Research Article

Effect of phosphorus concentration on nutrient composition of soybean *Glycine max L*

Abstract

Nutrient-elements are essential in human and animals' diets. These nutrients are obtained from different sources such as food crops and sea-foods. Amongst these nutrients, phosphorus is one of the macro-nutrients that plays vital roles in growth and development of humans, animals and crops. Field experiment was conducted to evaluate the effect of phosphorus concentration in the nutritional composition of soybean. The experimental plots were harrowed, ploughed and the experimental design was laid out in a Randomized Complete Block Design (RCBD) followed by the planting of soybean seeds. The experimental designs such as: T_0, T_{20}, T_{40}, and T_{60} were used to represent the following rates of phosphorus fertilizer application: 0kg/ha (control) 20kg/ha, 40kg/ha, and 60kg/ha respectively at one week-before-planting. The soybean (*Glycine max L.*) seeds were harvested at maturity (12weeks after planting), threshed and weighed. The seeds were taken to the laboratory for proximate and mineral analyses. The results showed that soybean treated with T_{60} (60kg/ha P) had the highest yield of 190.76kg/ha. Similarly, the result of proximate analysis showed that soybean treated with T_{60} (60kg/ha P) recorded the highest crude protein content of 39.51%. In addition, the data obtained from the mineral analysis showed that the Control, T_0 (0kg/ha P) recorded significantly higher values for iron and calcium than others; while soybean treated with T_{20} (20kg/ha P) had the highest value for magnesium. Conclusively, application of phosphorus fertilizer at a rate of 60kg/ha was more promising for optimum seed-yield and better nutritional quality of soybeans. Therefore, this study recommends that soybean farmers should use phosphorus fertilizer at 60kg/ha.

Keywords: soybean, mineral-nutrients, phosphorus, yield, fertilizer,

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Introduction

The soybean (*Glycine max*) is a species of legume, and a native of East Asia, widely grown for its edible bean which has numerous uses. It is one of the most important legume crops for human nutrition.[1] Soybeans originated in South East Asia and were first domesticated by Chinese farmers around 1100 BC. At the first century AD, soybeans were grown in Japan and many other countries. Research study reported that soybean seed from China was planted by a Colonist in the Britian.[2] However, soybean seed is a source of protein and oil for human nutrition and a source of soybean meal for livestock. For instance, in 2006 and 2007, soybean protein meal and soybean oil accounted for about 69% and 30% respectively of the world's supply of protein meal and edible oil.[1] Soybean contains significant amount of phytic acid, dietary minerals and vitamin B-complexes. Other uses of soybeans included but not limited to soymilk, soya-tofu, soya-meat and soya-vegetable-oil which is used for foods and for other industrial applications. Soybean is the most important protein source in animal-feed which in-turn yields animal protein for human consumption.[3] Soybean quality and protein content is influenced by nutrient availability in the soil. For instance, phosphorus has a positive effect on protein content on these beans. Consequently, phosphorus application is necessary in soybean production for high protein quality and seeds-yield.[4] Research studies had shown that soybean-seeds contain approximately 37–41% protein, 18 – 21% oil, 30 – 40% carbohydrate and 4 -5 Ash.[5] Furthermore, the yield of soybean biomass such as the straw, and seed was predicted to be due to the increase in the rate of phosphorus application.[6] Phosphorus has significant impacts on the growth and yield of soybean.[7] Earlier publication highlighted that small quantity of phosphorus in the soil was a key hindrance to the growth as well as seed production of soybean. It also follows that soybean thrives well on a relatively well – drained loamy soil which is rich in phosphorus (-PO_4) with a pH range from 4.5 to 8.5, but performs badly on drought-stressed soils and water-logged soils as well as in a phosphorus deficient-soil.[8] Proper germination of soybean seedlings is assured on a soil adequately rich in phosphorus and on a well prepared farmland, which can be done mechanically or manually.[9] The recommended chemical fertilizer for soybean production is phosphorus (P_2O_5). Even though legumes like soybean fix some amount of nitrogen and phosphorus from the atmosphere through the "root nodules" into the soil. It is important to apply some amount of starter phosphorus to propel the growth of soybean crop before the development of nodules.[9,10] The most deficient nutrient in soybean production is phosphorus (K_2O) and must be used as a single super phosphate fertilizer (SSP) to augment the good growth in soybean production. Comparatively, Bhasin and Akpulu[11] opined that the use of phosphorus fertilizer is for better output to be achieved in soybeans production. This implied that phosphorus fertilizer should be applied before the soil is harrowed. Inadequate supply of P may decrease the enzyme activity and adenosine triphosphate (ATP) concentration in the nodules. Thus, decreasing the ability of soybean plant to fix N and thereby making it difficult to meet its N requirement.[12] Phosphorus is an important mineral-element for crops like soybean, and as such soybean yield is a function of phosphorus amendment fertilization.[13] Previous studies had stated that the main constraints in soybean production included but not limited to low soil-phosphorus level.[14] Phosphorus is needed for higher nutrients quality and better soybean-seed yields. The amount of soil-nutrients should be adequate enough to maximize seed-yielding potentials of soybean.[15] Soybean crops grow and yield best in a high fertile-soil rich in phosphorus. Research has also shown that phosphorus boost nutrients-accumulation in soybean seeds and it provides opportunities for better yield.[16] While Ball et al.[17] reported that phosphorus in soil provides nutrient uptake, remobilization and maximum yield, thereby reducing the risk of nutrient loss. Furthermore, phosphorus is needed for the promotion of a durable and resilient soybean Agro-ecosystem, high seed and nodule yields. Phosphorus fertilizer application provides additional nutrient-enhancement in soybean cultivation.[18] Phosphorus fertilizer application in soybean at seedling stage can influence maximum nutrient uptake and seed yield. The sustainability of soybean seedling depends on phosphorus nutrient concentrations which support the plant growth; and so phosphorus fertilizer application should be considered in soybean seedling.[19] Soybean requires phosphorus-soil-fertility. Ordinarily, legumes normally provide adequate N with the help of phosphorus (P) nutrient. To this end, phosphorus fertilizer would be best used to manage soybean production by increasing seed-yield and nodulation. Phosphorus in soybean seedling promotes root growth and provides adequate nutrition.[20]

Phosphorus from the soil is an important nutrient aimed at proper nodule development as well as securing and improving soybean production. In same wavelength, Antony et al.[21] described phosphorus as a key nutrient in fertilizer that plays essential role in energy transfer, photosynthesis and growth in plants. It is obvious that plant-yield has a direct relationship with soil nutrient, these variables or factors also contribute to quality and yield of soybean. Research studies had reported that phosphorus in soybean was estimated to be up to 81% of total P intake from soil during the growing season.[22]

Soil rich in phosphorus supplies enough nutrients to soybean and this stimulates uniform growth and enhances yield for sustainable crop production.[23] Soybean is directly dependent on the phosphorus nutrient and as such it increases soybean protein through phosphorus fertilizer application.[24,25] Phosphorus deficiency in soybean can limit the nodules formation while the P fertilization can overcome the deficiency.[26–28] Phosphorus makes significant impact on fixation of N, photosynthesis root expansion, seed establishment, flowering, maturing and quality of crop.[29,30] Phosphorus application through single super phosphate fertilizer significantly increased the seed protein content (SPC) and the seed yield of soybeans.[31]

Materials and method

Area of study

The field experiment was carried out at Ikenne, the out-station of the Institute of Agricultural Research and Training (IAR&T) in Ogun State, Nigeria which lies at the longitude of 3°43'E and latitude of 6°50'N.

Land Preparation and planting method

The experimental plot measuring 11.1 × 35 m² was prepared by ploughing and harrowing and laid out into 12 plots 11.1 × 2 m². Phosphorus fertilizers at different rates were incorporated into the soil a week before planting. The different rate of phosphorus fertilizer were: 20 kg/ha, 40 kg/ha, 60 kg/ha, and 0kg/ha (Control) with the following treatment designs: T_{20}, T_{40}, T_{60}, and T_0 respectively.

Planting Material

The soybean (*Glycine max* L) seed used was TGX 1440 I E (early maturing variety) and was obtained from the Seed Store of the Institute of Agricultural Research and Training (IAR&T) Moor Plantation, Ibadan, Nigeria.

Experimental Design

The experiment was laid out in the randomized complete Block Design (RCBD) with three replicates. Each replicate measures 11.1 × 2 m² separated by 1m apart and each replicate was divided into 4 plots of 2 × 2.4 m⁻² separated by 0.5m.

Data collection

Soybean seeds were harvested, threshed and weighed and weight recorded in kg/ha. Then the seed were taken to the laboratory for proximate analysis and mineral composition analysis.

Statistical Analysis

The data obtained were subjected to one-way analysis of variance (ANOVA) and means were separated using least significant difference (LSD) at 5% levels of probability.

Results and discussion

Properties of pre-cropping Soil

The physical and chemical properties of the soil used for the experiment is presented in Table 1. It showed that the soil was slightly acidic with a pH of 6.14. Total Nitrogen was very low (0.083%), compare to the standard value of (1 - 1.5) available phosphorus (7.63 mg/kg) compared to the standard value of (7 - 7.20) and organic carbon (0.83%) compared to the standard value of (1.0 - 1.4) were low. Exchangeable base: potassium, calcium, magnesium and sodium of the soil range from 0.29 – 1.10 and 0.40 cmol/kg. The texture of the soil was sandy- loamy soil with sand, silt and clay content of 861, 79 and 60 g/kg respectively. The effect of treatment on the yield of soybean is presented in Table 2, Soybean treated with T_{60} (60 kg/ha P) gave the highest yield of 190.76 kg/ha which was significantly higher than the control. Comparatively, the seed-yield obtained from T_{20} (20 kg/ha P) and T_{40} (40 kg/ha P) were far better than the control (T_0).

Table 1 Physical and chemical characteristics of experimental soil

Parameters	Value
pH	6.14
Total Nitrogen	0.08
Organic Crabon (g/kg)	0.83
Available phosphorus (g/kg)	7.63
Exchangeable Cations (cmol/kg)	
Ca^{2+}	0.59
Mg^{2+}	1.10
Na^{+}	0.40
K^{+}	1.01
H^{+}	1.01
ECEC	3.39
Particle e size distribution (g/kg)	
Sand	861
Clay	60
Silt	79
Textural class	Sandy loam

Table 2 Effect of phosphorus concentration on yield of Soybean (kg/ha)

Treatment(kg/ha P)	Yield
T_0(Control)	90.50±0.3^{d}
T_{20}	120.92±0.0^{c}
T_{40}	150.25±0.0^{b}
T_{60}	190.76±0.0^{a}

Means ± SE with the same letter in a column were not significantly different

Proximate composition of soybean seed

The result of proximate analysis of soybean seed is presented in Table 3. It was observed that treatment had no significant effect on moisture content of soybean seed; while there was positive impact of the treatment on the crude protein content of soybean. It follows that soybean treated T_{60} (60kg/ha P) had the highest value of crude protein (39.51%) followed by T_{40} (37.19%) and T_{20}(35.75%) while T_0 (34.79%) had the least. This result was in consonance with the reported data by Tanwar and Shaktawat[31] which stated that phosphorus application significantly increased the seed protein content (SPC) of soybean. In another development, the treatment appeared to have little or no effect on the seed crude-fat. Although, this observation was in contrast to the publication report by Brennan and Bolland[32] which highlighted that phosphorus significantly improved the oil content of many oil-seed crops. This study however strongly supported the findings of Rogerio et al.[33] which stated that different levels of phosphorus in oil-seed crops (Crambe for instance) does not significantly increase the oil content of the crop. Broad spectrum-evaluation showed that the control (T_0) was significantly higher in crude fibre than others. This indicated that crude fibre content of soybean was not dependent on the application of phosphorus fertilizer. It is worthy of note that crude fibre can be a derivative of other mineral salts or compounds in which soybean could obtain from the soil even without the application of phosphorus fertilizer. The total ash was slightly different among treatments. For instance, control (T_0) had the highest value (5.49%) followed by T_{20}, T_{60} and least in $T_{40.}$ Furthermore the nitrogen free extractive (NFE) was significantly different in all the treatments. Soybean treated with T_{40} Phosphorus experienced the highest amount of nitrogen free extractive (NFE) while there was comparable NFE value for T_{20} and the control (T_0). This observation vehemently agreed with the earlier literature report which indicated that application of phosphorus fertilizer facilitates the availability of free nitrogen to soybean.

Table 3 Proximate analysis of soybean

Treatment(kg/ha P)	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Total ash (%)	NFE (%)
T_0(Control)	9.58±0.0^b	34.57±0.2^d	24.23±0.0^a	6.70±0.0^a	5.49±0.0^a	19.45±0.0^c
T_{20}	9.70±0.0^a	35.75±0.1^c	23.46±0.0^c	6.22±0.0^b	6.30±0.0^b	19.50±0.0^b
T_{40}	9.35±0.0^c	37.19±0.0^b	22.82±0.0^d	5.38±0.0^d	4.88±0.0^d	20.38±0.0^a
T_{60}	9.70±0.0^d	39.51±0.0^a	5.97±0.0^b	5.97±0.0^c	5.05±0.0^c	15.95±0.0^d

Means ± SE with the same letter in a column were not significantly different

Mineral composition of soybean seed

The result of mineral Analysis of Soybean was presented in Table 4. The results showed that there was significant difference in iron content of soybean across all the treatments. Meanwhile, soybean without phosphorus fertilizer application (Control) had the highest iron content of 18.02%. In the same vein, there was significantly higher amount of calcium in soybean seeds obtained from the control treatment (T_0) than others. The increasing level of calcium in soybean from the treatments was in the order: $T_{40} < T_{20} < T_{60} < T_{0.}$ From this result, one can succinctly say that the mineralization of soil with phosphorus fertilizer was unconnected with calcium enrichment in soybean. Soybean from T_0 phosphorus treatment had the highest calcium content of 324.03%, while the soybean from T_{40} phosphorus treatment was significantly lower in calcium content. In addition, there was significant difference in magnesium content of soybean across treatments. For instance, soybean treated with T_{20} (20kg/ha P) had the highest magnesium content of 338.75%. The amount of magnesium obtained from T_{40} and T_{60} treatments were statistically higher than that of control (T_0).

Table 4 Mineral composition of soyabean

Treatment	Fe	Ca	Mg
(kg/ha P)	(mg/kg)	(Cmol/kg)	(Cmol/kg)
T_0(Control)	18.02±0.01^a	324.02±0.00^a	281.03±0.00^c
T_{20}	10.79±0.01^d	211.70±0.01^c	338.75±0.01^a
T_{40}	13.54±0.01^c	201.57±0.01^d	325.58±0.02^d
T_{60}	14.68±0.00^b	232.50±0.01^b	325.57±0.01^b

Means ± SE with the same letter in a column were not significantly different ($p<0.05$)

Conclusion

Phosphorus at the rate of T_{60} (60kg/ha) is needed to obtain optimum soybean-yield and for high protein quality. Other minerals like Magnesium also respond to application of phosphorus in soybean. However, crude fat does not response directly to phosphorus application in soybean production. In addition, results from control treatment without phosphorus fertilizer revealed that the crop could get nutrients such as iron and calcium from other sources. Selective Phosphorus concentration can be used in precision soybean cultivation to improve target nutrients in soybean. Soybean production make protein available for man and animals, hence this study recommends the applications of 60kg/ha of phosphorus to achieve optimum yield and high protein quality in soybean.

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Conflicts of interest

The authors declared that there are no conflicts of interest.

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