The Effects of Phosphorus Nutrition on the Growth and Seed Yield of Soybean (Glycine max (L.) Merril.)

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Abstract

An analysis of the effect of phosphorus nutrition (0, 25, 50, 100 and 200 kg p/ha SSP) on the performance of two varieties of soybean (TGx 536-02D and TGx 1485-1D) was carried out in pot experiment at the University of Ibadan. The experiment was a split-plot arrangement, with cultivars as main plots and phosphorus (P) nutrition levels as sub-plots. The experiment was laid out in a Randomized Complete Block design with five replicates. Growth and development attributes were determined by periodic plant sampling and yield attributes assessed by sampling at maturity (final harvest [FH]). Data collected were subjected to analysis of variance and means compared with the least significant difference (LSD) at P = 0.05. The responses of the two cultivars to P were similar although TGx 536 – 02D (V1) generally performed significantly better than TGx 1485 – 1D (V2). Growth and yield attributes were enhanced with increase in P levels up till 50kg P/ha and then there was a gradual decline. Application of 50kg P/ha was not significantly (P = 0.05) different from 25kg P/ha in most of the growth and yield attributes although they were both significantly different from the control. The reproductive efficiency of the plants was also at optimum level with the application of 50kg P/ha though not significantly different from 25kg P/ha. It would appear that under the prevailing local condition, application of between 25kg P/ha - 50kg P/ha (a total of 39.14kg - 64.14 kg soil P/ha) is adequate for soybean production. Excessive application could degrade the soil and reduce yield with negative environmental effects.

Keywords: Growth, N-fixation, Nutrition, Phosphorus, Soybean, yield

Introduction

Legumes have been known to contribute immensely to the addition of Nitrogen (N) to the soil. However, N fixation in legumes is affected by Phosphorous (P) availability especially in soils low in P (Robson *et al.*1981; Chien *et al.* 1993). This is because P is required for nodule metabolism (O'Hara *et al.*, 1988) and acute deficiency of P can prevent nodulation by legumes (Giller and Wilson 1991). Apart from enhancing N fixation, application of P to soybean, increases P status to a level sufficient for a subsequent crop (Ogoke *et al.* 2001).

Phosphorus is the key nutrient for increasing the productivity of grain legumes. Its deficiency is the most important single factor responsible for poor yield of grain legumes (Togun 1998). Application of phosphate fertilizer is therefore the basis for improving the production of grain legumes (Saraf 1983).

Phosphorus fertilizer although easily fixed is known to affect soil structure after continuous usage. However, cautious use of small but adequate quantity of P has been reported to be useful in improving legume productivity with minimal adverse consequences on the environment (Togun 1998). P has also been reported to increase soil organic Carbon (Ogoke *et al.* 2002)

In Nigerian soils, widespread P deficiency has been reported (Mokwunye 1979) and the most rapid benefits from agricultural production are likely to be seen through alleviation of environmental constraints on N_2 fixation by judicious use of small amounts of lime and fertilizers especially P & K (Giller and Wilson 1991). Studies in the Guinea Savanna zone have shown that phosphorus is the most important inorganic fertilizer for soybean production (Singh and Bajpai 1990). Fredeen *et al.,* (1989) reported that low phosphorus treatment decreased soybean growth, primarily reducing leaf surface expansion by 85%.

The objective of this study was to assess the effect of P nutrition on soybean with a view of determining the optimum P level for soybean performance under the prevailing local conditions, thereby preventing the deleterious effects of excessive P usage in the environment.

Materials and Methods

Two cultivars of soybean TGx 536 – 02D (V_1) and TGx 1485-1D (V_2) seeds were planted in 20 cm diameter at rim pots, each containing 5.26 kg sandy loam soil of basal phosphorus level (available P) of 14.14 kg P/ha from the University of Ibadan Teaching and Research Farm. The plants were grown outdoor on the roof garden of the Department of Crop Protection and Environmental Biology, University of Ibadan between the months of March and August.

Single Super Phosphate (SSP) fertilizer was used as the source of phosphorus. Five levels of phosphorus (0, 25, 50, 100 and 200 kg P/ha designated T1, T2, T3, T4, T5 respectively) were applied to the soil at planting in bands on the basis of the report of Gritsun *et al.,* (1981). The weights of the fertilizer required to supply the above rates per pot were 0, 0.849, 1.698, 3.396 and 6.792 g to give overall levels of 14.14, 39.14, 64.14, 114.14 and 214.14 kg P/ha respectively. The seedlings on establishment (2 weeks after sowing) were thinned to one per pot.

A split plot arrangement with cultivars as the main plots and level of applied phosphorus as sub-plot was employed in a Randomized Complete Block Design. Each main plot had 5 replicates. Sampling for growth and development was done every fortnight, starting from 4 weeks after sowing till 12 weeks after sowing and then final harvest. At each sampling, leaf areas (determined by graph paper method [Tayo and Togun 1984]) and numbers as well as the dry weights of the various parts were measured on each plant. The number of flowers that open or aborted per day and the total number of pods produced were determined on a sub-sample of five plants for each treatment and in each cultivar by the tagging method (Togun and Tayo 1990). At plant maturity, the number of pods/plant, dry weight of 100 seeds, total dry weight, husk dry weight and pod dry weight were determined. The data collected was subjected to 2-way analysis of variance and means were compared with LSD at P = 0.05.

Results

Application of phosphorus at the rate of 50 kg P/ha significantly (P = 0.05) increased number of leaves of soybean particularly at final harvest, however, number of nodules, number of nodes and number of branches were not significantly (P = 0.05) increased. Number of leaves, nodules, nodes and branches were all significantly (P = 0.05) reduced by the application of 100 and 200 kg P/ha (Fig. 1). Stem height and leaf area were not significantly (P = 0.05) increased by the application of 50 kg P/ha although the 50 kg P/ha plant had higher values for leaf area than others (Fig. 2). Application of 50 kg P/ha also significantly (P = 0.05) increased nodules dry weights, while stem, leaf and root dry weights were not significantly (P = 0.05) increased (Fig 3). Number of nodules was significantly increased at the application of 25 and 50 kg P/ha as compared to the control but there was no significant difference between the application of 25 and 50 kg P/ha particularly at 12 weeks after sowing (WAS). Generally, all the growth and development attributes were significantly (P = 0.05) reduced by the application of 100 and 200 kg P/ha (Figs. 1 - 3). The dry weight values of the various plant parts were higher in plants treated with 50kg P/ha for a greater part of the sampling period (Fig. 3).

In V_1 plants, the number of flowers produced increased with increasing P levels up to application of 50 kg P/ha and then declined. In V_2, plants that received 50 kg P/ha produced the greatest number of flowers followed by the control. However, in both varieties, plants that received 50 kg P/ha produced significantly (P = 0.05) more flowers than others. In both varieties plant that received 50 kg P/ha had significantly (P = 0.05) higher total number of pods carried to maturity as well as percent open flowers that formed matured pods than those of other treatments (Table1).

The V_1 plants had significantly (P = 0.05) more and heavier pods than V_2 at maturity (final harvest), plants that received 50 kg P/ha significantly (P = 0.05) had more pods than others from 10WAS till plant maturity (Table 2). V_1 had significantly (P = 0.05) higher values for most of the yield characteristics. However, the plants that received 50 kg P/ha were not significantly different from those that received 25 kg P/ha for most of the yield characteristics though both were significantly different from the control. The 50 kg P/ha plant had the highest seed weight while the number of seeds per pod was not affected by P fertilization (Table 3).

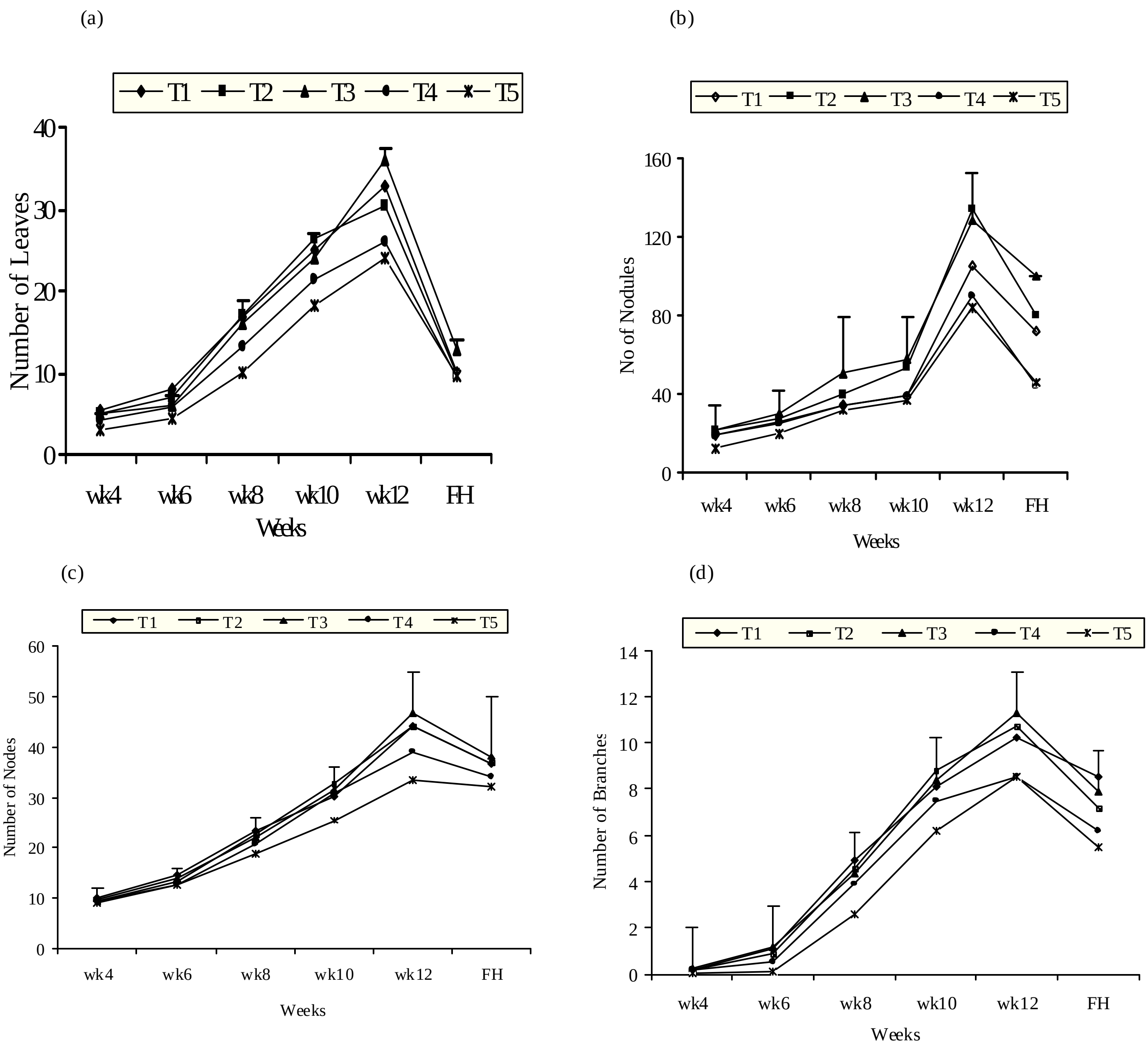
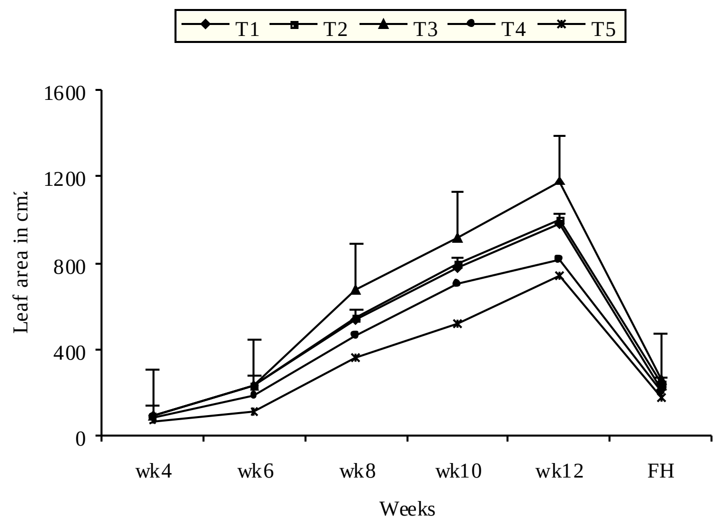


Fig. 1. Effect of P nutrition on number of (a) leaves (b) nodules (c) nodes (d) branches of soybean. Vertical bars represent LSD (P = 0.05); FH- Final harvest

(a)



(a)

(b)

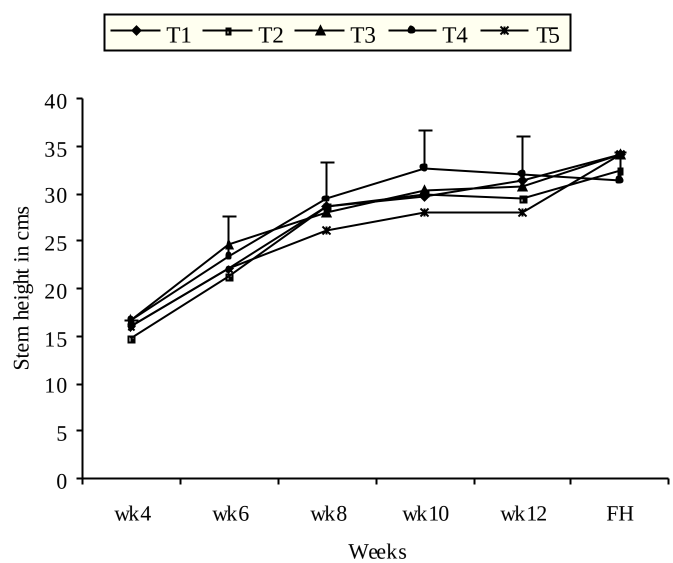


Fig. 2: Effect of P nutrition on (a) Leaf area (b) Stem height of soybean FH- Final harvest; Wk- Week; Vertical bars- LSD (p=0.05)

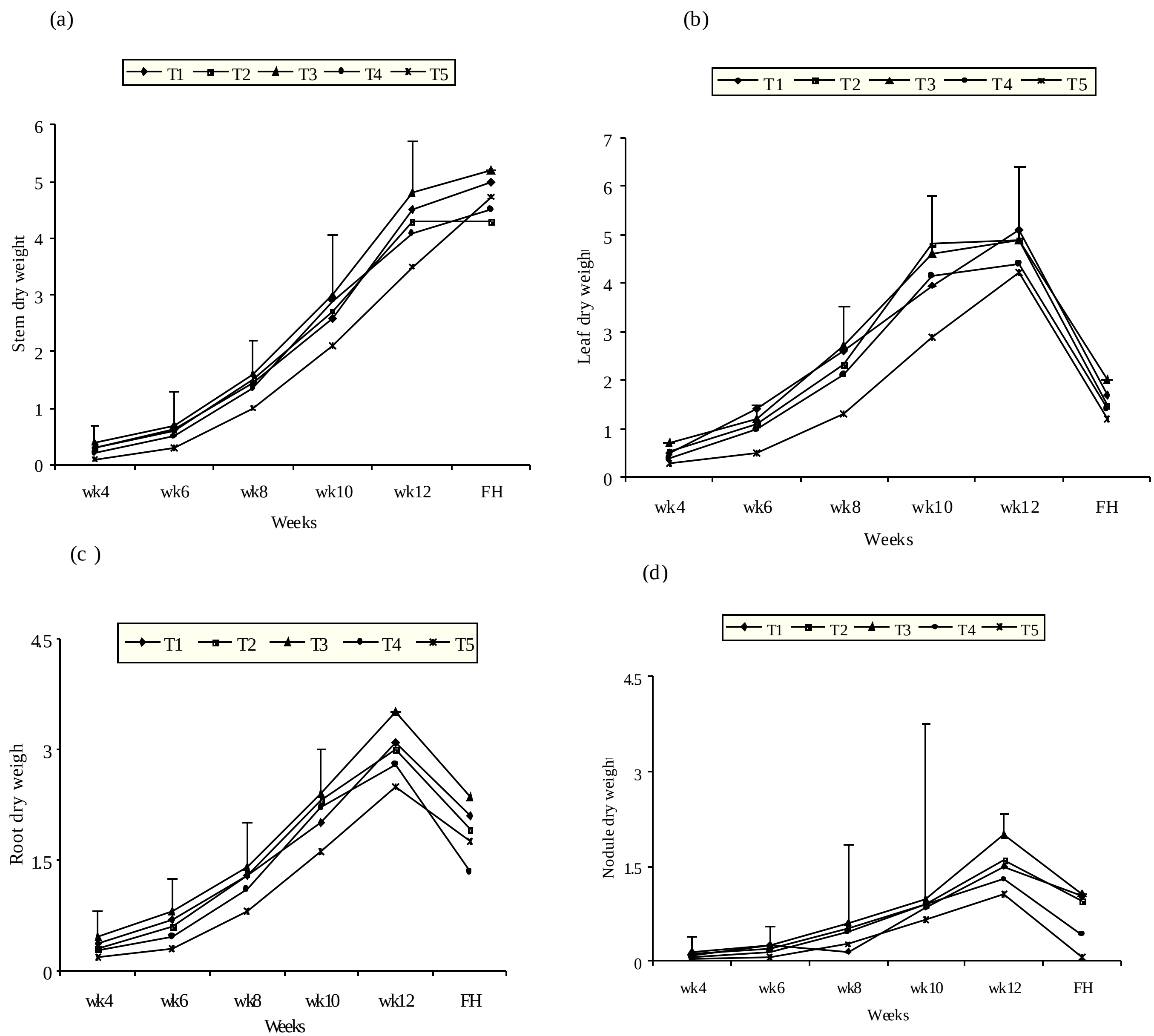


Fig. 3: Effect of P nutrition on dry weight of (a) stem (b) leaf (c) root (d) nodule of soyabean. FH- Final harvest; Wk- Week; Vertical bars- LSD (p=0.05)

Table 1. Flower and pod characteristics of two varieties of soybean as influenced by phosphorus nutrition (mean of five plants) in (a) V1 (TGx 536 – 02D); (b) V2 (TGx 1485 – 1D).

(a)						
FERTILIZER LEVEL (Kg/ha)	**0**	**25**	**50**	**100**	**200**	**LSD (P=0.05)**
Total no of opened flowers	265.6	320.4	332.6	308	276	10.00
Total no of flowers that formed pods	61.4	72.4	59.6	58.8	61.8	9.60
Total no of pods carried to maturity	42.4	44.6	53.2	37	36.8	2.45
Open flowers forming mature pods (%)	16%	14%	16%	12%	13%	1.51

(b)						
FERTILIZER LEVEL (Kg/ha)	**0**	**25**	**50**	**100**	**200**	**LSD (P=0.05)**
Total no of opened flowers	76.2	73.6	79.2	52.2	43.8	5.22
Total no of flowers that formed pods	31.4	25.6	34.2	19.6	13.6	2.16
Total no of pods carried to maturity	19.2	17.4	23.2	14	7.8	1.96
Open flowers forming mature pods (%)	25%	24%	29%	27%	18%	1.72

TABLE 2. Effect of different levels of soil applied phosphorus on number of pods and pod dry weight of two varieties of soybean.

WAS	**8**		**10**		**12**		**FH**	
	No of pods	**Pod dry weight**	**No of pods**	**Pod dry weight.**	**No of pods**	**Pod dry weight.**	**No of pods**	**Pod dry weight.**
V1	0	0	4.12	0.036	48.2	1.92	42.4	13.75
V2	11.08	0.536	15.28	2.222	13.7	3.94	16.7	6.32
LSD			3.219	0.3897	7.47	1.029	7.22	4.51
T1	13.40	0.641	7.70	0.817	28.7	3.03	30.7	10.37
T2	10.60	0.52	12.80	1.612	32.9	3.38	31.6	11.66
T3	14.40	0.64	11.50	1.599	39.5	4.03	35.6	12.59
T4	10.40	0.65	8.80	1.204	28.4	2.51	25.5	8.55
T5	6.60	0.23	7.70	0.413	25.2	1.67	24.3	7.13
LSD (P=0.05)	4.782	0.15	5.031	0.6165	11.79	11.79	1.629	11.7

WAS- Weeks after sowing; FH- Final Harvest; V1- TGx 536 – 02D ; V2- TGx 1485 – 1D ; T1,T2,T3,T4, &T5 are P levels of 0, 25, 50, 100 & 200 kg/ha respectively

Table 3. Yield characteristics of two varieties of soybean as affected by different phosphorus levels.

	NSBP	NEP	PDW	SDW	HDW	TSP	NSP	100SW	DWP	SWP	SHR	HI
V1	34.84	7.56	13.72	8.69	5.03	79.4	2.224	10.94	0.3273	0.2492	1.695	0.6252
V2	16.16	0.68	6.32	3.55	2.73	32.8	1.982	10.52	0.3627	0.2141	1.384	0.3460
LSD (P=0.05)	3.39	2.565	1.8	0.99	0.633	7.65	0.069	0.756	0.0321	0.0183	0.246	0.0276
T1	27.00	4.00	10.37	6.07	4.31	57.9	2.000	10.38	0.3531	0.2241	1.424	0.3080
T2	28.50	3.20	11.56	7.28	4.28	62.5	2.103	11.48	0.3750	0.2521	1.654	0.3600
T3	29.80	5.80	12.58	7.61	4.83	65.5	2.167	11.29	0.3620	0.2510	1.533	0.3360
T4	21.90	3.60	8.84	5.34	3.21	48.7	2.125	10.01	0.3430	0.2340	1.501	0.3490
T5	20.30	4.00	7.07	4.30	2.83	45.0	2.070	9.60	0.2920	0.1970	1.575	0.3250
LSD (P=0.05)	5.298	3.078	2.412	1.569	0.999	12.15	0.12	1.197	0.0507	0.0291	0.294	0.0438
V1T1	34.80	7.60	12.84	7.98	4.87	78.8	2.000	10.07	0.3026	0.2300	1.633	0.3200
V1T2	38.40	6.20	15.64	10.06	5.58	85.0	2.206	11.75	0.3480	0.2600	1.864	0.3840
V1T3	37.00	10.20	15.97	10.35	5.45	85.8	2.334	12.23	0.3460	0.2860	1.942	0.3500
V1T4	30.80	6.20	12.20	7.81	4.39	71.2	2.280	11.20	0.3400	0.2540	1.603	0.3040
V1T5	33.20	7.60	11.93	7.25	4.84	76.2	2.300	9.41	0.3060	0.2160	1.500	0.2680
V2T1	19.20	0.40	7.90	4.15	3.75	37.0	2.000	10.69	0.4038	0.2162	1.240	0.2960
V2T2	18.80	0.20	7.40	4.40	2.99	40.0	2.000	11.20	0.4020	0.2442	1.504	0.3360
V2T3	22.60	1.40	9.20	4.83	4.32	17.2	2.000	10.29	0.3840	0.2160	1.164	0.3420
V2T4	13.00	1.00	4.39	2.87	2.02	26.2	1.972	10.61	0.3460	0.2140	1.394	0.3940
V2T5	7.40	0.40	2.15	1.34	0.82	13.8	1.840	9.79	0.2780	0.1780	1.650	0.3820
LSD (P=0.05)	6.759	4.395	3.381	2.22	1.413	17.13	0.171	1.692	0.013	0.0411	0.417	0.0618

V1- TGx 536 – 02D; V2- TGx 1485 – 1D; T1,T2,T3,T4, &T5 are **P** levels of 0, 25, 50, 100 & 200 kg/ha respectively; NSBP- No of seed bearing pods; NEP- No of empty pods; PDW- Pod dry weight; SDW- Seed dry weight; HDW- Husk dry weight; TSP- Total seeds/plant; NSP- No of seeds/pod; 100SW- 100 seed weight; DWP- Dry weight/pod(g); SWP- Seed weight/pod(g); SHR- Seed to husk ratio; HI- Harvest index.

Discussion

Number of leaves was significantly (P = 0.05) increased by application of 50kg P/ha. This might have provided adequate photosynthetic capacity for the plant to function optimally. Significant (P = 0.05) increase in nodules dry weights by the application of 50kg P/ha, is in agreement with Jagtap & Adeleye, (1999) who reported increased dry matter due to increased P rate. These may be as a result of the effect of P on protein synthesis and cell growth as reported by Marre, (1961). It could also be due to stimulation of N fixation by the applied P.

Plant height was not significantly increased with phosphorus application as opposed to the report by Karim *et. al.*, (1981) probably as a result of differences in varieties used and environmental effects. Increasing P levels increased the number of flowers up to 50 kg P/ha and then declined. It is considered that the primary effect of limited P on soybean reproductive growth is to increase flower and pod abortion (Lauer and Blevins 1989). Seed yield was increased by application of 50 kg P/ha^{-1}. This could be as a result of the P requirement of N fixation being fully met as reported by Edward, (1977). P toxicity however, leads to reduced nodule numbers (Fletcher and Kurtz 1964) and reduced activity of nodule in N fixation thereby reducing yield. The reduction in growth and yield of soybean with 100 and 200 kg P/ha is attributed to P toxicity.

The significantly higher harvest index of plants with applied 25 kg P/ha^{-1} suggests enhanced efficiency of partitioning of dry matter into seeds as suggested by Togun and Tayo, (1994). Jagtap and Adeleye, (1999) reported increased dry matter due to increased P rate. The fact that growth and yield characteristics increased up to a peak at 50 kg P/ha^{-1} before declining shows that this level of P nutrition is optimum for soybean production, however, on economic basis, application of 25 – 50 kg P/ha seems adequate for soybean production under the prevailing local conditions. Also, this level of fertilizer application while alleviating the environmental constraints on N_2 fixation appears to be judicious enough to avoid pollution and P toxicity.

References

Chien, S, H., Carmona, G., Menon, R.G and Hellums, D.T (1993). Effect of phosphate rock sources on biological nitrogen fixation by soybean. *Fertilizer Research*, 34(2): 153-159.

Edwards, D. G (1977). Nutritional factors limiting N fixed by Rhizobia. In: Ayanaba,A., P.J. Dart (eds.) *Biological N_2 fixation in farming systems of the tropics.* Based on papers presented at a symposium held at the IITA Ibadan Nigeria in October 1975. A Wiley – Interscience publication.

Fletcher, H.F., and Kurtz, L.T. (1964). Differential effects of phosphorus fertility on soybean varieties. *Soil Sci. Soc. Amer. Proc.* 28: 225-228

Fredeen, A .L., Rao, M. Jerry, N. (1989). Influence of phosphorus nutrition on growth and carbon partitioning in G. max . *Plt. Phy.* 89 (1): 225 – 230

Giller, K. E. and Wilson, K.J. (1991). *Nitrogen Fixation In Tropical Cropping Systems*. C.A.B International, UK Pg 206.

Gritsun, A.T., Fedorov, A.A., Melnikov, G. I.; Pankov, N.V. (1989). Band placement of fertilizer for Soybean in the Primorsh region. *Soybean Abstract 1983:* 6(1) Pg6

Jagtap, S.S. and Adeleye, O (1999). Nutrient recovery and productivity of soyabean-maize rotation in the derived savanna ecology of West Africa. *Journal of Sustainable Agriculture*, 15, 75-85.

Karim, M., Ahmad, S.J., and Mir, H. (1981). Effect of phosphorus nutrition on the vegetative growth of soybean. *Journal of Agric Res.* 19(3) pp.117-123

Lauer, M. J. and Blevins, D. G. (1989). Flowering and podding characteristics on the main stem of soybean grown on varying levels of phosphorus nutrition. *Journal of Plant Nutrition* 12(9): 1061 – 1072.

Marre, E. (1961). Phosphorylation in higher plants. *Ann. Rev. Plant Physiol.* 13:14-19

Mokwunye, A. U., (1979). P fertilizers in Nigerian Savanna Soils. II. Evaluation of three PO_4 sources applied to maize at Samaru. *Tropical Agriculture* 56: 65 – 68.

Ogoke, I.J., Carsky, R.J., Togun, A.O and Dashiell, K. (2001). Maize yield following phosphorus-fertilized soybean in the Nigerian Guinea savanna. In: Badu-Apraku, B.; Fakorede, M.A.B.; Ouedraogo, M. and Carsky, R.J. (eds.), 2001. *Impact, challenges and prospects of maize research and development in West and Central Africa.* Proceedings of a Regional Maize Workshop, IITA-Cotonou, Benin Republic, 4-7 May, 1999. WECAMAN/IITA.

Ogoke, I.J. Carsky, R.J., Togun, A.O and Dashiell, K. (2002). Organic Carbon inputs by Soyabean in the West African moist savanna. *Biological Agriculture and Horticulture.* Vol. 20, p. 133-142

O'Hara, G. W., Boonkerd, N. and Dilworth, M.J. (1988). Mineral constraints to Nitrogen fixation. *Plant And Soil:* 108,93-110

Robson, A.D., O'Hara, G.W. and Abbott, I.K (1981). Involvement of phosphorus in n fixation by subterranean clover (*Trifolium Subterranean L*). *Aust. J.Plant Physiology;* 8 427-436.

Saraf, C. S. (1983). Advances in fertilizer management for rainfed pulses. *Fertilizer News* 28: 91 – 98.

Singh, V. K. and Bajpai, R.P (1990). Effect of P and Potash on the growth and yield of rainfed soybean. *Indian Journal Of Agronomy* 35(3): 310 – 311.

Tayo, T.O. and Togun, A.O. (1984). The responses of Pigeon Pea (*Cajanus cajan*) to the application of fertilizers. *Ann. Appl. Biol.* 105: 293-302

Togun, A.O. and Tayo, T.O., (1990). Flowering and pod and seed development in Pigeon Pea (*Cajanus cajan*). *Journal of Agric. Sci., Cambridge.* 115: 327-335

Togun, A.O., (1998). Improving Pigeon pea *(Cajanus cajan)* production in Nigeria. In: *Strategies and tactics of sustainable Agriculture in the tropics (STASAT) Vol 1* (Eds. M.A Badejo and A.O. Togun) College Press, Ibadan, Nigeria. In collaboration with Emproct Consultants, Lagos, Nigeria. Pg 85 –97.

Togun, A.O. and Tayo, T.O., (1994). Responses of Pigeon Pea (*Cajanus cajan* (L) Millsp.) to phosphorus fertilizer. *Nigerian Journal of Science* 28: 375-38.