Residual Effect of Phosphorus Application Rates on Soybean Nodulation, Post Harvest Soil Properties and Performance of Suceeding Maize

***Okunade, R.F.[1], Onasanya, R. O.[1], Agbebi O.M.[2]**

[1]Department of Crop Production, School of Agriculture, Federal College of Agriculture, Moore Plantation, Ibadan

[2]Department of Pest Management, School of Agriculture, Federal College of Agriculture, Moore Plantation, Ibadan

***Corresponding Author: racheal.okunade@yahoo.con; +2347032789474**

DOI: https://doi.org/10.51244/IJRSI.2026.1305000204

Received: 26 May 2026; Accepted: 01 June 2026; Published: 09 June 2026

ABSTRACT

Phosphorus is known to be a major nutrient that has significant effect on the growth and nodulation of legumes. A field experiment was conducted at the experimental site of the Federal College of Agriculture, Moor Plantation, Ibadan to determine the residual effect of phosphorus rates on soybean (*Glycine max*) nodulation, some post harvest soil properties and the performance of Succeeding Maize. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments, each replicated three times. The treatments consisted of different levels of phosphorus fertilizer including 0 kg / ha (control), 20 kg/ha, 40 kg/ha and 60kg/ha. Soybean seeds were sown at the rate of 2 seeds per hole. Parameters taken were; Yield of soybean, Number of Nodules per plant, Weight of Nodules per plot (g), nitrogen fixation by soybean, available phosphorus, organic matter of the post harvest soil the yield and yield component of succeding Maize.The results obtained showed that the treatment of soybean with 60kg /ha of P_0O_5 gave the highest yield of 979.73kg/ha. Similarly, treatment with 60kg/ha of P_0O_5 produced the highest nitrogen content (1.40g/kg) and highest organic matter content (24.26g/kg) in the post harvest soil. However, the highest number of nodules were produced by the soybean treated with 20kg/ha of P_0O_5 (6.08) while the least number of nodules were produced by 60kg/ha of P_0O_5 (2.92). Succeeding Maize planted on the plot with the highest Phosphorus rate also had the highest grain yield, seed weight and shelling percentage.Phosphorus levels had no significant effect on weight of nodules. It is therefore recommended that 60kg/ha of P_0O_5 on soybean be implemented for optimum yield of soybean and suceeding maize, more nitrogen fixation by soybean and more organic matter in the post harvest soil.

Key words: nodulation, nitrogen content, organic matter, yield, phosphorus

INTRODUCTION

Soybean (*Glycine max L.*) is a species of legume native to East Asia, widely grown for its edible bean which has numerous uses, oil and protein around the world. They are eaten in fresh green state and as dry beans. (Shurtleff *et al.*, 2007). Soybean is considered a very important source of edible vegetable oil protein, where seeds contain about 40% protein, 20% edible vegetable oil, 30% carbohydrates, 10% total sugar as well as 5% ash (IITA, 1993). The nutritional quality of protein in soybean as indicated by its amino acid distribution is nearly as good as meat proteins (IITA, 1992). The soybean meal is rich in minerals, particularly calcium, phosphorus, iron, (IITA, 1192) and niacin (Tiamigu and Idowu, 2001). The oil of soybean is rich in essential fatty acid, devoid of cholesterol and is also increasingly being used for biodiesel (Acikogoz *et al.*, 2009).

Soybean contains symbiotic bacteria *Rhizobia* within nodules of their root systems. These bacteria have the special ability of fixing nitrogen from atmospheric, molecular nitrogen (N_2) into ammonia (NH_3). The root nodules are sources of nitrogen for legumes, making them relatively rich in plant proteins. Nodule formation and nodule growth are influenced by various soil conditions (water content, pH, nutrition) and climatic conditions (solar radiation, temperature, rainfall). Soybean can fix atmospheric nitrogen by their root nodules associated with the soil bacteria, *Bradyrhizobia*.

Phosphorus is needed in large quantities by legumes for growth and has been reported to promote leaf area, biomass, yield, nodule number and nodule mass in different legumes (Berg and Lynd, 1985; Pascosky *et al.*, 1986). Furthermore, it assists in photosynthesis, root development, fruiting and improvement of crop quality (Sara *et al.*, 2013). However, many soils throughout the world are phosphorus deficient because the free phosphorus concentration (the form available to plants) even in fertile soils is generally not sufficient (Gyaneshwar *et al.*, 2002). 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. In soybean production, phosphorus and inoculation with the appropriate *Rhizobium* strain have quite prominent effects on nodulation, growth, and yield parameters (Shahid *et al.*, 2009; Kumaga and Efori, 2004).

Soil contribute to plant growth in several ways like; provision of essential elements which are referred to as plant nutrients a storehouse for water; oxygen for root respiration; mechanical support or anchorage. Soil pH also affects the availability of different nutrients and toxic element to plants. This is mostly due to the fact that change in pH leads to change in form of many of the nutrients and many of the form are relatively insoluble. Low pH causes nutrient deficiency, especially calcium, phosphorus and nitrogen. Extreme pH reduces the population of some useful organisms, such as bacteria which help in nodulation. Root nodules are an important source of nitrogen for legumes, making them relatively rich in plant proteins. Since phosphorus affects nodule formation, growth and yield in soybean, it is necessary to look at the phosphorus level that will enhance formation of root nodules in soybean, and the residual effect on Succeeding crops.

MATERIALS AND METHOD

Exprimental site

The field experiment was carried out at the experimental farm of Federal College of Agriculture at the Institute of Agricultural Research and Training [IART] Moor Plantation Ibadan. The experimental plot measured 35m by 11.1m and it was prepared by ploughing and harrowing and laid out into 12 plots of 11.1m by 2m. Phosphorus fertilizer at different rates were incorporated into the soil before planting. The different rates of phosphorus fertilizer applied were 20kg/ha, 40kg/ha, 60kg/ha, and zero level which served as the control rate. Soybean seeds were planted by hand at the rate of 2 seeds per hole.

The soybean (*Glycine max*) seed used was TGX 1440 IE (Early maturing) obtained from the seed store at the institute of Agricultural Research and Training (I.A.R & T), Moor Plantation, Ibadan. Urea was applied to the plant 2 weeks after planting at the rate of 20kg/ha which served as starter dose to the plant. Maize seeds were planted when the soybean had matured and at their senescence stage.

Experimental design

The experiment was laid out in a Complete Randomized Block Design (RCBD) with three replicates. Each replicate was separated by 1m. Each replicate consisted of 4 plots of 11.1m X 2m separated by 1m apart and each plot consisted of 4 sub – plots at 2 X 2.4m^2 separated by 0.5m.

Data collection

Five [5] plants were randomly selected from each net plot (2.4m^2) for data collection. The parameters assessed were:

i. Number and weight (g) of Nodules

When about 50% of the total population had flowered, the 5 plants randomly selected on each sub plot were uprooted and the respective nodules on their root were counted and weighed.

ii. Yield (kg/ha)

The tagged plants (5 on each sub plot) were cut after the plant maturation and grains were dried to facilitate threshing and to make storage possible. The grains from each plant of each sub plot for both soybean and maize were weighed and then converted to kilogram per hectre (kg/ha).

iii. Soil Parameter

At maturation of soybean before the maize seeds were down, soil samples were taken from each sub plot to determine the effect of different phosphorus levels on the Post-harvest soil properties. The soil samples were analyzed in the soil laboratory of Federal College of Agriculture.

Data Analysis

The data collected was subjected to statistical analysis using analysis of variance (ANOVA) and the significant means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS AND DISCUSSION

Pre-Cropping Soil Properties of the Experimental Site.

The results obtained from the laboratory analysis of the pre- cropping soil sample of the experimental site (Table 1) revealed that the soil was moderately acidic with pH of 6.05, with a low total nitrogen of 0.96g/kg, moderate available phosphorus of 7.62mg/kg, Exchangeable Sodium of 0.52 cmol/kg, calcium of 1.34 cmol/kg and exchangeable magnesium and potassium were 1.17 and 0.13 cmol/kg respectively. The soil also had exchangeable acidity H^+ of 0.11 cmol/kg. The textural class of the soil was sandy loam.

Effect of Phosphorus Levels on the yield of Soybean (kg/ha):

The result of effect of phosphorus level on the yield of Soybean (Table 2) showed that, 60kg of Phosphorus (P_3) gave the highest yield which was significantly ($p > 0.05$) different from Control (P_0) and 20kg of P_2O_5 (P_1) but was not significantly different from 40kg of P_2O_5 (P_2).This is in agreement with the work of Mabapa *et al.*, (2010) which observed increase in above biomass and grain yield of soybean following the application of 60kg P_2O_5. Also, Kamara *et al.*, (2007), reported increased soybean grain yield and its components with application of phosphorus fertilizer. This result could be the response of the crop to available phosphorus in the soil. More phosphorus was needed because the soil phosphorus was low. (Mallarino and Reuben, 2015) reported that soybean utilized applied phosphorus more when available soil phosphorus was low to attain high yield.

Effect of Phosphorus rates on the Number and weight (g) of Nodules:

The result obtained from effect of phosphorus level on the number of nodules produced by Soybean (Table 2) showed that application of 20kg of P_2O_5 (P_1) produced a significantly ($p > 0.05$) higher number of nodules than 60kg of P_2O_5 (P_3) but not significantly higher than Control (P_o) and 40kg of P_2O_5 (P_2). This is consistent with Almeida *et al.* (2000) who also observed that low phosphorus concentration can stimulate the growth of soybean nodules and inhibit nitrogen fixation by nodules. This could be due to different levels of low phosphorus stress or the change in the direction of phosphorus transport caused by low phosphorus stress. The result however differs from that of Yao *et al.* (2007) and Jemo *et al.* (2017) who found that soybean nodule dry weight and number decrease with decrease in phosphorus levels.

The table also showed that there was no significant effect recorded for Phosphorus rates on the weight of nodules. This differs from the result of Le Roux *et al*. (2008) who observed that increase in phosphorus supply increases the nodule number in leguminous crops.

Table 1: Physical and Chemical Properties of the Experimental Pre-Cropping Soil.

Properties	**Value**
pH	6.05
Organic Carbon *(g/kg)*	9.6
Nitrogen *(g/kg)*	0.96
Available Phosphorus *(mg/kg)*	7.62
Exchangeable Cation *(cmol/kg)*	
Na^+	0,52
Ca^{2+}	1.34
Mg^{2+}	1.87
K^+	0.23
Exchangeable H^+ *(cmol/kg)*	0.11
Exchangeable Cation Exchange Capacity *(cmol/kg)*	4.06
Particle Size Distribution	
Sand	844
Clay	84
Silt	72
Textural Class	Sandy Loam

Table 2: Effect of phosphorus Rates on yield of Soybean (kg/ha), Number of nodules (kg/ha) and weight of Nodules (g)

Treatments	Yield (kg/ha)	Number of Nodules (kg/ha)	Weight of Nodules (g)
P_0	494.63b	3.67^{ab}	0.11
P_1	508.20b	6.08^{a}	0.20
P_2	726.92ab	3.67^{ab}	0.16
P_3	979.73a	2.92^{b}	0.90
			ns

ns: not significant

Means with same letter in a column are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

Effect of Phosphorus Rates on Nitrogen Fixed in the post harvest soil

The result obtained from application of different levels of phosphorus on nitrogen fixation by soybean (Table 3) revealed that 60kg of P_2O_5 have the greatest amount of nitrogen fixed which is significantly different from P_o and P_1 but not P_2 ($p > 0.05$). This is in agreement with the work of Bhuiyan *et al*. (2008) who observed that application of phosphorus increased nodulation, N-fixation of legumes. Also, Magadlela *et al.* (2016) concluded that low phosphorus concentration inhibited the Nitrogen fixation of legumes by inhibiting the growth and phosphorus absorption of of plants.

Effect of Phosphorus Rates on Available Phosphorus and organic matter of Post-Harvest Soil

The result of effect of application of different levels of Phosphorus on the availabe phosphorus in the post harvest soil (Table 3) showed that the treatment had no significant effect on the available phosphorus in the post harvest soil.

The result of effect of levels of Phosphorus on organic matter content of the post harvest soil (table 3) shows that 60kg of P_2O_5 (P_3) produced the greatest amount of organic matter 24.26 g/ kg which was significantly (p >

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue V May 2026

0.05) higher than other treatments. The table also shows increase in organic matter as the concentration of phosphorus level increases; Po (17.19g/kg) < P_1 (18.00g/kg) < P_2 (19.08g/kg) P_3 < 24.26 g /kg in that order. This result could probably be because phosphorus indirectly increases soil organic matter by stimulating crop growth which boosts the amount of root biomass, crop residues and root exudates returned to the soil. Hence, with more levels of phosphorus concentration, more organic matter is available in the soil. This could therefore be translated to the result obtained from the soybean yield which was also better at 60 kg P/ ha. The result also agrees with the work of Yumei *et al.*, (2024) who also observed increase in disolved organic matter with increase in phosphorus application rate.

Table 3: Effect of Phosphorus Rates on Nitrogen fixation, Available Phosphorus, Organic Matter of Post-Harvest Soil, Yield and Yield components of suceeding maize

Treatments	Nitrogen *(g/kg)*	Available Phosphorus *(mg/kg)*	Organic Matter *(g/kg)*	GY (kgha^{-1})	100SW(g)	SP	HI
P_0	0.98^{b}	9.15	17.19^{b}	563.8b	20.0b	43.2c	37.7
P_1	1.05^{b}	11.36	18.00^{b}	755.2ab	23.0ab	49.7b	44.7
P_2	1.12^{ab}	11.96	19.08^{b}	833.4a	26.0a	49.8b	45.1
P_3	1.40^{a}	11.88	24.26^{a}	902.8a	29.0a	54.8a	46.5
		ns		101.4	4.0	4.3	ns

ns: not significant

Means with same letter in a column are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

Effect of Phosphorus Rates on performance of Suceeding Maize

P level significantly influenced grain yield of suceeding maize with grain yield of 60 P kg/ha being superior to yields at other P levels by 7.68, 16.35 and 37.55 percent. The result obtained on effect of phosphorus on the yield of succeeding maize showed that maize on the plot treated with phosphorus (especially 40 and 60 kg P/ha) produced significantly high yield could probably be due to the effect of P on the preceding soybean which is needed for the whole growth of soybean. Phosphorus is needed for fruiting, nodule formation and N-fixation in legumes. (Mclaren and Cameron, 1996). The fixed N was used by the subsequent crop for their growth and yield.

Shelling percentage and hundred seed weight were also affected by phosphorus application rates. Hundred seed weight took the same trend as the maize grain yield. For shelling percentage, application of 60 kg/ha of phosphorus had high shelling percentage, which was higher than those of other treatments. In all the three parameters however, zero application had lower values. This could also be because, according to Ogoke *et al.* (2006), phosphorus is needed by legumes (preceding crop) for N fixation. Hence, with more P, more N is fixed which is an essential nutrient for maize according to Osunde *et al. (*2003). A small percentage of the N fixed by the legume is used by the crop hence the N balance is then left in the soil for succeeding crop (Sanginga, 2003).

CONCLUSION

The phosphorus supply level for optimum soybean yield was 60 kg / ha. The same phosphorus level fixed the highest quantity of Nitrogen and gave the greatest amount of organic matter. More nodules were produced in soybean roots with application of 20 kg /ha of Phosphorus. Optimum maize yield was also obtained from plots where 60 kg/ha of P were previouly applied.

RECOMMENDATION

Phosphorus level of 60 kg/ha is recommended for optimum soybean yield, adequate supply of nitrogen and organic matter in the post harvest soil for better perfomance of succeeding maize.

REFERENCES

1. Ackigoz, E., M. Sincik, A. Karasu, O. Tongel and G. Wietgrte et al., (2009). Forage soybean production for seed in Mediterranean environments. Field crops Res., 110:213 – 218.
2. Almeida, J.P., Hartwig, U.A., Frehner, M., Nosberger, J., Luscher, A. (2000): Evidence that P deficiency induces N feedback regulation of symbiotic N2 fixation in white Clover (Trifolium repens L.). J. Exp. Bot. 51, 1289-1297.
3. Berg R.K and Lynd J.Q (1985). Soil fertility effects on growth, yield, nodulation and nitrogenase activity of Australian winter pea. Journal of Plant Nutrition. 8:131-145.
4. Bhuiyan, M.M.H., Rhaman, M.M., Afonze, F. Sultradhar, G.N.C. and Bhuiyan, M.S.L. (2008): Effect of Phosphorus, Molybdenum and Rhizobium innoculation on growth and nodulation of Mungbean. Journal of soil Nature 2 (2): 25-30.
5. Gyaneshwar P, Kumar G.N, Parekh L.J, Poole PS (2002).Role of soil microorganisms in improving P nutrition of plants. Plant and Soil. 245: 83-93.
6. IITA, 1992. Soybean Production Training manual. International Institution of Tropical Agricultrure, USA., pages :341
7. IITA 1993. Archival report (1988 - 1992), crop improvement division, grain legume improvement program part III. International Institute of Tropical Agriculture, Soybean Biological Nitrogen Fixation. Pp:10.
8. Jemo, M., Suleiman, S., Bekkaoui, F., Olomide, O.A.K., Hashem, A., Abd Allah, E.F., Alquarawi, A.A., Tran, L.P (2017). Comparative Analysis of the Combined Effects of dfferent water and Phosphate levels on Growth and Biological Nitrogen Fixation of nine Cowpea Varieties. Front. Plant Sci. 8: 2111. [Google Scholar] [CrossRef] [Green Version].
9. Kamara, A.Y., Abaidoo, R., Kwari, J., Omoigui L. (2011).influence of Phosphorus application on growth and yield of Soybean genotypes in the Tropical Savannah of North- east Nigeria. Achives of Agronomy and soil Science 53: 539- 552.
10. Kumaga, F.K. and Ofori, K. (2004). response of soybean to Bradirhizobia inoculation and phosphorus application. International Journal of Agriculture and Biology, 2004; 6 (2) 324-327.
11. Le- Roux, M.R., Khan, S., Valentine, A.J. (2008): Organic acid accumination may inhibit N2 fixation in phosphorus -stressed lupin nodules. New Phytol. 177, 956-964
12. Mabapa, P.M., Ogola, J.B.O., Odhiambo, J.J.O., Whitbread, A. and Hargreaves, J.(2010). Effect of phosphorus fertilizer rates on growth and yield of three Soybean (glycine max) cultivars in Limpopo province. African Journal of Agricultural Research 5 (19): 2650- 2660
13. Magadlela, A., Perez-Fermandez, M.A., Kleinert A., Dreyer, L.L., Valentine, A.J. (2016): source of inorganic N affects the cost of growth in a legume tree species (virgilla divaricata) from the Mediterrean-type Fynbos ecosystem. J. plant Ecol. 9, 752-761
14. Mallarino, A.P. and Reuben, D. (2005): Phosphorus and Potassium fertilization and placement methods for corn- soybean rotations managed with no till and chisel plough tillage. Lowa state University, Northern Research and Demonstration farm ISLF 04-22.
15. Mclaren, R.G. and Cameron, K.C.(1996): Soil Science Sustainable Production and Enviromental Protection.Oxford University Press.
16. Ogoke, I.J., Togun A.O. Carsky, R.J, and Dashiel, K. (2006): Effect of Phosphorus fertilizer on Soybean pod yield in Guinea savannah.Dept. of Crop Science and Technology.Federal University of Technology, P.M.B. 1526.Oweri, Nigeria. Niger Agric. Journal 35: 40-50.
17. Osunde,A.O., Bala, A., Gwam, M.S., Tsado, P.A.,Sangiga, N. and Okogun, J.A. (2003): Residual effect of promiscus soybean to maize (Glycine max L.) grown on farmers field around Minna, the southern Guinea Savannah Zone of Nigeria. Agriculture, ecosystem and environment 100, 209-220.
18. Pacovsky R.S, Bethlenfalvay G.J and Paul E.A (1986). Comparisons between P-fertilized and mycorrhizal plants. Crop Sciences. 26:151-156.
19. Sara S, Morad M, Reza C.M (2013). Effects of seed inoculation by Rhizobium strains on Chlorophyll content and protein percentage in common bean cultivars (Phaseolus vulgaris L.). International Journal of Biosciences.Vol 3, No. 3, p. 1-8.
20. Sangiga, N. (2003): Role of biological Nitrogen Fixation in legume based cropping system: a case study of West Africa Farming Systems. Plant and soil 252: 25-39.

21. Shahid M.Q., Saleem M., Khan H.Z., Anjum S.A. (2009). Performance of soybean (Glycine max L.) under different phosphorus levels and inoculation. Pakistan Journal of Agricultural Sciences. 46(4): 237-241.
22. Shurtleff W, Aoyagi A, (2007). History of Green Vegetable Soybeans and Vegetable Type Soybeans. Lafayate California.
23. Tiamigu, S.A, and A.A Idowu, (2001). Economics of resources use among small scale soybean farmers in Niger State. Trop oilseed J., 6: 71 -75.
24. Yao, Y. B., Wu, D.T., Gong, Z.P., Zhao, J.K.; Ma, C.M. (2018): Variation of nitrogen accumunation and yield in response to phosphorus nutrition of soybean (Glycine max L merr.). J. Plant Nutr. 41, 1138-1147.
25. Yumei, P., Nigan N., Yalei, H., Chumpeng, H., Chia, S., Zhangmin, F., Yuxin, Y., Ziyun, Z. and Zang, W. (2024). long term effects of Nitrogen and Phosphorus Fertilization on Profile Distribution and Characteristics of Dissolved Organic Matter in Fluvo- aquic soil. Journal of Enviromental Management. Vol. 366. August 2024, 121834. Science Direct.