

RESIDUAL EFFECT OF PHOSPHORUS FERTILIZER APPLICATION RATE AND ITS RESIDUAL EFFECT ON THE YIELD AND YIELD COMPONENTS OF PIGEON PEA (*Cajanus cajan*) IN DEGRADED ULTISOL

*¹Dania, Stephen. O., ²Ozegbe, B., ³Osawe, G. O and ⁴Michael. C.G.
Department of Soil Science, Ambrose Alli University, Ekpoma, Edo State, Nigeria.
⁴Department of Agronomy, Taraba State University, Jalingo, Taraba State.

ABSTRACT

Phosphorus (P) is one of the major essential plant nutrients and it plays an important role in nitrogen fixation of leguminous crops. A two-year experiment was conducted at the Teaching and Research Farm of Ambrose Alli University, Ekpoma, Nigeria to investigate the effect of different rates of phosphorus fertilizer on the growth, yield, nodulation and nutrient uptake of pigeon pea (*Cajanus cajan*). The experimental design was a randomized complete block design with seven treatments and three replicates. The treatments were P rates (0 kg ha⁻¹ (control), 25 kg ha⁻¹, 50 kg ha⁻¹, 75 kg ha⁻¹, 100 kg ha⁻¹, 125 kg ha⁻¹ and 150 kg ha⁻¹) of phosphorus fertilizer were laid out in a Randomized Complete Block Design with three replicates and managed for two consecutive years. Data on plant growth, yield, nutrient uptake and soil properties were collected every season for four seasons and analysed using ANOVA at p = 0.05. The result of the pre-planting soil analysis showed that the soil nutrient content was below critical levels. The application of phosphorus and cultivation of pigeon pea significantly increased the soil nutrient content after the first cropping season. In both experiments, there was no significant difference in height and stem girth of pigeon pea. The application of 75 kg ha⁻¹ significantly (p=0.05) increased the number of leaves, biomass and nodules of pigeon pea. The application of 25 - 75 kg ha⁻¹ of phosphorus fertilizer increased the grain yield of pigeon pea than other rates of application in the first cropping season. In the residual experiment, the control and 25 kg ha⁻¹ application of P had the grain yield of 1,493.3 kg ha⁻¹ and 1,498.0 kg ha⁻¹ respectively, and were significantly (p=0.05) higher compared to other treatments. Therefore, the application of phosphorus fertilizer at the rate of 25 - 75 kg ha⁻¹ significantly improved the yield, nodulation and nutrient uptake of pigeon pea in degraded ultisol.

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Keywords: pigeon pea, nutrient uptake, nodulation, yield, phosphorus fertilizer.

1. INTRODUCTION

Pigeon pea (*Cajanus cajan*) is a leguminous food grain shrub rich in protein and contain good quality carbohydrate, crude fibre and lipids. It is also a source of dietary minerals and vitamins (Thiamine, Riboflavin and Niacin). The intercrop of Pigeon pea as a cover crop with maize, increases maize yield [1]. In addition to its food uses, pigeon pea has outstanding soil amelioration and conservation properties. The growth habit facilitates soil protection as it form canopy which help to control erosion.

Pigeon pea produces more nitrogen from plant biomass per unit area of land than many other legumes and it also fixes atmospheric nitrogen [2]. Pigeon pea when used as green manure provides the benefit of improving longer term soil quality and fertility. Pigeon pea is drought resistant due to its deep rooting system and osmotic adjustment in the leaves; it also helps to mitigate the impacts of climate change [3, 4].

The application of macro and micronutrients in optimum quantity and right proportion is essential in crop production. The application of organic and inorganic fertilizer contributes significantly to the growth and yield of *C.ajanus cajan*. Phosphorus is an essential macronutrient in plants as it is part of Adenosine Triphosphate (ATP), DNA, RNA and plays a major role in energy storage and transfer. Due to its importance in biological activities in plants, phosphorus plays an important role in the growth and yield of pigeon pea [5].

Application of 26.4 kg P ha⁻¹ significantly improved seed yield, nodulation and nitrogenase activity in pea [6]. Also, it was reported that the application of 17- 43 kg P ha⁻¹ significantly improved the growth and yield of *C.ajanus cajan* in nutrient depleted soil [7, 8]. Phosphorus deficiency is a problem in highly weathered ultisols and this condition adversely affects crop production. Ekpoma soils are classified as ultisol and are generally low in available phosphorus and it was necessary to apply some quantity of phosphorus fertilizer to improve the yield and nodulation of pigeon pea. It was therefore important to investigate the rate of phosphorus fertilizer application that will best suit pigeon pea production in this area.

2 Materials and methods

~~Two years field experiment was carried out at the Teaching and Research Farm, Ambrose Alli University, Ekpoma, Nigeria in 2010 and the residual experiment was conducted in 2011. Ekpoma lies between Latitude 6° 45' 34" North and longitude 6° 8' 27" East with average annual rainfall of about 1500 mm. A two-year field experiment was carried out at the Teaching and Research Farm, Ambrose Alli University, Ekpoma, Nigeria in 2010 and the residual experiment was conducted in 2011. Top soils (0-15 cm) were collected from the site prior to each planting season, the soils were air dried, sieved and the samples were analysed for both chemical and physical properties.~~

~~Particle size analysis was carried out using hydrometer method [9]. The pH was determined in water (ratio 1:1, soil: water). Soil pH in KCl (1:1), 20g of soil and 20ml of water was used and equilibrated for 30 minutes with occasional stirring. pH was determined and measured in KCl [10]. Organic carbon was determined by wet dichromate method [11] and Available phosphorus by Bray extraction method [12]. Total nitrogen was determined by Kjeldahl method [13].~~

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Exchangeable cations (potassium, calcium and magnesium) were extracted with ammonium acetate. Potassium was determined by flame photometer while calcium and magnesium by atomic absorption spectrophotometer [10]. Micronutrients such as copper, zinc, iron and manganese were also determined using the method described [14].

The experimental design was a randomized complete block design with seven treatments and three replicates. The treatments include 0 kg ha⁻¹ (control), 25 kg ha⁻¹, 50 kg ha⁻¹, 75 kg ha⁻¹, 100 kg ha⁻¹, 125 kg ha⁻¹ and 150 kg ha⁻¹ of Phosphorus fertilizer. The fertilizer was applied at four weeks of planting at the above rate using ring method of application. The plot measured 4.0 m x 3.0 m and the field was manually cultivated. A long duration varieties of pigeon pea used was IAR&T50. The planting distance was 1m x1 m, the seed were sown at the rate of 3 - 4 seeds per stand and later thinned to one plant per stand at three weeks of planting. The field was weeded twice manually and no irrigation water was applied because it was rain fed.

The height, stem girth and number of leaves were measured at 2, 6, 10 weeks after fertilizer application. The dry matter weight of shoot and grain yield in both cropping season were determined. While while nodules count, weight and index were evaluated for the first cropping season only. Top soils (0-15 cm) were collected from the site prior to each planting season, the soils were air dried, sieved and the samples were analysed for both chemical and physical properties. Particle size analysis was carried out using hydrometer method [9]. The pH was determined in water (ratio1:1, soil: water). Soil pH in KCl (1:1), 20 g of soil and 20 ml of water was used and equilibrated for 30 minutes with occasional stirring. pH was determined and measured in KCl [10]. Organic carbon was determined by wet dichromate method [11] and available phosphorus by Bray-1 extraction method [12]. Total nitrogen was determined by Kjeldahl method [13]. Exchangeable cations (potassium, calcium and magnesium) were extracted with ammonium acetate. Potassium was determined by flame photometer while calcium and magnesium by atomic absorption spectrophotometer [10]. Micronutrients such as copper, zinc, iron and manganese were also determined using the method described [14].

Data analysis

The nutrient uptake; nitrogen, phosphorus and potassium in pigeon pea were also calculated by multiplying nutrient concentration in the plant tissue by the dry matter weight, that is:

Nutrient uptake = concentration x dry matter yield.

Nodules index = (Dry weight of nodules / Dry weight of shoot) x 100 [15].

Data collected were analysed using Anova and Duncan's multiple range test was used to separate means.

RESULTS

3.1.1 Soil Analysis

The pre-planting soil analysed analysis showed that the soil was deficient in organic matter and other essential nutrient mostly nitrogen, phosphorus, potassium, magnesium. The soil was slightly acidic

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with sandy loam texture (Table 1). The soil of the same plots after harvesting pigeon pea in 2010 was used for the residual experiment and soil analysis was also carried out. It was observed after the first experiment, that there was increase in the soil nutrient content compared to the result obtained from the pre planting soil analysis (Table 1 & 4). In Table 4, the organic carbon at the end of the experiment was higher in the control (21.5 g kg⁻¹) and lower at the application rate of 50 kg ha⁻¹ and 125 kg ha⁻¹ of P. The phosphorus content ranges from 10.0 mg g⁻¹ in 100kg ha⁻¹ to 12.5 mg g⁻¹ in the control. The application of fertilizer at 50 kg ha⁻¹ increased calcium, magnesium and potassium content of the soil. Also the application of 125 kg ha⁻¹ application of fertilizer to pigeon pea increased the ECEC of the soil. The iron content ranges from 39.42 mg g⁻¹ in 150 kg ha⁻¹ to 77.63 mg g⁻¹ at the application of 25 kg ha⁻¹ of phosphorus. Copper and zinc were higher in 50 kg ha⁻¹ and 150 kg ha⁻¹ of phosphorus application (Table 4).

Comment [R5]: For all the means, indicated the standard errors (or confidence intervals).

3.1.2 Growth parameters of pigeon pea.

There was no significant difference in the height of pigeon pea with or without the application of fertilizer. Fertilizer application rate of 75 kg ha⁻¹ significantly (p=.05) increased the stem girth of *Cajanus C. cajan* at ten weeks after planting compared to other rates of application. It was also observed that the application of 75 kg ha⁻¹ of phosphorus significantly (p=.05) increased the number of leaves of pigeon pea compared to other treatments throughout the growth season (Table 3). During the residual experiment, there is no significant difference in pigeon pea's height and stem girth. The number of leaves of pigeon pea was increased at twelve and sixteen weeks after planting with the application of 25 kg ha⁻¹ of fertilizer compared to other treatments (Table 5).

3.1.3 Nodulation and yield of pigeon pea

The application of 75 kg ha⁻¹ of phosphorus fertilizer increased nodules count and weight by 52.9 % and 54.7 %, respectively than the control and the values were significantly (p=.05) higher compared to other rate of application (Table 3). Also the nodules index and above ground biomass of *Cajanus C. cajan* were significantly (p =.05) higher in 75 kg ha⁻¹ fertilizer application compared to other treatments. The application of 25 – 75 kg ha⁻¹ of phosphorus fertilizer significantly (p=.05) increased the grain yield of pigeon pea compared to other treatments. It was also observed that the application

143 of 25 kg ha⁻¹ of fertilizer had the highest pigeon pea grain yield and it was 53.8 % higher than the
144 control.

145 3.1.4 Nutrient uptake (tonnes ha⁻¹)

146 The nitrogen uptake of *pigeon-peaC. cajan* was significantly ($p=0.05$) lower ($p=0.05$) at the rate of 125
147 kg ha⁻¹ and 150 kg ha⁻¹ application of *phosphorus-P* fertilizer (Table 6). Phosphorus uptake in *pigeon*
148 *peaC. cajan* at 50 kg ha⁻¹ application of the fertilizer was 10.9 tonnes per hectare and this was
149 significantly ($p=0.05$) higher compared to other treatments. The control (0 kg ha⁻¹) had the highest
150 uptake of potassium of 40.5 tonnes per hectare than other treatments (Table 6).

151 3.1.5 Dry matter and grain Yield (tonnes ha⁻¹)

152 The dry matter weight of pigeon pea was higher at the application of 50 kg ha⁻¹ of phosphorus fertilizer
153 with the value of 3.2 tonnes ha⁻¹ while the least dry matter weight was recorded in 150 kg ha⁻¹ of
154 fertilizer with the value 2.13 tonnes ha⁻¹ (Table 6). The grain yields of pigeon pea were significantly
155 ($p=0.05$) higher at the application rate of 25 - 75 kg ha⁻¹ of fertilizer compared to other rate of
156 application but not difference from the control (Table 6).

158 DISCUSSION

159 The cultivation of pigeon pea increased the soil organic matter due to its litter fall which
160 decomposed into organic matter and this confirmed the earlier work done [16]. Also the cultivation of
161 *pigeon-peaC. cajan* and the addition of small quantity of phosphorus fertilizer increased the essential
162 nutrient elements (nitrogen, phosphorus, potassium, magnesium) above the critical values. It has
163 been reported that the cultivation of pigeon pea increased the organic matter and other nutrient in the
164 soil [17]. The soil cultivated with *pigeon-peaC. cajan* had higher phosphorus content which indicated
165 that *pigeon pea* can utilized and mined phosphorus due of its deep rooting system and this confirmed
166 the earlier work done [18, 19]

167 The growth of pigeon pea was significantly influenced by the application of small quantity of
168 phosphorus fertilizer however, heavy application of phosphorus above 75 kg ha⁻¹ does not improved
169 the growth and yield of pigeon pea. Oversupply of P caused decrease in plant growth, nodulation and
170 nutrient uptake in *Cajanus C. cajan* [20]. The nutrient (nitrogen, phosphorus and potassium) uptake in
171 pigeon pea was significantly ($p=0.05$) higher above the critical value due to the application of small
172 quantity of phosphorus fertilizer. There was significant interaction between phosphorus fertilizer and
173 pigeon pea which enhanced nutrient uptake. Phosphorus improve nodules formation in pigeon pea
174 thereby increased nitrogen fixation and uptake [21, 22].

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175 The application of 50 kg ha⁻¹ of phosphorus fertilizer significantly (p=.05) increased the
176 phosphorus uptake of *Cajanus cajan*. This showed that pigeon pea requires small amount of fertilizer
177 to enhance its P uptake [23]. The application of P at the rate of 25 kg ha⁻¹ – 75 kg ha⁻¹ significantly
178 (p=.05) improved the growth, yield, nodulation and nutrient uptake of pigeon pea and these has been
179 reported that legumes such as pigeon pea response to small quantity of P depending on P status of
180 the soil [2, 24]. The residual effect of P did not significantly influence the growth and yield of pigeon
181 pea. It is therefore evidence that P has little or no residual effects on the growth and yield of pigeon
182 pea.

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184 CONCLUSION

185 The application rate of 25 – 75 kg ha⁻¹ of P fertilizer significantly improved the growth and yield of *C.*
186 *cajan*. It was also observed the application of 25 – 75 kg ha⁻¹ rate of phosphorus fertilizer increased
187 the nodulation and nutrient uptake of pigeon pea. The application of 25 – 75 kg ha⁻¹ of P fertilizer and
188 the cultivation of pigeon pea significantly improve the nutrient status of the soil. From the experiment,
189 P fertilizer had little or no residual effect on growth and yield of *C. cajan*. Application of P fertilizer
190 above 75 kg ha⁻¹ reduced the yield of pigeon pea. Therefore the application of 25 – 75 kg ha⁻¹ of
191 phosphorus fertilizer is recommended.

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Comment [R7]: If you had used regression, it would have been possible to determine the optimum amount of P for the preferred soil and plant parameters.

194 ACKNOWLEDGEMENT

201 AUTHORS' CONTRIBUTIONS

203 Dania Stephen – Design, supervise the experiment & write up.

204 Ozegbe Blessing – student; execute and carried out the experiment.

205 Osawe Grace – Student; execute and carried out the experiment.

206 Michael, G. C – read through and correct the manuscript

Table 1: Pre planting physico-chemical properties of the soil used for the investigation.

Parameters	Results	methods
pH (1:1) H ₂ O	5.4	Glass electrode pH meter [10]
pH (1:1) KCl	4.7	Glass electrode pH meter [10]
N (g/kg)	0.36	Modified kjeldahl method [13]
OC (g/kg)	14.9	Wet dichromate method [11]
P (mg/g)	8.04	Bray 1 method [12]
Exchangeable bases (cmol/kg)		
Ca	0.57	Atomic absorption spectrophotometer [10]
Mg	0.36	
K	0.08	Flame photometer [10]
Na	0.10	
Acidity (H and Al)	0.60	
ECEC	1.71	
Mn	69.34	DTPA soil test method [14]
Fe	41.82	
Cu	7.83	
Zn	2.63	
Particle Size Analysis	g / kg	Hydrometer method [9]
Sand	876	
Silt	104	
Clay	20	
Textural Class	Sandy Loam	

Comment [R8]: This table should be merged with table 4 as a column for pre-planting soil properties.

It is also good to indicated the standard errors whenever you report means. See tables below

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Table 2: Effect of different levels of phosphorus fertilizer on pigeon pea height, stem girth and number of leaves

Comment [R9]: Always ensure you report some measure of precision (std dev, std error, confidence interval) whenever you report a mean value.

Treatment s	Weeks after phosphorus fertilizer application								
	← Height (cm) →			← Stem girth (cm ²) →			← Number of leaves →		
	2	6	10	2	6	10	2	6	10
0	47.100 a	84.47 a	144.20 a	3.03 a	3.87 a	4.30 b	76.33b	262.7 c	1265.3 b
25	42.667 a	86.87 a	148.14 a	2.97 a	3.80 a	4.48 b	69.00b	295.7 c	987.7c
50	45.900 a	98.67 a	161.67 a	2.97 a	4.00 a	4.82 b	74.67b	355.0 b	1438.0 b
75	52.100 a	97.80 a	161.33 a	3.13 a	4.50 a	5.86 a	112.33 a	562.0 a	1883.3 a
100	45.900 a	80.13 a	135.97 a	2.83 a	3.70 a	4.98 b	70.00b	274.3 c	892.3c
125	44.900 a	92.47 a	156.43 a	2.93 a	3.93 a	4.18 b	81.67b	393.7 b	1398.7 b
150	46.233 a	86.67 a	151.57 a	2.83 a	3.87 a	4.65 b	73.00b	375.7 b	1137.7 b
	NS	NS	NS	NS	NS				

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Mean values followed by the same letter under the same vertical column are not significantly ($p < 0.05$) different according to Duncan's multiple range test.

228 Table 3: Effect of different levels of phosphorus fertilizer on nodules count, dry weight, index, dry
 229 matter weight of shoots, leaves and grain yield.

Treatments	Number of Nodules ha ⁻¹	Weight of Nodules (kg ha ⁻¹)	Nodules Index	Dry matter wt. of shoots (kg ha ⁻¹)	Dry matter wt. of leaves (kg ha ⁻¹)	Grain Yield (kg ha ⁻¹)
0	576.70c	8.00c	0.24c	3101.00a	1003.00b	495.00c
25	666.70c	9.000c	0.27c	3333.00a	1333.00b	1071.00a
50	620.00c	8.00c	0.22c	3667.00a	1500.00b	969.70a
75	1223.30b	17.67a	0.44a	3833.00a	2000.00a	990.30a
100	673.30c	11.00b	0.35b	3167.00b	1500.00b	711.70b
125	1206.70a	13.33b	0.38b	3500.00a	1500.00b	884.30b
150	876.70c	10.33b	0.28c	3667.00a	1833.00a	857.30b

230 Mean values followed by the same letter on the same vertical column are not significantly ($p \leq 0.05$)
 231 different according to Duncan's multiple range test..

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Table 4: Physico-chemical properties of soil used for the residual experiment.

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Table 5: Residual effect of different rates of phosphorus fertilizer on pigeon pea height, stem girth and number of leaves.

Weeks after phosphorus fertilizer application												
Treatments	← Height (cm) →				← Stem girth (cm ²) →				← Number of leaves →			
	8	12	16	20	8	12	16	20	8	12	16	20
0	83.57	172.47	245.33	386.67	3.08	8.97	25.18	30.92	71.67	349.00	1202.30a	1534.00a
25	93.60	171.50	269.83	370.00	4.84	9.67	22.15	27.15	91.67	390.30	1200.70a	1495.30a
50	90.83	189.43	295.00	382.69	3.40	10.25	22.15	27.25	94.67	256.30	834.30b	1145.30b
75	88.27	183.33	280.07	391.50	4.22	10.56	26.33	31.84	84.00	360.30	1362.70a	1592.70a
100	86.23	164.00	231.03	318.00	4.80	9.25	19.00	24.39	90.33	167.00	879.40b	1212.00b
125	80.90	156.17	230.00	314.00	2.87	7.85	17.18	25.11	76.67	206.70	709.00b	1198.70b
150	68.69	136.43	209.50	306.67	2.27	7.20	16.31	22.12	69.33	177.00	432.00c	1144.00b
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

Mean values followed by the same letter under the same vertical column are not significantly different according to Duncan's multiple range test (p=.05).

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241 Table 6: Residual effect of different rates of phosphorus fertilizer on nutrient uptake, dry matter and
242 grain yield of pigeon pea (tonnes/ha)

Treatments	Application rate of phosphorus fertilizer						
	0	25	50	75	100	125	150
N	113.00a	95.77a	113.60a	117.8a	94.67a	39.7b	19.50b
P	8.37b	4.90b	10.93a	6.50c	5.23d	4.40d	3.17e
K	40.47a	32.5b	26.87c	25.50bc	21.83d	29.40bc	24.27d
Dry matter yield	3.11a	3.13a	3.20a	3.11a	26.6b	3.03a	2.13b
Grain yield	1.49a	1.50a	1.23a	1.10a	0.78b	0.55b	0.33b

243 Mean values followed by the same letter on the same row are not significantly different according to
244 Duncan's multiple range test. ($p \leq 0.05$)

248 CONCLUSION

249
250 The application rate of 25 — 75 kg ha⁻¹ of phosphorus fertilizer significantly improved the growth and
251 yield of pigeon pea. It was also observed the application of 25 — 75 kg ha⁻¹ rate of phosphorus
252 fertilizer increased the nodulation and nutrient uptake of pigeon pea. The application of 25 — 75 kg ha⁻¹
253 of P fertilizer and the cultivation of pigeon pea significantly improve the nutrient status of the soil.
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263 AUTHORS' CONTRIBUTIONS

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266 Ozegbe Blessing — student; execute and carried out the experiment.

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268 Michael, G. C — read through and correct the manuscript

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