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RESPONSES OF SOYBEAN [*Glycine max* (L.) Merrill] TO PHOSPHORUS FERTILIZER TIMING AND RATES IN MAKURDI, NIGERIA.

Agricultural Science

Terkula Joseph Maga Department of Plant Breeding and Seed Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria.

Terhide Samuel Ter Department of Soil Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria

Kator Jeremiah Aorga Department of Plant Breeding and Seed Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria.

ABSTRACT

The Low phosphorus content in tropical and subtropical soils constitutes a limiting factor to soybean production, although agronomists have indentified phosphorus fertilization as a remedy, the optimum rate and time of application are still unknown. Thus two field experiments were conducted at the Teaching and Research Farm of the University of Agriculture, Makurdi in 2014 and 2015 cropping seasons to determine the effects of phosphorus fertilizer rates and timing on yield and yield components of soybean in Makurdi. The experiment was a 3 x 5 factorial laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted of three timing schemes of phosphorous application (at planting, one and two weeks after planting) as well as fertilizer rates (0, 15, 30, 45 and 60 kg/ha). Parameters measured were plant height, number of leaves per plant, number of branches per plant, days to 50% flowering, pod length, number of seeds per pod, pod weight, 100-seed weight, number of pods per plant and grain yield. Data collected were subjected to Analysis of Variance (ANOVA). The result of the analysis showed that phosphorus fertilizer timing had no significant effect on the yield and yield parameters although delaying application appeared to decrease yield. Fertilizer rates significantly affected soybean yield and yield components except days to first flowering and 100-seed weight. Application of 60 kg/ha P produced the highest seed yield. 60 kg/ ha P is recommended for soybean production in Makurdi.

KEYWORDS:

Phosphorus rates, soybean, phosphorus fertilizer, vegetative growth, yield components.

INTRODUCTION

Worldwide, there is a growing demand for soybean seeds either as source of vegetable oil or protein or both. Soybean is also valuable on account of its ability to fix nitrogen into the soil and enhance soil conditions. These properties have given soybean a premium status and attracted research attention (Biowatch 2004). Apart from being a source of vegetable oil, protein and beneficial role in Biological Nitrogen Fixation (BNF), soybean is becoming increasingly a major source of biodiesel production with a potential to replace fossil fuel in the foreseeable future. This new use of soybean has further underscored the need to improve its productivity in order to meet the expanding demand. For instance, in South Africa, efforts are being made to train farmers to optimize soybean yield for biodiesel production (Mabapa *et al.*, 2010).

To date, the Guinea Savannah agro-ecology is regarded as the home for soybean, accounting for over 44 percent of the total soybean output in Nigeria (Dugje *et al.*, 2009). There is however a declining trend in the soybean yield across soybean producing areas which has remained a source of concern for research workers. Poor soil fertility has been identified to be one of the most abiotic factors responsible for the declining yield (Mabapa *et al.*, 2010). The low level of phosphorus in the bulk soil limits plants uptake. Thus, supplemental application of phosphorus fertilizer is therefore required for optimum crop productivity. Phosphorus is critical to soybean production by regulating metabolic pathways and constitutes part of substances that are building blocks of genes and chromosomes (Theodorou an Plaxton, 1993; Schachtman *et al.*, 1998; Anonymous. 1999; Ferguson *et al.*, 2006). It plays a significant role in biochemical processes of the plant and enhances enzymes activity (Schachtman et al., 1998). Therefore, appropriate phosphorus fertilization program may likely improve soybean productivity and enhance supply of seeds.

To optimize yield, basic information on phosphorus fertilizer use and timing are extremely important to ensure its efficient utilization by plants. Previous studies were restricted to determining the appropriate rates without regard to the flexibility in timing of its application (Aduloju *et al.*, 2009; Mahamood et al., 2009; Mabapa et al, 2010; Ahiabor *et al.*, 2014; Ojo et al., 2016).

Some researchers have recommended application of phosphorus fertilizer prior to planting to encourage early growth and crop establishment, however, research results obtained from Nebraska, USA could not find a great advantage of this practice (Ferguson *et al.*, 2006). Applying at planting may result to damage of the seeds if not properly handled. In order to avoid the danger of likely seed damage, most farmers apply phosphorus well after crop establishment. The effect of applying at or after crop establishment is still a matter under debate. It is therefore not clear the degree of flexibility that is available in applying phosphorus in soybean. There is also no consensus among scientists on the appropriate rates to be used for optimum soybean yield even within the same agro-ecological zone (Aduloju *et al.*, 2009 and Ojo *et al.*, 2016).

The inconsistency in phosphorus recommendations coupled with the scanty knowledge of its appropriate timing has greatly limited phosphorus fertilizer use that could have significantly increased soybean yield; hence the present study was therefore initiated to fill this gap.

MATERIALS AND METHODS

Experimental location

The experiment was conducted at the Teaching and Research Farm of the University of Agriculture, Makurdi, Nigeria during the 2014 and 2015 cropping seasons. Makurdi lies between Latitude. 7041' N and Longitude 8028'E and falls within the Southern Guinea Savannah Agro-ecological Zone. The experimental site used for this study was kept fallow for three years, and no history of previous application of phosphorus fertilizer on the site was known.

Cultural practices

Land preparation involves manual clearing of an area of land measuring 52 x 10 m (520 m2). Seedbeds were then constructed with manually. Each plot measured 2.5 x 2.5 m (6.25 m2). Two plants were planted per hill and two weeks later thinned down to one plant per hill. Plants were planted at the spacing of 0.1 m x 0.75 m, giving a total of 13,333 plants per hectare. Phosphorus fertilizer application was done according to the treatment plan (0kg/ha P, 15kg/ha P, 30kg/ha P, 45kg/ha P and 60kg/ha P). Treatments were carefully administered on the plots. Weeding was carried out at 2 weeks after planting (WAP) and subsequently to ensure a weed free condition. Planting was done on the 8th July in 2014 and 10th July in 2015 (Dugje et al., 2009). TGx 1448-2E, a popular soybean variety in Makurdi was used as a test crop for the experiment.

Experimental treatments

Four rates of phosphorus fertilizer (0, 15, 30, 45 and 60 kg/ha) and three regimes of fertilizer application (At planting, 1 week after planting (WAP) and 2 WAP) constituted the treatments. Treatments were arranged in a factorial and laid out in a randomized complete block design (RCBD) with three replications. Treatments were carefully applied as specified in the design using band method placed 10 cm away from the plant. Single super phosphate (SSP 18% P) was used as the source of phosphorus.

Soil properties

Some physical and chemical characteristics of the soil under study before the experiment was mounted were as follows: particle size distribution: sand (%) = 75.80; silt (%) = 10; clay (%) = 14.20; texture: sandy loam; organic carbon (%) = 1.0; pH = 6.90; soil organic matter (%) = 1.70; Nitrogen (%) = 0.056; phosphorus (mg/kg) = 0.30; potassium (cmol/kg) = 0.23. both the physical and chemical soil properties were measured using standard procedures.

Data collection

Data collected included plant height, number of leaves per plant, number of branches per plant, days to first flowering, pod length, number of seeds per pod, number of pods per plant, one hundred seeds weight and grain yield. Five plants were tagged and all observations were taken from those plants. All data were subjected to analysis of variance using GLM procedure of the SAS 9.1 (2003) and significant means were separated using F-LSD at 5 % probability level.

RESULTS AND DISCUSSION

Effect of fertilizer timing and phosphorus rates on yield and yield components of soybean

Plant height

Phosphorus fertilizer timing had no significant effect on plant height at 5% probability level (Table 1). The non-significant effect of timing on plant height could be attributed to the slow-releasing nature of single super phosphate. Between 0-14 days in which application was varied, it was not long enough to release substantial amount of phosphorus into the soil to elicit differential response. Similar observation was reported by Ojo *et al.* (2016). Significant differences were however observed in plant height due to phosphorus fertilizer rates (Table 2). Application of 60 kg/ha P significantly gave the highest plant height (37.61 cm), while the least (30.0 cm) was recorded in control plots. This result is in agreement with previous studies that had reported that increased phosphorus levels significantly led to increase in plant height (Rani, 1999, Tomar *et al.*, 2004; Ahiabor *et al.*, 2014; Ojo *et al.* 2016). The interaction between fertilizer timing and phosphorus levels was also not significant, indicating that differences observed in plant height were due to the main effects of the treatments applied (Table 3).

Number of leaves per plant

The number of leaves per plant was significantly influenced by time and rate of phosphorus fertilizer (Table 1). Significant higher number of leaves per plant (64.50) was obtained when phosphorus was applied at planting, while the least (56.00) occurred when phosphorus was delayed for 2 WAP (Table 2). This result highlighted the usefulness of phosphorus as a major requirement for soybean vegetative growth since it has a role to influence photosynthesis. Application of phosphorus at the rates of 45 and 60 kg/ha gave the highest number of leaves compared to the control which produced the least (45.00). Ojo *et al.* (2016) also obtained significant difference in number of leaflet count at apical node in their study. The interaction between timing and phosphorus level on number of leaves per plant was however not significant (Table 3).

Number of branches per plant

Number of branches per plant was not significantly affected by time of phosphorus application (Table 1), although the highest number of branches was recorded at 60 kg/ha P, while the control produced the least branches number. The highest (6.50) number of branches per plant was obtained when 60 kg/ha P was applied at planting or 7 days after planting (Table 2). At low phosphorus application rate, the number of branches per plant decreased to 4.50. The significant increase in number of branches as a result of increase in P corroborates the study reported earlier (Asia *et al.*, 2005). The interaction between time of application and phosphorus rates revealed no significant difference (Table 3)

Number of days to 50% flowering

The mean square estimate revealed that both phosphorus fertilizer rates and timing all had no significant effect on days to 50% flowering (Table 1). The reason behind this observation might be that days to flowering among a few traits that are not greatly influenced by changes in soil nutrient status (Ojo et al., 2016). Numerically, delaying phosphorus fertilizer application by 1 or 2 WAP resulted in reduction of the number of days required to attain 50% flowering unlike when phosphorus is applied earlier (at planting). Similarly, application of 60 kg/ha P delayed flowering while plots that receive little or no phosphorus attained 50% flowering earlier (Table 2). This result suggests that phosphorus plays an important role towards transition from vegetative to reproductive phase in the development of soybean (Schachtman *et al.*, 1998). A similar result was reported in soybean (Ojo *et al.*, 2016). These authors also found a non-significant effect of phosphorus on days to flowering when soybean genotypes with varied genetic background were evaluated under varying phosphorus fertilizer levels.

Pod length

Neither phosphorus fertilizer rate nor timing significantly affected pod length (Table 1). However, application of 60 kg/ha P produced maximum (3.56 cm) pod length while plots that received no phosphorus gave the least (3.41 cm). Similar trend was reported by Ahiabor *et al.* (2014) who also observed higher pod weight when 45 kg/ha P was applied and minimum pod weight when no phosphorus was applied. Higher number of seeds is likely to be obtained in longer pods, which underscores the importance of pod length as a yield component. Phosphorus fertilizer timing and its interaction with phosphorus rates also had no significant effect on pod length.

Number of seeds per pod

The mean square estimates showed non-significant effect of number of seeds per pod when phosphorus application was varied, but for the rate, a significant difference was noted (Table 1). There was no consistent pattern of variation observed by applying phosphorus at different levels. This further emphasizes the stability of this trait regardless of the timing of phosphorus application. Significantly higher number of seeds per pod (2.62) was obtained by applying 20 kg/ha P, while the least seeds (2.33) was recorded in control and at 30 kg/ha P (Table 2). However, there is a relationship between the pod length and seeds per pod which tend to suggest that longer pods are likely to have more seeds. This in turn would lead to higher productivity. Turuko and Mohammed (2014) reported a significant difference with phosphorus rate on number of seeds per plant when P was applied at 20 kg/ha. Phosphorus application at different application dates had no significant effect but the interaction between rates and timing produced a significant effect on seeds per pod. Delaying phosphorus application by two weeks impacted positively on seeds per pod especially when higher levels of phosphorus are applied (60 kg/ha P) The result of the present study confirmed the finding of Hernandez and Cuevas (2003) and Asia et al. (2005) who recorded significantly higher number of seeds per pod when sufficient amount (100 kg/ha P) of phosphorus was applied compared to the minimum number of seeds that was produced when no phosphorus was applied.

Number of pods per plant

Although phosphorus fertilizer timing had no significant effect on number of pods per plant (Table 1), delaying the application for two weeks greatly influenced increase of pods per plant (99.74 pods). Early (at planting) application appears to have a retarded effect on pod formation (86.72 pods) and cause lower number of pods to be produced. This observation appears to suggest that late application of phosphorus ensured availability of phosphorus at the critical period especially during pod formation. Increased level of phosphorus led to a corresponding increase in number of pods per plant (Table 2). However, at 60 kg/ha P, maximum (122.80 pods) number of pods produced were statistically at par with those produced when 45 kg/ha P was applied but significantly different from the rest. Whereas the present result contradicts the previous reports by Ojo *et al.* (2016) who found that applying phosphorus beyond 40 kg/ha in soybean could compromise yield, the present study provided evidence that soybean requires phosphorus far more what these worker reported (Ferguson *et al.*, 2006). The divergence in our opinions might be due to the background of the genotypes evaluated. Ahiabor *et al.* (2014) reported that regardless of whether plants were inoculated or not, pod production apparently increased with increasing rates of P application which agrees with the result of this study. There was no evidence of interaction between phosphorus timing and rates on soybean yield components (Table 3).

One hundred seed weight

Varying date of phosphorus application had no significant effect on one hundred seed weight but different phosphorus rates had (Table 1). Applying 60 kg/ha P significantly increased soybean seed size to 12.03 g over the control (0 kg/ha P) 11.09 g. However, the seed size obtained when 45 kg/ha P (11.72 g) was applied was statistically at par with those at 60 kg/ha P (Table 2). For economic reasons, application of 45 kg/ha P appears to be reasonable since there was no marginal advantage applying phosphorus at maximum rate (60 kg/ha P). A similar result was reported in a previous study (Ojo et al., 2016) in which phosphorus rates significantly affected seed size. The interaction between phosphorus fertilizer timing and rates was however not significantly different (Table 3).

Grain yield

Results of mean square estimate revealed no significant effect of phosphorus timing on soybean grain yield but significant effect of phosphorus fertilizer rate was observed (Table 1). This result suggests that applying phosphorus at planting or two weeks later have no significant effect on grain yield. A similar observation was previously reported in Nebraska with starter fertilizer (Hergert *et al.*, 2012) where it was observed that application of starter fertilizer conferred no consistent advantage. Grain yield consistently and progressively increased with increase in phosphorus rates (Table 2). The highest grain yield (3.75 t/ha) was obtained at 60 kg/ha P while the least (1.90 t/ha) occurred when no phosphorus was applied (0 kg/ha P). This result confirmed the importance of phosphorus to soybean grain yield as earlier noted by Ahiabor *et al.* (2014) who also observed a consistent increase in grain yield of soybean at every higher rate of P application. There was no evidence of interaction between phosphorus fertilizer timing and rates on grain yield (Table 3). Although application of 60 kg/ha P at planting gave significantly higher grain yield (3.82 t/ha) compared to when no phosphorus fertilizer was applied (1.76 t/ha). This result suggests that application of 60 kg/ha P at planting greatly enhanced soybean grain yield even though such yield difference was not statistically different with those obtained when phosphorus was applied one week or two weeks after plant.

Summary and conclusion

Based on the results of this experiment, phosphorus fertilizer timing had little or no effect on the yield and yield components of soybean. This result indicated that there is flexibility in the time of application of phosphorus fertilizer in soybean. It can be applied soon after planting or delayed for two weeks after planting without adverse effect on grain yield. This study also revealed that application of 60 kg/ha P significantly increased yield and yield components of soybean. Thus, 60 kg/ha appears to be the optimum phosphorus fertilizer rate for soybean in Makurdi.

Recommendation

The present study indicated that phosphorus can be applied at planting, or delayed by two weeks without adverse compromising grain yield. However numerically, applying phosphorus at planting appeared to have better effect on grain yield as it leads to an increase. There was a progressive increase of soybean yield and most of the components with increasing level of phosphorus fertilizer. Thus, further study is recommended to investigate the performance of soybean under higher phosphorus levels since the maximum rate used in this study was far less than the quantity suggested by earlier researchers.

Authors

First author: Mr. T. J. Maga, Department of Plant Breeding and Seed Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria terkulamaga@yahoo.com, and magatj@uam.edu.ng +234832166984 (Corresponding Author).

Second Author: Mr. T. S. Terhide, Department of Soil Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria.

Third Author: Mr. J. K Aorga, Department of Plant Breeding and Seed Science, University of Agriculture, P. M. B. 2373, Makurdi, Nigeria.

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