. Significantly fewer pods (360 m^{-2}) were produced in the early maturing variety compared to 549 m^{-2} in the medium, 543 m^{-2} in TGx923-2E and 550 m^{-2} in TGx1670-1F (standard error = 28.5). The effect of P application was significant ($p = 0.01$) on number of pods in soyabean. From 393 pods m^{-2} when no P was applied, number of pods was increased by up to 29% with P treatment. The number of pods due to 30 and 60 kg ha^{-1} P application were, however, not significantly different.

Pod dry weight

Site x P rate interaction had a significant ($p = 0.01$) effect on the dry weight of pods in soyabean (Table 3). Within site (Table 4), increasing P rate had no significant effect on pod dry weight in soyabean at Mokwa. P application, however, significantly increased pod dry weight by 58% at Fashola, 128 to 169% at Gidan Waya, and 57 to 71% at Kasuwan Magani. At these three sites pod dry weight values when 30 and 60 kg P ha^{-1} was applied, were not significantly different. There was also a significant ($p = 0.05$) effect of variety x P rate interaction on pod dry weight. Results show that pod dry weight generally increased with P rate within variety. Only in the two late varieties, however, were the increases in pod dry weight of 53 to 59% in TGx923-2E, and 71 to 90% in TGx1670-1F due to P application significant. The effects of 30 and 60 kg P ha^{-1} application on pod dry weight were, however, not significantly different in these varieties. Averaged over sites and varieties, pod dry weight significantly ($p = 0.01$) increased by 46 to 49% when P was applied. No significant difference was, however, observed between the effects of P application rates of 30 and 60 kg P ha^{-1} on pod dry weight. In this study a significant ($p = 0.01$) site effect on pod dry weight was obtained from the analysis of variance using the GLM procedure of SAS. Pod dry matter content was observed to be higher at Mokwa compared to any site although this was not significantly different from that at Kasuwan Magani. Pod dry weight was also significantly lower at Fashola by 21 to 44% compared to other sites. The effect of duration to maturity in the varieties of soyabean significantly (p = 0.01) affected pod dry weight. No significant difference was observed in the pod dry weight between the early and medium varieties, between the two late varieties, and between the medium and TGx923-2E (one of the two late varieties).

Grain dry weight and shelling percentage

Soyabean grain dry weight averaged 99 g m^{-2} and was significantly affected by site x P rate interaction of (p = 0.01). The response of P application at sites with low initial soil test P resulted in significant increases in grain dry weight. At Mokwa where initial soil test P was high, however, the application of P led to a depression in

Table 3 shows that Grain dry weight was significantly (p = 0.05) affected by site. Table 5 shows that the significantly lower grain dry weight of 78 g m^{-2} (or at least 17% lower than any other site) was obtained at Fashola followed by Gidan Waya. The difference in dry weight at Mokwa and Kasuwan Magani were not significant. The treatment effect averaged over sites and P rates was significant (p = 0.01) on grain yield. Grain dry weight increased with duration to maturity in soybean. Among the varieties, TGx1670-1F had the significantly larger grain dry weight (12 g m^{-2}). Comparatively, grain dry weight averaged for the early and medium varieties was 22% lower than for the late varieties. Averaged over sites and varieties, grain dry weight was significantly (p = 0.01) increased by P application. While the application of P at 30 kg ha^{-1} increased grain dry weight by 44%, the effect of a second increment was not significantly different.

Of all the main and interaction effects, only site was significant (p = 0.01) on soyabean shelling percentage (Table 3). The significantly lower shelling percentage

grain dry weight (Table 5). Where positive responses to P application were observed, grain dry weight increased by 56 to 156% when P was applied compared to no P was application. At any site in this study the difference in grain dry weight at 30 and 60 kg ha^{-1} P rates was not significant. The effect of variety x P rate interaction was significant (p = 0.01) on grain dry weight. While the responses of the early and medium maturing soyabean to P application had no significant effect on grain dry weight, P application significantly increased grain dry weight by 42 to 111% in the late varieties. Results show that of the two late maturing varieties, TGx1670-1F had the larger response to P application.

(49%) was obtained at Mokwa. While the shelling percentage at Fashola (64%) and Gidan Waya (61%) were not significantly different (standard error=1.2), the value obtained at Kasuwan Magani was 57%.

DISCUSSION

There was no site by P rate interaction effect on number of soyabean pods at Mokwa and Fashola, and on soyabean pod dry weight at Mokwa. This was because at Mokwa, for instance, initial soil test P was high 16.2 mg kg^{-1}, a value higher than the 10.5 mg kg^{-1} reported by Aune and Lal (1995) to be optimum for grain legumes in the tropics. Without P treatment at this site therefore, available soil P was sufficiently able to meet the P requirement of the soyabean varieties. At Fashola on the other hand, although soil test P was low the non-significant site x P rate interaction effect on the number of soyabean pods may be attributable to soil moisture status. Although the amount of rainfall at Fashola was 1075 mm during the year, relatively higher sand and lower clay fractions at this site may have resulted to low soil moisture retention. As a consequence a limited dissolution of the phosphate fertilizer may have occurred. Site x P rate interaction, however, had a significant effect on soyabean pod weight at Fashola. Although pod dry weight increased by at least 58% when 30 or 60 kg P ha^{-1} was applied, pod dry weight was low at this site. While the significant site x P rate interaction effect on number of soyabean pod at Kasuwan Magani may have resulted from the build up in available P with increases in P rate, a strongly acidic (pH 4.9) soil reaction at Gidan Waya may have contributed an additional effect. This is because with the fixation of P by Al and Fe ions (Brady, 1990) increasing P rate will be required for enhanced P availability.

The main effects of site on the number of soyabean pods and pod dry weight were derived from initial soil available P status, soil reaction and soil moisture. Consequently, averaged over varieties and P rates, significantly more pods and consequently more pod dry weight were produced at Mokwa where initial available soil P was high (16.2 mg kg^{-1}). The number of soyabean pods and pod dry weight produced at Kasuwan Magani where initial soil test P was low (5.7 mg kg^{-1}), was however not significantly different from that at Mokwa. This may be because the applied P fertilizer was able to build up soil available P status to sufficient concentration especially because soil reaction was moderately acidic (pH 5.6) and the levels of Al and Fe ions were not as high as to cause significant P fixation as was the case at Gidan Waya where soil reaction was strongly acidic (pH 4.9). At Fashola on the other hand soil reaction was not a limiting factor, and although initial soil test P was low, the application of P was only able to raise available soil P to just below 10.5 mg kg^{-1}.

Ayodele and Agboola (1981) have reported that most Nigerian soils show no response to P if soil test is 15 mg kg^{-1} or more. This is corroborated by results from this study in which grain dry weight was significantly increased by P application only at 3 sites where initial soil test P was equal to or less than 6.2 mg kg^{-1}. In fact at the only site where initial soil test P was high, the application of P depressed grain yield although not significantly. Although soyabean pod dry weight was high at Mokwa compared to any site, a significantly higher shelling percentage at Kasuwan Magani resulted in a high grain dry weight. For all the parameters reported here (except HI) and at sites where responses were observed due to initial soil test P, the effect of P application at the rate of 30 kg P ha^{-1} was not different from when 60 kg P ha^{-1} was applied. The application of 30 kg P ha^{-1} may have, therefore, been able to increase available soil P above the level reported by Aune and Lal (1995). In agreement with this, results of soil analysis carried out after soyabean cropping (data not shown) showed that available P was 9.8 mg kg^{-1} at Fashola, and at least 16 mg kg^{-1} at Gidan Waya and Kasuwan Magani. Afolabi and Osiname (1979), and IITA (1975, 1976) have similarly reported responses to 13.2 to 30 kg P ha^{-1} in soyabean. The effect of soyabean duration in the field was evident from the effect of the varieties and their responses to P application. A longer duration to maturity implies a longer period of P uptake with the consequent increase in carbon assimilation. Giller and Wilson (1991) have reported that dry matter accumulation increases with duration to maturity. Similarly in this study the early maturing variety TGx1485-1D had the significantly lower pod number, pod dry weight and grain dry weight compared with significantly higher pod dry weight and grain dry weight in the late variety TGx1670-1F.

CONCLUSION

While grain dry weight was significantly increased by P application at sites where initial soil test P was equal to or less than 6.2 mg kg^{-1}, the application of P depressed grain yield where initial soil test P was high (16.2 mg kg^{-1}). Soyabean pod dry Weight and number of pods also responded positively to P application at sites where available P was low. These results show the importance of a P fertilizer programme for soyabeans. It is also evident that applying P at rates above 30 kg P ha^{-1} may not be desirable for soyabean even when soil test P is low.

Table 1. Some soil chemical and physical properties at the experimental sites before the planting.

Properties	Site			
	Mokwa	Fashola	Gidan Waya	Kasuwan Magani
pH(H_2O)	6.1	6.1	4.9	5.6
Organic C (g kg^{-1})	5.1	5.9	8.7	7.5
Total N (g kg^{-1})	0.60	0.69	1.13	0.78
Bray-II P (mg kg^{-1})	16.2	5.2	6.2	5.7
Textural Class	Loamy Sand	Loamy Sand	Sandy Loam	Sandy Loam

Table 2. Amount and distribution of rainfall at experimental sites in 1996.

Month	Amount of Rainfall (mm)		48	
	Mokwa	Fashola	Gidan Waya	Kasuwan Magani
January	na	na	na	0
February	na	na	na	0
April	30	na	na	19
May	186	154	48	213
June	230	286	282	282
July	110	124	420	262
August	266	175†	367	416
September	148	237	156	300
October	87	99	100	44
November	0	0	0	0
December	0	0	0	0
Total	1057 (623)*	1075 (635)*	1373 (1045)*	1537
Rainfall				(1089)*

na = rainfall data not available

*Amount of rainfall received from planting to grain harvest

Table 3. Significance of site, soyabean variety, phosphorus fertilizer rate and interactions on number of pods, pod dry weight, grain dry weight and shelling percentage in soyabean

Source of Variation	Degrees Of Freedom	Probability level of F for test of effect: Number of Pod	Pod Dry weight	Grain dry weight	Shelling %
Site	3	0.01	0.01	0.05	0.01
Variety	3	0.01	<0.01	0.01	0.71
Site x Variety	9	0.22	0.09	0.61	0.90
Phosphorus	2	<0.01	<0.01	<0.01	0.49
Site x Phosphorus	6	0.01	0.01	<0.01	0.44
Variety x Phosphorus	6	0.44	0.05	0.01	0.26
Site x Variety x Phosphorus	18	0.12	0.17	0.13	0.91

Table 4. Effect of Site x P rate, and Variety x P rate interactions on number of pods and pod dry weight in soyabean.

	P rate (kg P ha^{-1}) 0	30	60	Mean
	----------Number of pods----------			
Site				
Mokwa	618.3	658.8	544.4	607.2
Fashola	254.8	389.0	358.3	334.0
Gidan Waya	224.4	575.1	592.3	463.9
Kasuwan Magani	475.3	639.1	682.2	598.8
Mean	393.2	565.5	544.3	
	----------Pod dry weight----------			
Mokwa	220.4	232.5	194.5	215.8
Fashola	87.4	137.9	137.7	121.0
Gidan Waya	77.1	175.7	207.0	153.2
Kasuwan Magani	146.1	229.3	250.3	208.6
Variety				
TGx1485-1D	118.4	143.3	153.1	138.3
TGx536-02D	137.4	178.9	163.8	160.0
TGx923-2E	137.1	217.4	209.7	188.1
TGx1670-1F	138.1	235.6	262.9	212.2
Mean	132.7	193.8	197.4	

Standard error (Number of pods): Site x P rate=49.2; Variety = 28.5; Site = 28.5; P rate=24.6

Standard error (Pod dry weight): Site x P rate=15.1; Variety x P rate=15.1; Site = 8.7; P rate=7.6

Table 5. Effect of Site x P rate, and Variety x P rate interactions on grain dry weight in soyabean.

	P rate (kg P ha^{-1})			
	0	30	60	Mean
Mokwa	117.2	110.1	90.1	105.8
Fashola	55.9	90.0	87.2	77.7
Gidan Waya	49.3	104.3	126.4	93.4
Kasuwan Magani	80.9	132.2	145.3	119.5
Variety				
TGx1485-1D	68.7	83.2	86.7	79.5
TGx536-02D	82.4	104.0	94.8	93.7
TGx923-2E	77.3	122.4	109.4	103.1
TGx1670-1F	74.8	127.0	158.0	119.9
Mean	75.8	109.2	112.2	

Standard error: Site x P rate=9.2; Variety x P r Ate=9.2; Site = 5.3; P rate=4.6

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