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Cowpea Yield as Affected by Level and Time of Mineral Phosphorus Fertilizer Application in the Guinea Savanna Agro-Ecological Zone of Ghana

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Abstract- Phosphorus, although not required in large quantities, is very critical to cowpea production because of its multiple effects on nutrition; shoot development and its influence on nodulation. Phosphorus application stimulates plant root growth, early flowering, enhances fruiting, initiate nodule formation as well as increase in yield of cowpea. In spite of this immense importance of P in soils, its availability to cowpea growth and development is influenced by several factors, which include level and time of application. Knowledge in level of P and time of application to facilitate timely availability of the P fertilizer to improve cowpea yield is critical in order to avertthe continues reduction of cowpea yield by farmers. As a result a 3x4 factorial experiment arranged in split-plot design was conducted at the University for Development Studies experimental site, Nyankpala near Tamale in the northern region of Ghana campus to determine the appropriate P fertilizer levels and timing of application. Three levels of P fertilizer; 24, 48 and 60 kg ha^{-1} P was applied at 30, 15 days before plating. However, a third application was implemented at sowing.

Keywords: *phosphorus, nodule number, nodule weights, time of application.*

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Abstract- Phosphorus, although not required in large quantities, is very critical to cowpea production because of its multiple effects on nutrition; shoot development and its influence on nodulation. Phosphorus application stimulates plant root growth, early flowering, enhances fruiting, initiate nodule formation as well as increase in yield of cowpea. In spite of this immense importance of P in soils, its availability to cowpea growth and development is influenced by several factors, which include level and time of application. Knowledge in level of P and time of application to facilitate timely availability of the P fertilizer to improve cowpea yield is critical in order to averthe continues reduction of cowpea yield by farmers. As a result a 3x4 factorial experiment arranged in split-plot design was conducted at the University for Development Studies experimental site, Nyankpala near Tamale in the northern region of Ghana campus to determine the appropriate P fertilizer levels and timing of application. Three levels of P fertilizer; 24, 48 and 60 kg ha^{-1} P was applied at 30, 15 days before plating. However, a third application was implemented at sowing.

Results of the experiment indicated no significant affect (P>0.05) of P fertilizer rate applied on grain yield, root biomass and nodulation. However, there was significant effect (P<0.05) of P fertilizer on biomass yield. Similarly, time of application of P fertilizer had no significant effect (P>0.05) on grain yield, biomass weight, nodulation and root biomass. Furthermore, there was no interaction effect on P levels and time of application. However, application of 24 kg ha^{-1} P produced the highest grain yield of 1021 kg ha-1but was not significantly different from where 48 and 60 kg ha^{-1} P was applied.

Keywords: phosphorus, nodule number, nodule weights, time of application.

I. Introduction

Cowpea (*Vigna unguiculata* (L.) Walp. is a major food crop in Africa because of its high protein content, acceptable palatability and low cost of production. Cowpea have the potential to contribute substantially to human and animal health, income creation, food security and agricultural sustainability of less developed countries such as Ghana, Nigeria, Zambia and several others in sub-Saharan Africa (Muimui, 2010). Cowpea possesses the capacity to fix atmospheric nitrogen in poor soils and it is very adapted to arid areas and support high temperature and tolerates droughts (Ehlers and Hall, 1997). Sub Saharan Africa accounts for 84% of the world's cowpea grain production. Nigeria produces more than 45% followed by Niger that is nearly 15% of the world cowpea grains of 6.7 million metric tons produced each year covering an area of about 14.5 million hectares (Abate *et al.,* 2012). In Ghana 143,000 MT of cowpea is produced annually on about 156,000 ha making Ghana the fifth highest producer in Africa (MoFA, 2012). Economically, Ghanaian households generate annual income of about GH¢760 - 800 through increased production due to two or three cycles of production per year. And in Northern Ghana an additional income of between GH¢ 15 to GH¢ 16 million is generated yearly, at least 40% of this directly going to women farmers (ICRISAT, CIAT and IITA, 2012).

Cowpea is among the lowest yielding crops in the Africa averaging 310kg\ha (Ofosu Budu *et al.,* 2007) and this is because of declining soil fertility mainly N, P and K. Phosphorus is an important plant nutrient involved in several energy transformation and biochemical reactions including biological nitrogen fixation. However phosphorus availability is low in the moist savanna zone of West Africa and considerably limits cowpea crop production (Fox and Kang, 1977).Soil phosphorus deficiencies primarily result from either inherent low levels of soil phosphorus or depletion of phosphorus through cultivation. P fertilizers have low efficiency of use due to chemical fixation in soil (Gaur, 1983) and poor solubility of native soil phosphorus, sometimes there is a buildup of insoluble phosphorus as a result of chemical phosphorus application (Dubey, 1997). Furthermore, phosphorus can be fixed into forms unavailable to plants by Fe and Al oxides found in

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tropical soils (Sample *et al.,* 1980). Ineffective application of inorganic phosphorus fertilizer can therefore not be relied upon to adequately alleviate phosphorus deficiency for improved cowpea production (Devi *at al.,* 2013).

Phosphorus is effective in enhancing the nodulation, yield components and yield of cowpea. Similarly agronomic efficiency of phosphorus, physiological efficiency and phosphorus use efficiency are also higher with application of triple super phosphate (Kumar and Kushwaha, 2006). Therefore the development of appropriate management strategies to overcome phosphorus deficiency and increase production of these important crops requires in-depth knowledge of phosphorus application and its utilization (Devi *at al.,* 2013). Therefore, this experiment was setup to determine the appropriate P level as well as the time of application that would increase growth, development and yield of cowpea.

II. Materials and Methods

a) *Experimental area*

The experiment was conducted at University for Development Studies, Nyankpala campus farming for the future site, Nyankpala near Tamale in the Northern Region of Ghana on the coordinate (latitude 9.4075°N and 0.85333°W). The area has a unimodal rainfall season starting from April/May to September/October with a peak season in July/August with an annual average of 1100 mm within 95 days of intense rainfall. Consequently, staple food crop farming is highly restricted by the short rainfall duration. The mean day temperature ranges from 33 °C to 39 °C while mean night temperature range from 20°C to 22°C. The mean annual day sunshine is approximately 7.5hours (SARI, 2001). The area is characterized by natural vegetation dominated by grasses with very few shrubs.

b) *Experimental design*

The experiment was a 3 by 4 factorial laid in a split-plot design with three replications. Each replication contained 12 plots with six rows with plot size of 15 m^2. An alley of 1.5m and 1m between separated each replication and plot respectively. P fertilizer levels applied were 24, 48 and 60 kg ha^{-1}P and a control plot, which was considered as the main factor and was assigned to the main plots. P was applied at 30 and 15 days before planting as well as the day of planting. Consequently, the time of application of P was assigned to the sub plots. All plots received 30 kg ha^{-1} nitrogen and potassium respectively. Source of P, K and N used were triple super phosphate, muriate of potash and sulphate of ammonia respectively.

Cowpea variety *Padi-tuya* was planted at 60 and 20 cm between rows and plants respectively, on 16th July 2013 after the land was ploughed, harrowed and ridged. Pre-emergence herbicide cymethox super was applied at 50 ml ha^{-1} immediately after planting. Further weed control was carried out manually as needed.

Spraying was achieved at pre-flowering, flowering, podding and browning of the pods using dimethoatghte to control aphids, trips and maruca and pod sucking insects respectively.

Harvesting was done when pods were fully matured and dried. Hand picking was done several times due to different drying periods. An area of 4m^2 was used for data collection throughout the experiment. After harvesting, the cowpea pod were bagged and threshed. Seeds were separated from the haulm through winnowing and cleaned. Seeds were dried to constant weight before it was bagged and stored.

Field characterization was done to determine the initial soil fertility status. Parameters measured include soil pH, available P was determine using Bray 1 extraction procedure, total nitrogen was estimated using Khedjal method and exchangeable cations were estimated using 1 N ammonium acetate solution.

III. Results and Discussion

a) *Experimental site characterization*

Rainfall was uniformly distributed throughout the growing season even though it started late. Highest rainfall was obtained in early August and September. Highest rainfall values recorded were 80 and 75 mm respectively (Figure 1).This however facilitated good crop establishment and the crop did not suffer from water stress during the growing season. However, higher intermittent down pours during flower initiation affected flowering as a result of flower abortion.

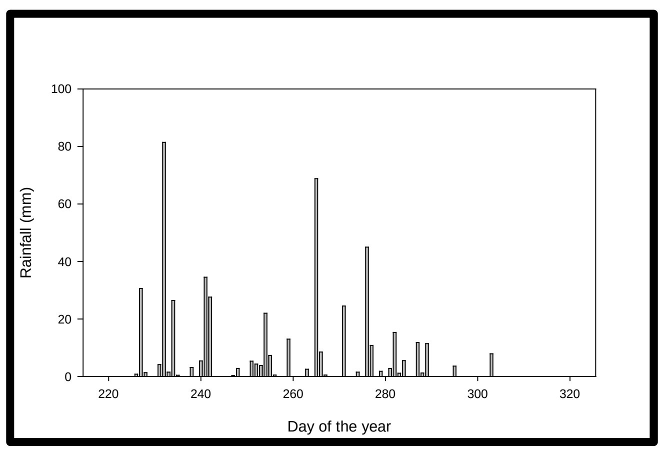

Figure 1 : Rainfall distribution during the growing season

Soil samples were taken from the experimental site and analyzed for pH, organic carbon, available P, total nitrogen and exchangeable cations before P fertilizer application. The results are however, presented in Table 1. Average pH measured was 5.19 indicating that the soil is acidic and this influences P availability due to fixation resulting in the limited P concentration of 2.26 mg/kg soil in the soil solution recorded. Similarly, the soil was low in organic carbon, total nitrogen with a C:N ratio of 9. The soil was further characterized by low Effective Cation Exchange Capacity (ECEC). Particle size distribution analysis of the soil using the hydrometer method indicated sandy loam.

Table 1 : Physical and chemical properties soil at the experimental site

Parameter	
pH (2:1 water)	5.19
% OC	0.461
Available P.(Bray 1) mg P/kg soil	2.26
Total. Nitrogen (%)	0.048
Al+H (Cmol/kg soil)	0.15
Ca	1.27
Mg	1.16
K	0.32
ECEC	3.87
Sand	64.89
Silt	34.34
Clay	0.77

b) *Effect of P application on nodulation, root biomass, stover and grain weight*

Six (6) plants were randomly selected from each plot within an area of 4 m^2marked for the data collection. Application of 48 kg ha^{-1} P resulted in higher number of effective nodules. On the contrary, application of 60 kg ha^{-1} P produced lowest number of effective nodules compared to application of 24 kg ha^{-1} P. However, where no P fertilizer was applied produced 90 effective nodules, which is less than where 60 kg ha^{-1} was applied. This however implies that, native rhizobia were affected by P application. Statistical analysis indicated significant difference between effective nodules produced where 48 kg ha^{-1} P was applied and the control. Values recorded were 121.3 and 90.3 with and least significant difference of 28.81 respectively. This indicated that, application of P did not have any effect on number of effective nodules produced. Each plant on the average produced 16, 18, 20 and 16 effective nodules from the control, 24, 48 and 60 kg ha^{-1} P plots respectively. Statistical analysis showed no significant difference ($P<0.05$) among treatments (Figure 2). Furthermore, statistical analysis showed no significant ($P>0.05$) interaction effect on number of effective nodules produced (Figure 4). Values recorded are presented in Table 2.

Table 2 : Interaction effect of time and levels of P application on cowpea nodulation

Fertilizer (kg/ha P)	Day of Application (Before)	A	B	C
0		90.7	95.7	84.7
24		96.3	115.7	114.7
48		95	132	137
60		91.7	87.7	115.3

Lsd = 43.61

Table 3 : Interaction effect of time and levels of P application on cowpea dry root biomass

Fertilizer	Day of Application (Before)	A		C
0		8.46	8	5.71
24		5.04	6.24	8.74
48		6.01	6.68	9.16
60		7.07	6.08	7.68

Lsd = 3.863

Table 4 : Interaction effect of time and levels of P application on cowpea grain yield

Fertilizer	Day of Application (Before)	A	B	C
0		819	993	794
24		826	1171	1066
48		935	847	1156
60		967	941	1096

Lsd = 389.2

Table 5 : Interaction effect of time and levels of P application on cowpea stover

Fertilizer	Day of Application (Before)	A	B	C
0		217.8	217.1	185.9
24		259.7	260.5	221.2
48		285	233	323.6
60		317.7	228.5	250.6

Lsd = 199.2

Similarly, there was no significant effect ($P>0.05$) on dry root biomass. However, contrary to number of effective nodules, application of 24, 48 and 60 kg ha^{-1} P reduced root biomass compared to controlled ploteven though there was no significant difference ($P>0.05$), (Figure 2). Values recorded were 18.47, 16.68, 18.21 and 7.36 kg ha^{-1} for control, 24, 48 and 60 kg ha^{-1} P plots respectively (Figure 2). Statistical analysis indicated a least significant difference value of 3.206.Similar to nodulation, there was no interaction effect on days of P application and P applied on dry root biomass. Statistical analysis showed no significant difference ($P>0.05$) among interactions (Figure 5). Recorded values are presented in Table 3.On the contrary, application of P affected stover yield significantly ($P<0.05$), (Figure 2). Stover weight recorded were 517, 618, 701 and 664 kg ha^{-1} from control, 24, 48 and 60 kg ha^{-1} P plots respectively (Figure 2) with a least significant value of 118.4 Although, application of P did not affect dry root biomass significantly, it however improved effective root nodulation although it was not significant. However, the improvement in stover weight was as a result of improved N fixation and use efficiency catalyzed by the application of P. However, there was no interaction effect. Values recorded are presented in Table 5. Similarly, grain yield was improved as a result of improved nodulation. Again statistical results indicated no significant difference (P>0.05), (Figure 2). Highest grain yield of 1021 kg ha^{-1}was recorded with application of 24 kg ha^{-1} P. Least significant value recorded was 266.4. Similar to above, statistical analysis did not show any significant difference (P>0.05) on stover yield and grain weight respectively, (Figures 6 and 7). Furthermore, there was also no interaction effect. Again values recorded are presented in Table 4.

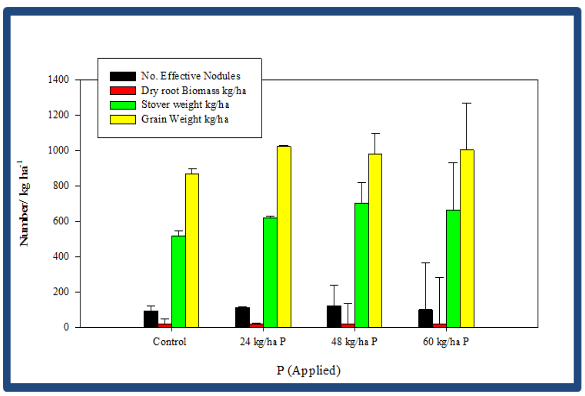

Figure 2 : Effect of P on Nodulation, root biomass, stover and grain weight

c) Effect of day of P application on nodulation, root biomass, stover and grain yield

Time of application of P fertilizer did not have significant effect (P>0.05) on effective root nodulation. However, application of P at 15 and 30 days after application improved cowpea nodulation compared to application at planting. Values recorded were 93.4, 107.8 and 112.9 respectively (Figure 3). This confirms the idea that P is slow releasing coupled with it fixation under soil with acidic conditions. Similarly, time of application of P did not influence dry root biomass significantly (P>0.05), (Figure 3). It however improved dry root biomass compared to where no P fertilizer was applied. 19.56, 16.87 and 16.61 kg ha^{-1} dry root biomass were recorded from plots where P was applied at planting, 15 and 30 days after planting, respectively. Furthermore, time of P application did not have significant effect on grain yield as well as stover (Figure 3). Although, time of application of P had no significant (Figure 3) effect on grain yield and stover, it improved yield compared to where no P was applied.

Positive correlation was established between effective nodule numbers and grain yield (Figure 8). Increasing number of nodules resulted in marginal increase in grain yield. R^2 value obtained was 0.581. On the contrary, root biomass did correlate with effective nodule numbers (figure 9). Higher root biomass did not result in nodule numbers.

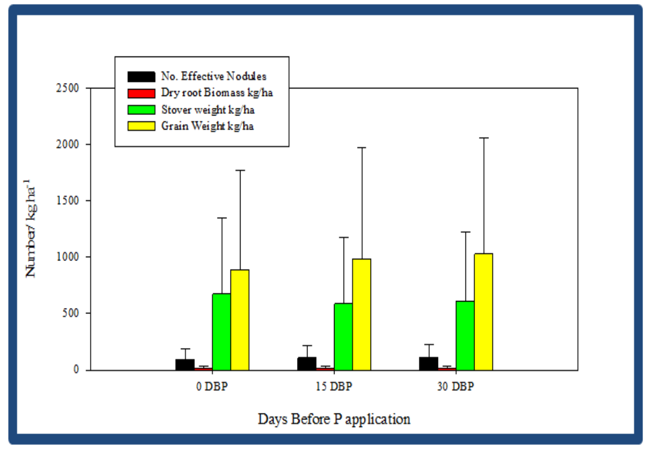

Figure 3 : Effect of day of P application onnodulation, root biomass, stover and grain yield

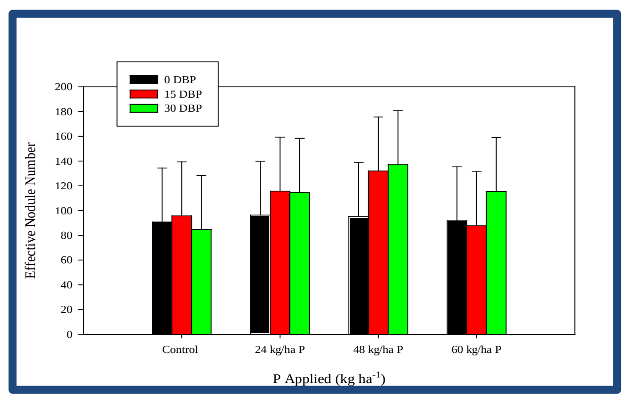

Figure 4 : Interaction effect of day and rate of P application on number of effective nodules

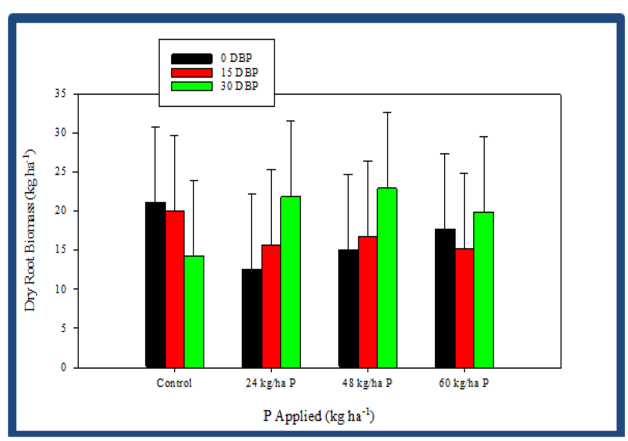

Figure 5 : Interaction effect of day and rate of P application on dry root biomass

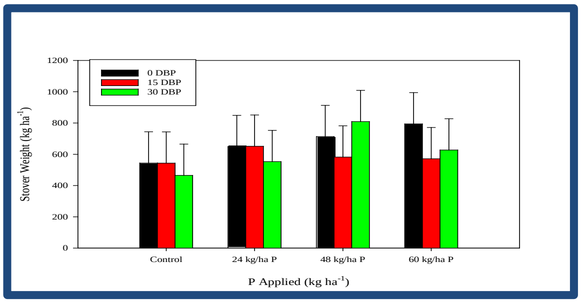

Figure 6 : Interaction effect of day and rate of P application on stover weight

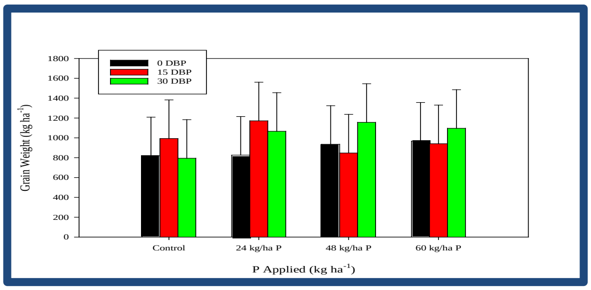

Figure 7 : Interaction effect of day and rate of P application on grain yield

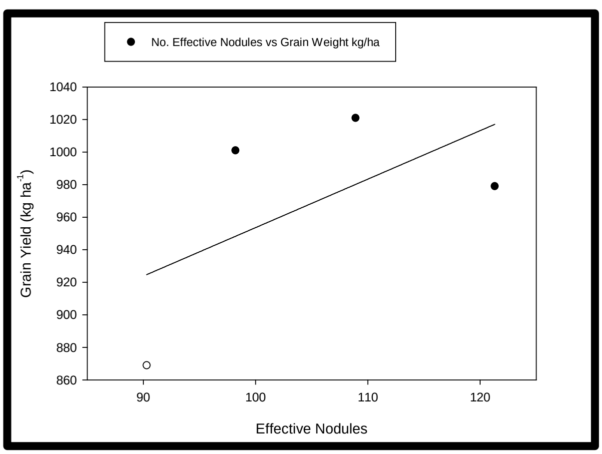

Figure 8 : Correlation between effective nodules and grain yield

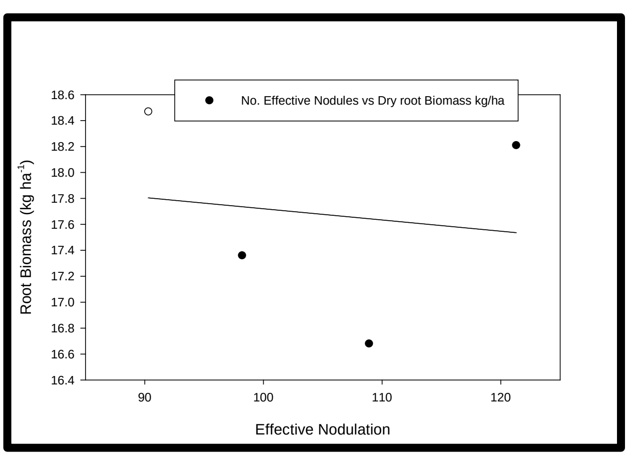

Figure 9 : Correlation between effective nodules and root biomass

IV. Conclusion

Application of 24 kg ha^{-1} P resulted in increased grain yield even thought it was not significantly different (P>0.05) from 48 and 60 kg ha^{-1} P. Similarly, application of 48 kg ha^{-1} P resulted in increased nodulation. Again it was also not significantly different (p>0.05) from 24 and 60 kg ha^{-1}. Days of P application did not affect nodulation, stover and grain yield. However application of P at 30 days before planting increased nodulation and grain yield although it was not significantly different from when P was applied 15 days before planting and also at Planting.

Finally, there was no interaction effect on days of P application and levels of P application on nodulation, stove and grain yield.

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