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Effect of Phosphorus Levels on Growth and Yield of Cowpea (*Vigna unguiculata* (L.) Walp.) in Zaria, Nigeria

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Abstract

Phosphorus is critical to cowpea yield because it stimulates growth, initiate nodules formation as well as influencing the efficiency of rhizobium-Legume symbiosis. In Nigeria, legumes receive little form of mineral phosphorus fertilizer as they accordingly depend on the natural soil available phosphorus for growth and yield which results to low yield. It was due to this problem that field trials were conducted at the Research Field of Horticultural section of Samaru College of Agriculture, Ahmadu Bello University, Zaria, Nigeria during 2015 and 2016 wet seasons to investigate the effect of phosphorus levels on the growth and yield of cowpea (SAMPEA 17). The treatments consisted of five levels of phosphorus (0, 10, 19, 29 and 39 kgPha^{-1}) in the form of single superphosphate laid out in randomized complete block design (RCBD) and replicated four times. The results showed that application of 39 kgPha^{-1} resulted to highest growth in terms of plant height, number of branches per plant, leaf area index and yield. This rate is therefore recommended for enhancing growth and yield of the cowpea.

Keywords: Cowpea, Phosphorus, Growth, Yield

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important grain legumes produced and consumed in Sub-Saharan Africa (SSA). With the current challenges of climate change, the importance of cowpea will increase significantly in the dry savanna regions where both water stress deficit and poor soil fertility are frequently observed. As a legume, cowpea has the ability to fix atmospheric nitrogen (*Ishiyaku et al.*, 2013). Cowpea is an important grain legume in the dry savanna of the tropics covering 12.5 million hectare with annual production of 3 million tons (FAO, 2005). Nigeria is one of the world largest producers of cowpea with average production of 2.92 million tons followed by Niger republic with 1.1 million tons (FAO, 2012). Cowpea can be grown under rain fed conditions as well as irrigation or residual moisture along river lake or flood plains during dry season provided the range of minimum and maximum temperature is between 18^oC and 30^oC (day and night respectively) during the growing season. Depending on the variety, cowpea performs well in agro ecological zones where rainfall ranges between 500 mm to 1200 mm per year (Madamba *et al*., 2006). Best yields are obtained in well drained sandy loam soils with pH range of 5 – 7 (Ecocrop, 2009).

Cowpea is a major staple food crop in sub-sahara Africa, especially in the dry savanna regions of West Africa. The grains are major source of plant proteins and vitamins for man, feed for animals, young leaves and immature pods are eaten as vegetable and also source of cash income (Sheahan, 2012). There are available markets for the sale of cowpea grains and fodder across West Africa. Cowpea does not require too much nitrogen fertilizer because it fixes its own nitrogen from the atmosphere using nodules in its roots. In areas where soils are poor in nitrogen, there is a need to apply a small quantity such as 15 kgNha^{-1} as a starter dose for the crop. If too much nitrogen is used, the plant will grow luxuriantly with very low grain yield. Cowpea requires more phosphorus than nitrogen in the form of single superphosphate or SUPA (FAO, 2005). Tropical soils are inherently low in nutrients especially nitrogen and phosphorus (Haruna 2011). Phosphorus is critical to cowpea yield because it is reported to stimulate growth, initiate nodules formation as well as influence the efficiency of rhizobium-legume symbiosis (Haruna, 2011). In Nigeria under farmers practice, legumes usually receive little mineral phosphorus fertilizer, they therefore rely partly on the natural available soil phosphorus and other nutrients for nitrogen fixation and growth, and this resulted to low yields (Singh *et al*, 2011 and Nkaa *et al*, 2014).

It is base on the above mentioned problems that this study was conducted to determine the optimum level of phosphorus in the form of single super phosphate which will enhance the growth and yield of cowpea. The result of this work is expected improve cowpea production as the most important food and forage legumes in Nigeria.

Materials and Methods / Methodology

The Field experiments were conducted in 2015 and 2016 wet seasons at Two different plots in horticultural section of Samaru college of Agriculture, Ahmadu Bello University, Zaria, Nigeria (Lat. 11^o 11' N : Long 7^o 38' E : 686 m above sea level). The cowpea variety used for the experiment was SAMPEA 17. It is an early maturing variety (70 – 76 days), heat tolerant and photo-insensitive with upright growth habit. Seed size is medium to large with rough seed coat. In addition to being resistant to *Alectra* and *striga* tolerant, the variety has resistance to major diseases and insect pests (Ishiyaku *et al*, 2013). The treatments consisted of five levels of Phosphorus (0, 10, 19, 29 and 39 kgPha^{-1}) in the form of single superphosphate were laid out in Randomized Complete Block Design (RCBD) and replicated four times. Each gross plot consisted of 17.1m^2 measuring 3.8m x 4.5m and net plot measured 6.75m^2 (4.5m x 1.5m) while the sides' ones were used as discard for growth data collection. Two seeds were manually sown per hole at the depth of 3 cm and spacing of 30 cm between stands. Phosphorus application was carried out during land preparation before planting. The application was according to treatments. Two weeding were carried out manually with hand hoe at 2 and 5 weeks after sowing to control weeds. The data collected on growth parameter were: plant height, number of branches per plant and leaf area index while grain yield was determined at harvest. Plant height, number of branches per plant and leaf area index were determined at 3, 6 and 9 WAS. The plant height was measured with a meter ruler from ground level to the top most leaf of the terminal branch, this was determined from the Five randomly selected and tagged plants in each treatment plot. The total value of heights for the Five plants were divided by Five for the average. The number of branches per plant was also determined from the Five tagged plants where the number of branch of each plant was counted after which the total sum of the number of branches for the Five plants were added and divided by Five for the average. For determination of the leaf area, Five plants were selected and up rooted from the discards. The leaf area of each plant was measured using leaf area meter Model L1 – 3100C after which the sum total of the leaf area for the Five plants were added and divided by Five for the average. The leaf area index was then calculated through dividing the leaf area by the total ground area covered by the plant canopy. This was done according to treatment plots. The crop in each net plot were harvested at physiological maturity: when the leaves turned brown in color and the grains produced cracking sound on chew. Harvesting was done by handpicking of the pods. The pods were threshed by beaten with sticks and grains were separated from the chaff. The grains were further dried,

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weighed and expressed in $Kgha^{-1}$. General Linear Model procedure (GLM) of the Statistical Analysis System package (SAS, 1999) was used for the statistical analysis of the data collected. The treatment means were then compared using Duncan Multiple Range Test (Duncan, 1955).

Results and Discussion

Before land preparation in each site, soil samples were randomly taken from various points at the depth of 0 -30cm using soil auger and the samples were analyzed for soil texture, pH, organic carbon, organic matter, Total Nitrogen, Available Phosphorus, Exchangeable Bases such as Potassium, Magnesium, Calcium, Sodium and Cations Exchange Capacity using standard procedure as described by Black (1965) in the Laboratory of Agronomy Department, Ahmadu Bello University, Zaria. The results of physical and chemical properties of the soil sample for the experimental site before planting is shown in Table 1. The soil of the study area was predominantly sandy loam in texture. It was of good drainage and well aerated. The soil was slightly acidic with pH value of 5.60. The available phosphorus was moderately low (3.50 $mgkg^{-1}$) while the exchangeable cat ions were low especially K^+ (0.42 $Cmolkg^{-1}$), Ca^{2+} (5.40 $Cmolkg^{-1}$), Mg^{2+} (0.84 $Cmolkg^{-1}$) and Na was moderate (1.57 $Cmolkg^{-1}$). The soil was therefore low in nutrient status.

Effect of phosphorus levels on plant height

Table 2 showed effect of phosphorus levels on plant height of cowpea variety, SAMPEA 17 at various sampling period in 2015 and 2016 wet season. In 2015, at 3 WAS, application of 29 and 39 $Kgha^{-1}$ of Phosphorus produced significantly ($P<0.05$) taller plants than the control. At 6 WAS application of 39 $kgPha^{-1}$ produced significantly ($P<0.05$) the tallest plants while 0 and 10 $kgPha^{-1}$ produced the shortest plants. At 9 WAS, plant height increased significantly ($P<0.05$) with each increase in phosphorus application from 0 $kgPha^{-1}$ up to 29 $kgPha^{-1}$ beyond which there was no significant increased in plant height. In 2016 at 3 and 9 WAS, application of 39 $kgPha^{-1}$ produced significantly ($P<0.05$) tallest plants compared with all other P level including the control. The control and 10 $kgPha^{-1}$ resulted in the comparable but significantly shorter plants compared with P at 19 and 29 $kgPha^{-1}$ respectively. Increasing P level from 19 to 29 $kgha^{-1}$ significantly increased plant height. At 6 WAS, plant height increased significantly ($P<0.05$) with each increased in phosphorus application from 0 to 39 $kgPha^{-1}$. The plant heights of 2016 were taller than those of 2015 probably due to erratic down pour in the latter year. The role of phosphorus in cell division could be responsible for the increase in the plant height. This finding is in conformity with that of Ayodele and Oso, (2014) who reported that application of 20$kgPha^{-1}$ significantly increased plant height and leaf area index. Sanginga *et al.*, (2013) observed that plant height and number of leaves per plant were significantly enhanced by phosphorus application.

Effect of phosphorus levels on number of branches per plant

Table 3 showed effect of phosphorus levels on number of branches per plant of cowpea variety Sampea 17 at various sampling period in 2015 and 2016 wet seasons. In 2015 at 3 and 9 WAS, application of 39 kgPha^{-1} produced significantly (P<0.05) the highest number of branches per plant while the control produced the least. At 6 WAS, each increase in phosphorus from 0 to 39 kgPha^{-1} resulted in significant increase in number of branches. In 2016 at 3 WAS, application of 39Kgha^{-1} of Phosphorus produced significantly (P<0.05) highest number of branches per plant while the control produced the least. At 6 WAS, number of branches per plant increased significantly (P<0.05) with each increase in phosphorus application from 0 to 39 kgPha^{-1}. At 9 WAS, 29 and 39 kgPha^{-1} produced statistically similar, but significantly (P<0.05) the higher number of branches per plant compared with the other phosphorus levels. The 0 and 10 kgPha^{-1} produced the least number of branches per plant. The positive effect of phosphorus on number of branches per plant could be due to the significant role of the element on cell division and elongation which resulted in the production of more lateral buds that developed into branches. Nkaa *et al*,. (2014) reported that phosphorus fertilizer application to cowpea varieties had positive effect on number of leaves and branches per plant. Ayodele and Oso (2014) also reported that total number of branches per plant increased with phosphorus application up to 40 kgPha^{-1}. Number of reproductive branches per plant (flower bud-bearing) was positively affected by phosphorus application up to 40 kgPha^{-1} (Muhammed *et al.*, 2013). Another contributing factor that probably enhanced number of branches per plant could be the soil texture of the plot which is sandy loam. This textural class facilitated soil moisture holding capacity that reserved adequate water for the crop usage especially in photosynthesis, translocation of assimilate and other physiological processes.

Effect of phosphorus levels on leaf area index

Table 4 showed effect of phosphorus levels on leaf area index at various sampling periods in 2015 and 2016 wet seasons. In 2015 at 3 and 9 WAS, application 29 and 39 kgPha^{-1} produced significantly (P<0.05) higher leaf area index than the control. At 9 WAS, application of 29 and 39 Kgha^{-1} of Phosphorus produced statistically (P<0.05) similar, but significantly (P<0.05) higher leaf area index compared with other Phosphorus levels. Leaf area index influence by 10 and 19 kgPha^{-1} were at par, but significantly higher than that given by the control which produced the least leaf area index At 6 WAS, 39 kgPha^{-1} produced significantly (P<0.05) the highest leaf area index while control produced the least. In 2016 at 3 and 9 WAS, 39 kgPha^{-1} produced significantly (P<0.05) the highest leaf area index while 0 and 10 kgPha^{-1} produced the least. At 6

WAS, 29 and 39 kgPha^{-1} produced significantly ($P<0.05$) the highest leaf area index per plant while 0 and 10 kgPha^{-1} produced the least. Phosphorus is mobile in plants and highly concentrated in places of cell division and development, hence its positive role on enhancing number of branches per plant, leaf area and number of leaves per plant could be responsible for enhancing leaf area index. Ndor *et al*., (2012) and Nkaa *et al*., (2014) reported that growth attributes such as plant height, leaf area index and number of branches per plant were significantly increased with phosphorus application. Subbarao *et al*., (2014) reported that phosphorus application increased number of leaves per plant and leaf area index.

Effect of Phosphorus levels on grain yield

Table 5 showed effect of phosphorus levels on yield of SAMPEA 17 cowpea variety. In 2015, application of 39 kgPha^{-1} produced significantly ($P<0.05$) the highest grain yield while 0 and 10 kgPha^{-1} produced the lowest yield. In 2016, application of 29 and 39 kgPha^{-1} produced significantly ($P<0.05$) the highest yield while 0 and 10 kgPha^{-1} produced the lowest yield. The positive response of grain yield to phosphorus application could be due the significant role of the element on enhancing the photosynthesis apparatus such number of leaves per plant and leaf area. The soil pH (5.6) of the experimental site which was slightly acidic could also be responsible for the higher yield. Haruna and Usman (2013) reported getting higher yield at 30 kgPha^{-1} while Singh *et al*., (2011) recorded the highest yield at 60 kgPha^{-1}. According to Ecocrop (2009), best yield of cowpea was obtained under soil pH of 5 -7 while other agronomic practices were carried out as recommended. Results of the research conducted at Sadore in South of Niamey, Niger republic during 2012 and 2013 wet seasons revealed that application of 60 kgha^{-1} of phosphorus significantly increased cowpea yield by 30.8% (Shagari, 2014).

Conclusion

The results obtained from this trial indicated that application of 39 kgPha^{-1} under rain fed conditions, in well drained sandy loam soil resulted to highest growth and yield of SAMPEA 17 cowpea variety in Zaria, Nigeria. Accordingly, the rate is then recommended for best growth and yield of the cowpea.

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Table 1: Physico-chemical properties of the soil samples for the experimental sites in 2015 and 2016

Soil properties	**Values obtained**	
	2015	**2016**
Physical properties		
Sand (gkg^{-1})	44	51
Silt (gkg^{-1})	34	32
Clay (gkg^{-1})	22	25
Soil textural class	Sandy Loam	Sandy Loam
Chemical properties		
pH in H_2O (1:2:5)	5.6	5.4
Total nitrogen (gkg^{-1})	0.35	0.37
Available phosphorus ($mgkg^{-1}$)	3.50	4.57
Exchangeable bases ($Cmolkg^{-1}$)		
Calcium (Ca^{2+})	5.40	2.50
Magnesium (Mg^{2+})	0.84	1.21
Potassium (K^{+})	0.42	0.50
Sodium (Na^{+})	1.57	1.35
CEC ($Cmolkg^{-1}$)	5.90	5.40

Table 2: Effect of Phosphorus levels on plant height of SAMPEA 17 cowpea variety in 2015 and 2016 wet seasons

Treatment Phosphorus ($KgPha^{-1}$)	Plant height at various sampling periods					
	2015 Plant height(cm)			**2016 Plant height (cm)**		
	3 WAS	6 WAS	9 WAS	3 WAS	6 WAS	9 WAS
0	12.04^{c}	14.02^{d}	16.17^{d}	16.21^{d}	26.00^{de}	31.62^{d}
10	13.11^{c}	14.89^{d}	19.51^{c}	17.08^{d}	28.35^{d}	32.22^{d}
19	16.74^{ab}	18.13^{c}	23.60^{b}	19.30^{c}	30.14^{c}	39.19^{c}
29	18.00^{ab}	21.35^{b}	48.79^{a}	23.74^{b}	34.80^{b}	42.47^{b}
39	22.46^{a}	29.40^{a}	49.16^{a}	26.42^{a}	39.18^{a}	48.11^{a}
SE±	1.47	1.98	2.10	1.20	1.60	1.79

Means in a column of any set of treatment followed by different letter (s) are significantly different at 5% level of probability.
WAS = Week(s) after sowing

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Table 3: Effect of Phosphorus levels on number of branches per plant of SAMPEA 17 cowpea variety in 2015 and 2016 wet seasons

Treatment Phosphorus ($KgPha^{-1}$)	Number of branches per plant at various sampling periods					
	2015			2016		
	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
0	4^{d}	6^{e}	9^{d}	6^{d}	7^{e}	10^{c}
10	7^{c}	10^{d}	11^{c}	10^{c}	10^{d}	11^{c}
19	11^{b}	12^{c}	12^{c}	11^{c}	12^{c}	14^{b}
29	12^{b}	14^{b}	16^{b}	13^{b}	14^{b}	16^{a}
39	14^{a}	17^{a}	18^{a}	15^{a}	16^{a}	17^{a}
SE±	1.04	1.24	1.53	1.26	1.40	1.47

Means in a column of any set of treatment followed by different letter (s) are significantly different at 5% level of probability. WAS = week(s) after sowing

Table 4: Effect of Phosphorus levels on leaf area index of SAMPEA 17 cowpea variety in 2015 and 2016 wet seasons

Treatment Phosphorus ($KgPha^{-1}$)	Leaf area index at various sampling periods					
	2015			2016		
	3WAS	6WAS	9WAS	3WAS	6WAS	9WAS
0	0.107^{b}	1.394^{c}	1.406^{c}	0.102^{c}	1.413^{c}	2.304^{c}
10	0.182^{ab}	1.601^{b}	2.214^{b}	0.148^{c}	1.605^{c}	2.208^{c}
19	0.190^{ab}	1.648^{b}	2.413^{b}	0.320^{b}	2.222^{b}	3.400^{b}
29	0.205**a**	1.661^{b}	3.040^{a}	0.311^{b}	3.403^{a}	3.101^{b}
39	0.207^{a}	2.294^{a}	3.927^{a}	1.304^{a}	3.020^{a}	4.143^{a}
SE±	0.040	0.109	0.117	0.153	0.200	0.240

Means in a column of any set of treatment followed by different letter (s) are significantly Different at 5% level of probability. WAS = week(s) after sowing

Table 5: Effect of Phosphorus levels on yield of SAMPEA 17 cowpea variety in 2015 and 2016 rainy seasons

Treatment Phosphorus ($kgPha^{-1}$)	Grain Yield ($kgha^{-1}$)	
	2015	2016
0	703.62^{c}	803.12^{c}
10	791.14^{c}	812.03^{c}
19	1531.83^{b}	1561.40^{b}
29	1544.60^{b}	1927.08^{a}
39	1830.71^{a}	1994.62^{a}
SE±	16.092	18.740

Means in a column of any set of treatment followed by different letter (s) are significantly different at 5% level of probability. WAS = week(s) after sowing