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Effect of Lime and Phosphorus Fertilizer Rate on Growth and Yield of Cowpea [*Vigna unguiculata* (L.) Walp] in Afikpo, Ebonyi State Nigeria

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Abstract

Soil acidity and poor soil fertility continues to represent huge obstacles to securing the needed harvest in south eastern Nigeria. At the study area, soil acidity is a well-known problem limiting crop productivity. This, study was conducted to determine the effect of lime and phosphorus fertilizers on growth and yield of cowpea and to explore the best treatments that can maximize the productivity of cowpea. Factorial combinations of three lime levels (0, 2.1 and 4.2 t ha-1) and four P. levels (0, 20, 40 and 60 kg ai ha-1) were laid out in a Completely Randomized Design (CRD) with three replications. Data on growth and yield components, were collected and analyzed using Minitab Statistical Software version 2017. Means were compared using Turkey Pairwise at 1 % and 5 % level of probability. The results revealed that, there was a significant ($p<0.01$) effect of lime and P. on all the yield components tested, and also P. by lime interactions were significant ($p<0.01$) on some yield components. The results on growth parameters reveal no significant effect except on days to first flowering where lime and the interactions were highly significant. However, the effects varied with treatment levels and interactions. While the effects increased with rate of application, interactions consistently showed superior effect on all the yield parameters studied. Thus, treatment combination of 60 kg P. ha-1 and 4.2 t ha-1 of lime relatively gave the most appreciable result in terms of yield of cowpea thus are recommended. In conclusion further studies should be conducted on higher phosphorus and lime levels since increasing their various levels tends to increase yields respectively.

Keywords: Lime, Phosphorus fertilizer, Soil Acidity, growth, yield, cowpea.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] is a vital leguminous grain crop, a staple food consumed by almost every home in Nigeria. About 83.4 % of cowpea cultivated land worldwide comes from sub-Saharan Africa while more than 80 % of cowpea production in Africa comes from West Africa including Nigeria being the largest producer of cowpea in Africa (Omoigui *et al*., 2016). Cowpea grain contains about 25 % protein, making it a cheap source of protein in the daily diet of rural and urban populations, it's as well provides cash income for the farmers and traders (Aboki *et al*., 2013; Ahenkora *et al*., 2018). The seeds also contain several minerals, vitamins and dietary fibre (Aboki *et al*., 2013; Ahenkora *et al*., 2018). Its haulms are important as nutritious fodder for livestock in the dry savannas (Omoigui *et al*., 2020).

Despite the importance of cowpea, its productivity in sub-Saharan African farmers' fields is low due to numerous problems including lack of application of the right type and amount of fertilizers and poor soil fertility / acidity management. In Southeastern Nigeria, one of the causes of low productivity could be continues cultivation without proper soil management which causes soil acidity and phosphorus (P) deficiency. Azu *et al*. (2018) did a study to determine phosphorus levels in soils of Ebonyi State to their mineralogical compositions. According to them, most soils of Ebonyi State, Nigeria are formed from shale with high concentration of clay minerals, and these minerals have the tendency of adsorbing phosphate ions, thereby making them unavailable to growing plants.

Deficiency of phosphorous can be corrected by soil liming and application of organic or inorganic P. fertilizer (Chemining'wa *et al*., 2018). Lime contains Ca^{2+} and or Mg^{2+} that displaces Al^{3+} and Fe^{3+} hence P. becomes available for plant use (Kisinyo, *et al*., 2012). Similarly, molybdenum which enhances the activity of the nitrogen as enzyme in nodules becomes available when acid soils are limed (Havlin, *et al*., 2005).

According to earlier research findings, the preceding liming of highly weathered acid soils may have a positive or negative impact on the amount of applied phosphate that is available (Opala, 2017). These outcomes seem to be influenced by the rates of applied lime and P. fertilizer as well as their interactions [Sumner *et al*., 1986]. For instance, high lime rates cause the soil pH to rise to >6, the soluble P. to form a complex with Ca, and this reduces the amount of P. that is available (Bolan *et al*., 2003; Fageria, 1984), while low lime rates are insufficient to get rid of the soluble Al and Fe that fix P. at low pH (Opala, 2017). In order to improve crop growth in acid soils, it is vital to combine P. and lime in the right amounts (Fageria, 1995).

Despite the numerous research work done by other researchers, there has been little recommendation as to the optimum level of lime and phosphorus fertilizer to be combined which will enhance the growth and yield of cowpea especially in Ebonyi State. It is this gap that this research work seeks to address. This study was therefore designed to investigate the interactive effects of lime and phosphate fertilizer on growth and yield of cowpea in an ultisols of southeastern Nigeria.

Materials and Methods

Experimental Site

A pot experiment was carried out in the Screen House of the Department of Horticulture and Landscape Technology, Akanu Ibiam Federal Polytechnic Unwana from April 2023 to July 2023. Geographically, Unwana is on latitude 5°48'N and longitude 7°55'E. The climate and vegetation type are generally humid tropical rainforest with annual rainfall of about 3500 mm and daily temperature range of 21°C - 32°C (Nwagbara, 1994). According to Njoku *et al*. (2006) the temperature is generally high throughout the year with annual relative humidity of between 60 - 80 %. The soils which are derived from shale and sand stone belong to the order 'Ultisol" and have been classified as typical hapludult (FDAL, 1985, Nwaogu, 2009).

Planting Material

Cowpea variety (FUAMPEA 1), which is an early maturing variety 60 - 65 days with upright growth habit, rough seed coat, white color with brown helium, medium size, tolerant to drought and resistance to striga obtained from the Molecular Biology Laboratory, Joseph Sarwuan Tarka University, Makurdi, was used for this study.

Experimental Design and Treatment

The experiment was a 3 x 4 factorial arrangement laid out in a Completely Randomized Design (CRD) with three replications. Treatment factors consisted of three lime rates (0, 2.1 & 4.2 t ha-1) and four P. rates (0, 20, 40 & 60 kg ai ha-1) which resulted in a total of 12 treatment combinations and these gave a total of thirty-six (36) observational units. The P. fertilizer was applied using single superphosphate (20 % ai) while lime was applied as calcium trioxocarbonate (iv), $CaCo_3$. The trial was planted in 40 cm diameter, 23 cm height planting pots with each having 7 kg of soil and the soil was thoroughly mixed with each treatment in each pot. Two weeks after treatments application, three cowpea seeds were sown per pot and later thinned to 2 plants per pot at one week after crop emergence.

Data Collection

Phonological and Growth parameters such as days to first flower, height were taken at 14, 21 and 32 Days after planting (DAP) were considered for data collection. Also yield data such as number of seeds per pod, pod length and grain yield in kg per ha were recorded.

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using Minitab Statistical Software version 2017. Means were compared using Turkey Pairwise at 1 % and 5 % level of probability.

Results

Analysis of Variance showing the Effect of Lime, Phosphorus Fertilizer and their Interactions on the Performance of Cowpea

The analysis of variance result presented in table 1 shows that, there was no significant difference among the phosphorus levels tested for all the growth parameters. However, all the yield parameters measured showed significant difference ($P \leq 0.01$). Lime effect showed significant difference ($P \leq 0.01$) for plant height at 32 days after planting, days to first flower, number of pods per pot, number of seed per pod, pod length, seed weight per pod, seed weight per pot and grain yield per ha. However, there was no significant difference for plant height at 14 and 21 days after planting. Phosphorus × Lime interaction showed highly significant difference for days to first flower, number of seeds per pod, pod length, seed weight per pod and gain yield per ha at 1 % probability level. However, there was no significant difference for plant height at 14, 21 and 32 days after planting, and number of pods per pot and seed weight per pot.

Table 1: Analysis of Variance on effect of lime and phosphorus on the growth and yield of cowpea in Afikpo

SOV	P14DAP	P21DAP	P32DAP	DFF	NS/Pod	Pod length	GY kg/Ha
SSP (P_20_5)	1.38ns	1.61ns	1.60ns	6.80ns	22.74**	30.79**	1256503.00**
Lime	1.03ns	2.53ns	11.38**	178.42**	90.77**	71.25**	6476988.00**
SSP x Lime	1.13ns	1.09ns	2.35ns	12.83**	1.51**	3.58**	331014.00**
SE	0.25	0.24	0.28	0.65	0.46	0.46	124.00
CV	1.34	6.69	7.58	7.89	28.06	18.43	41.00

Key: ** = Highly Significant, * = Significant, ns = Not Significant, P14DAP = plant Height at 14 Days After Planting, P21DAP = plant Height at 21 Days After Planting, P32DAP = plant Height at 32 Days After Planting, DFF = Days to First Flower, NS/Pod =Number of Seeds per Pod, GY kg/Ha = Grain Yield in Kilogram Per Hectare, SOV = Source of Variations, SSP = Single Superphosphate, SE = Standard Error, and CV = Coefficient of Variation

Main effect of Phosphorus ($P_2 0_5$) on growth and yield of Cowpea

The main effects of phosphorus levels on growth and yield of cowpea is presented in table 3. The result shows that 60 kg $P_2 0_5$ha-1 recorded the highest plant height across all measured plant heights at various days which was not significantly different from control. The result for days to first flower showed that, application of 60 kg $P_2 0_5$ha-1 flowered early, followed by control (0 kg $P_2 0_5$ ha-1). however20 kg $P_2 0_5$ ha-1 and 40 kg $P_2 0_5$ ha-1 had the highest number days to first flower with mean values of 48.72, 49.44, 50.00 and 50.77 respectively.

Table 3 again showed that, 60 kg $P_2 0_5$ ha-1 significantly recorded higher number of seeds per pod among the phosphorus levels. This was followed by 40 kg $P_2 0_5$ha-1, 20 kg $P_2 0_5$ha-1 with the control (0 kg $P_2 0_5$ha-1) significantly recording the least number of seeds per pod with mean values of 11.66, 10.44, 9.55 and 7.88 respectively. The outcome of analysis on pod length showed that 60 kg $P_2 0_5$ha-1 significantly recorded the highest pod length over control with mean values of 17.11 and 12.62 respectively. However, 40 kg $P_2 0_5$ha-1 and 20 kg $P_2 0_5$ha-1 recorded a non-significant pod length with mean values of 15.33 and 14.77 respectively. The main effects of phosphorus levels on grain yield per hectare showed that 60 kg $P_2 0_5$ha-1 and 40 kg $P_2 0_5$ha-1 were not significantly different from each other but were however significantly higher than 20 kg $P_2 0_5$ha-1 and control with mean values of 2209.95 kg, 2019.39 kg, 1650.42 kg and1374.56 kg respectively.

Table 2: Main Effect of Phosphorus Levels on Growth and Yield of cowpea in Afikpo

SSP ($P_2 0_5$)	P14DAP	P21DAP	P32DAP	DFF	NS/Pod	Pod length	GY kg/Ha
0 kg/ha	21.12a	22.21a	22.61a	49.44a	7.88d	12.62c	1374.56c
20 kg/ha	20.43a	21.94a	21.85a	50.00a	9.55c	14.77b	1650.42b
40 kg/ha	21.01a	22.00a	21.95a	50.77a	10.44b	15.33b	2019.39a
60 kg/ha	21.35a	22.86a	22.65a	48.72a	11.66a	17.11a	2209.95a

Key: Means that do not share a letter within a column are significantly different, P14DAP = plant Height at 14 Days After Planting, P21DAP = plant Height at 21 Days After Planting, P32DAP = plant Height at 32 Days After Planting, DFF = Days to First Flower NS/Pod =Number of Seeds per Pod, GY kg/Ha = Grain Yield in Kilogram Per Hectare.

Main effect of Lime Levels on Growth and Yield of Cowpea

The results on main effects of lime levels on the growth and yield of cowpea is presented in table 4.The outcome of the analysis shows that, the control (0 t/ha) recorded the highest plant height at 14 days after planting, which was not significantly different from 2.1 t/ha and 4.2 t/ha with mean values of 21.25 cm, 21.02 cm and 20.66 cm, respectively. However, at 21 days after planting the result shows that,2.1 t/ha of lime recorded the highest plant height above other lime levels, but was not significantly different from the control (0 t/ha) and 4.2 t/ha with mean values of 22.52 cm, 22.51 cm and 21.72 cm, respectively. The main effect of lime levels on plant height at 32 days after planting, shows that, control (0 t/ha) recorded the highest height above other lime levels tested, although it was not significantly different from 4.2 t/ha and 2.1 t/ha with mean values of 23.39 cm, 21.77 cm and 21.64 cm, respectively. on the other hand, the result showing the effect of lime levels on days to first flower recorded a significant lower number of days to first flower from the control (0 t/ha) compared to 4.2 t/ha and 2.1 t/ha with mean values of 40.50 days, 50.66 days and 53.04 days, respectively. The outcome of analysis shows that lime levels significantly affected all the yield parameters. according to the result, 4.2 t/ha gave the highest number of seeds per pod, followed by 2.1 t/ha and the least number from the control 0 t/ha with mean values of 12.66, 9.83 and 7.16, respectively. A similar trend was recorded in respect to pod length with mean values of 17.55 cm, 14.60 cm and 12.72 cm, respectively from 4.2 t/ha, 2.1 t/ha and 0 t/ha. In a similar direction, seed yield kg/ha was significantly increased with increase in lime levels ranging from 2502.74, 1897.43 and 1040.58, respectively from 4.2 t/ha, 2.1 t/ha and 0 t/ha.

Table 3: Main Effect of Lime Levels on Growth and Yield of Cowpea in Afikpo

Lime	P14DAP	P21DAP	P32DAP	DFF	NS/Pod	Pod length	GY kg/Ha
0 t/ha	21.25a	22.51a	23.39a	45.50c	7.16c	12.72c	1040.58c
2.1 t/ha	21.02a	22.52a	21.64b	53.04a	9.83b	14.60b	1897.43b
4.2 t/ha	20.66a	21.72a	21.77b	50.66b	12.66a	17.55a	2502.74a

Key: Means that do not share a letter within a column are significantly different, P14DAP = plant Height at 14 Days After Planting, P21DAP = plant Height at 21 Days After Planting, P32DAP = plant Height at 32 Days After Planting, DFF = Days to First Flower, NS/Pod =Number of Seeds per PodGY kg/Ha = Grain Yield in Kilogram Per Hectare.

Interaction Effects of Lime and Phosphorus Fertilizer on Growth and Yield of Cowpea

In general, number of seeds per pod increased with increase in lime levels, irrespective of phosphorus levels. However, the highest number of pods was recorded in 4.2 t/ha lime interacting with 60 kg P_20_5, while the least number of seeds per pod was recorded in 0 t/ha interacting with 0 kg P_20_5 with mean values of 15.33 and 5.33 seeds. The result in figure 1 again showed an increase in pod length (cm) with increase in lime interacting with increase in phosphorus levels. The highest pod length was recorded in 4.2 t/ha lime interacting with 60 kg and the least was recorded from 0 t/ha interacting with 0 kg P_20_5 with mean values of 21.33 cm and 14.00 cm, respectively. Pod length does not show significant interaction effect at 4.2 t/ha x 40 kg P_20_5 and 4.2 t/ha x 20 kg P_20_5 with an average mean values of 17.66 cm and 17.16 cm, respectively. Figure 2 shows the interaction of lime and phosphorus levels as it affected days to first flowering and final grain yield of cowpea. From the result there was no significant difference in respect to days to first flower except at the interaction between 0 kg P_20_5 and 4.2 t/ha lime that recorded above 53 days after sowing as compared to others with mean values ranging from 43 to 46 days after sowing. However, grain yield per hectare recorded an inconsistent result.

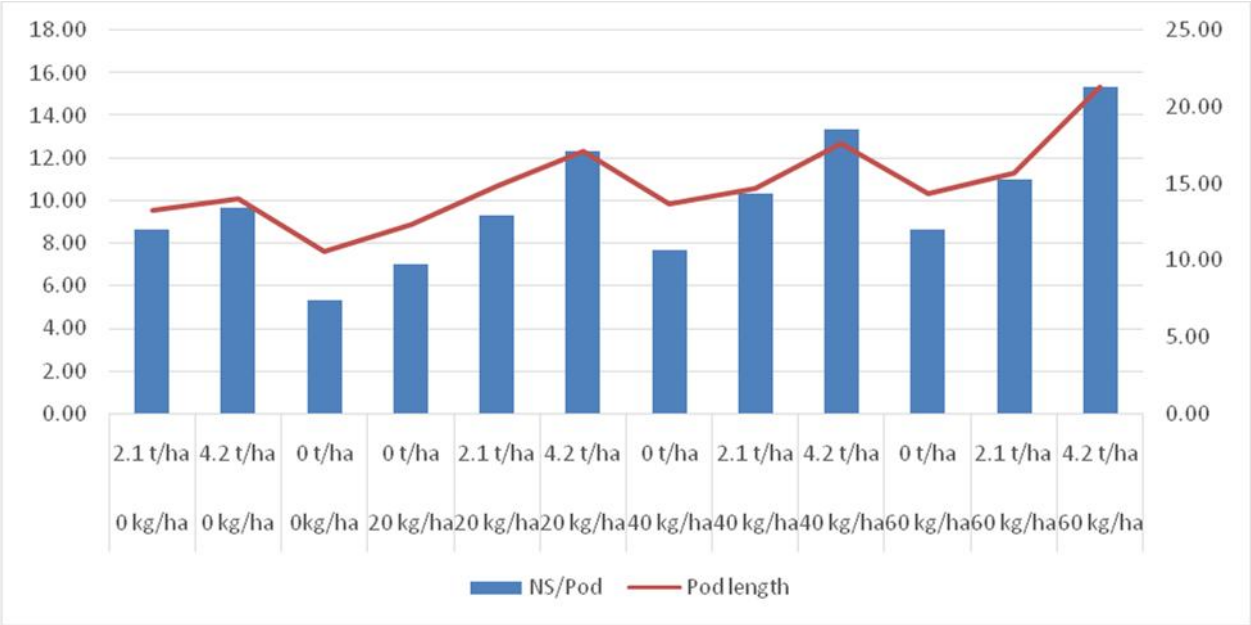

Figure 1. Interaction Effect of Phosphorus and Lime Levels on Number of Seeds per Pod and Pod Length of Cowpea

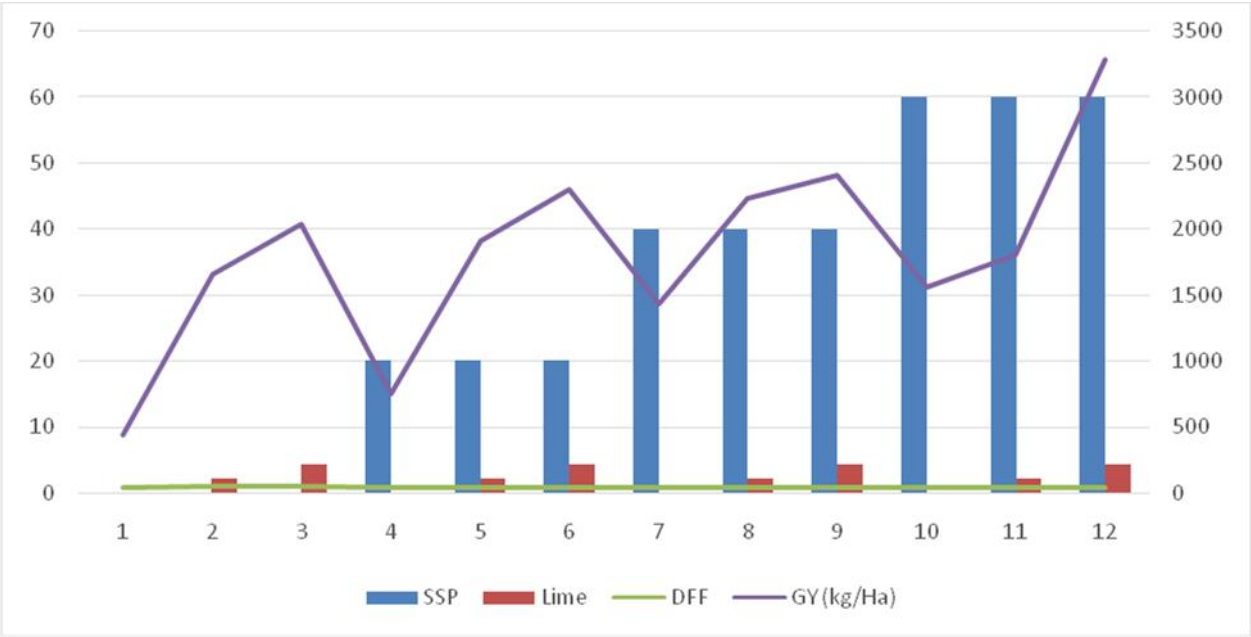

Figure 2. Interaction Effect of Phosphorus and Lime Levels on Days to First Flowering and Gain Yield of Cowpea

According to the result, the highest grain yield (3280.27 kg/ha) was observed in 60 kg P_20_5 interacting with 4.2 t/ha lime. This was followed by 40 kg P_20_5 interacting with 2.1 t/ha lime (2404.38 kg/ha), 20 kg P_20_5 interacting with 4.2 t/ha lime (2292.03 kg/ha), 0.0kg P_20_5 interacting with 4.2 t/ha lime (2034.27 kg/ha) with the least grain yield recording from the control (434.90 kg/ha).

Pearson's Correlation on Growth and Yield of Cowpea in Afikpo

Correlation result shows that there is positive and highly significant relationship between plant height at 14 days after planting and plant height at 21 and 32 days after planting. However, there is negative and non-significant relationship between plant height at 14 days after planting and other parameters. Plant height at 21 days after planting shows a negative and non-significant relationship among all parameters except plant height at 32 days after planting which showed a positive and highly significant correlation. The result on 32 days after planting shows a negative and non-significant relationship for number of seed per pod and pod length however it shows negative and significant relationship for days to first flowering and grain yield per hectare at 0.01 % and 0.05 %, respectively. Days to first flowering shows a positive and significant correlation with grain yield per hectare and number of seeds per pod at 0.01 % and 0.05 %, respectively. However, it shows positive and non-significant relation with pod length. The correlation result in table 4 again shows a positive and highly significant relationship in respect to pod length and gain yield per hectare. A similar trend was also recorded in respect to pod length and grain yield per hectare with positive and highly significant relationship.

Table 4: Pearson's Correlation on Growth and Yield of Cowpea in Afikpo

	P14DAP	P21DAP	P32DAP	DFF	NS/Pod	Pod length	GY kg/Ha
P14DAP	0.00						
P21DAP	0.87**						
P32DAP	0.58**	0.60**					
DFF	-0.03ns	-0.08ns	-0.56**				
NS/Pod	-0.08ns	-0.11ns	-0.27ns	0.42*			
Pod length	-0.07ns	-0.09ns	-0.20ns	0.30ns	0.94**		
G/Ha	-0.04ns	-0.09ns	-0.36*	0.56**	0.92**	0.91**	0.00

Key: ** = Highly Significant, * = Significant, ns = Not Significant, P14DAP = plant Height at 14 Days After Planting, P21DAP = plant Height at 21 Days After Planting, P32DAP = plant Height at 32 Days After Planting, DFF = Days to First Flower, NS/Pod =Number of Seeds per PodGY kg/Ha = Grain Yield in Kilogram Per Hectare

Discussion

Phonological / growth attributes

Number of days to first flower initiation, plant height at 14, 21 and 32 days after planting did not differ significantly following phosphorus fertilizer applications. This could be attributed to slow mobility / diffusion of phosphorus in the soil, making the soil nutrients immobile because of inadequate water in the soil which thus decreased vegetative growth. The result is in conformity with the findings of other researchers (Karikari*et al*., 2015; andMaphoto, 2018) who also discovered non-significant difference on some growth parameters evaluated.Significant effect was observed on days to first flower initiation following lime application and interactions. This could be due to the fact that application of lime increased concentration of soil available P, soil organic carbon and percentage of organic matter which attributed to vigorous growth. The results are in line with the earlier findings of Costa and Rosolem (2007); Legesse et al. (2013) and Anetor and Akinrinde (2006) who indicated that lime application significantly increased legumes grown under acidic soils. However, there was no significant difference across plants heights measured at various days, and this could be due to slow release of nutrients by lime and the interaction. This is similar to the finding of Maphoto, 2018 who found no significant difference on plant heights

Yield Attributes.

Phosphorus application improved all the yield attributes taken into consideration in this study: number of seeds per pod, pod length, and grain yield per ha. The result could have attributed to the fact that, cowpea being a legume uses more of phosphorus than other macro elements especially for yield and yield components. These were found to be significantly different at 0.01 level of significance and this is in conformity with the findings of other researchers (Okeleye and Okelana, 2000; Haruna and Usman, 2013; Odundo *et al*., 2001; Ntare and Bationo, 2002; Nyoki *et al*., 2013; Singh *et al*., 2011 and Ndor *et al*., 2012) who also discovered significant increase in yield of cowpea in response to phosphorus application. However, Agboola and Obigbesan (2001) reported that phosphorus application did not significantly increase cowpea yield but rather enhanced nodulation and phosphorus content of leaf and stem. Highest value in all the yield characters measured was observed at phosphorus fertilizer rate of 60kgha-1 and this is in conformity with the findings of Singh *et al*., (2011) and Shagari, 2014 who recorded highest yield at 60 kgha-1 in their experiment and suggested that may be the optimum as further application of phosphorus may or may not increase yield of cowpea. The significant response of the measured yield characters of cowpea to phosphorus application could be attributed to the role of phosphorus in seed formation and grain filling (Haruna and Usman, 2013).

The significant effect of lime application on number of seed per pod, pod length and grain yield per ha could be due to the fact that application of lime increased concentration of soil available P, soil organic carbon and percentage of organic matter which attributed to vigorous plant growth and increased yield. The results are in line with the earlier findings of Costa and Rosolem (2007); Legesse *et al*. (2013) and Anetor and Akinrinde (2006) who indicated that lime application significantly increased yield attributes of legumes grown under acidic soils. Highest value in all the yield characters measured was observed at lime rate of 4.2 t ha-1 and this is in conformity with the findings of PN Maphoto, (2018) who recorded highest yield at 4 t ha-1 and suggested that high lime rates should be tested in such acidic soils.

A combination of lime and phosphorus fertilizer resulted in higher significant effect on number of seed per pod, pod length and grain yield per ha than that with lime or P used independently. The highest yield parameters of cowpea measured was obtained from plants treated with 4.23t/ha lime + 60 P_20_5 kg/ha, for instance, the highest grain yield (3280.27 kg ha-1) was obtained from the combination 60 kg P_20_5 ha-1 and 4.2 t lime ha-1 against the untreated (0 kg P_20_5/ha and 0t/ha lime) which gave the lowest yield (434.90 kg ha-1). The positive response of cowpea to the applied lime and P might be due to the probability of obtaining the available Phosphorus from decomposed by microorganisms, when the pH value of the soil improved due to liming, which might have resulted in increased yield (Anetor O. & E. Akinrinde, 2006). Liming can reduce availability of micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), or boron (B) and increase the availability of the micronutrient molybdenum (Mo) which are essential for growth of the crop (Sumner ME, Noble AD, 2003). The observed increase in grain yield with increasing Phosphorus rate in treatments with no lime application confirmed that P was limiting factor to cowpea growth in this soil. Calcium is a structural component of cell walls and is therefore vital in the formation of new cells; hence the Ca supply through liming in the present study could have had a favorable effect on cowpea crop yield in the limed plots. Calcium sometimes improves soil structure and soil stability. This could be due to its effect on organic matter decomposition yielding humus and promotes root activity. The results of the present study are in conformity with the work of Mesfin *et al*. (2014b) who reported the highest grain yield (1488.4 kg ha-1) of common bean from the combination of 30 kg P_20_5 ha-1and 0.4 t lime ha-1.

Conclusion and Recommendations

The results obtained from this trial indicated that application of combined 4 t ha−1 of lime with 60 kg P_20_5 ha−1 under rain fed conditions, in well drained clay loam soil resulted to highest growth and yield of the cowpea variety tested in Afikpo, Nigeria. Accordingly, the rate is then recommended for best growth and yield of the cowpea. The lime and Phosphorus rates obtained in this study could serve as a reference to boost cowpea production in the study area and areas with similar agroecology having soil acidity problems. Also, further studies should be conducted with higher levels of lime and phosphorus since increasing their levels increases yields respectively.

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