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Cowpea (*Vigna unguiculata* L. Walp) response to phosphorus fertilizer under two tillage and mulch treatments

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ABSTRACT

The response of cowpea to four rates of phosphorus (P) fertilizer (0, 15, 30 and 45 kg P ha^{-1}) on an *Ultisol* in south-eastern Nigeria was evaluated under two tillage and two mulch treatments. Tilled plots produced plants with significantly larger leaf area indices (2.82–4.05) than the untilled plots (2.11–3.22), while significant differences in dry matter accumulation occurred when plots were mulched, tilled plot values ranged from 3.83 to 5.53 t/ha while the untilled plots were between 2.77 and 3.97 t/ha. Plants in mulched plots were 39–80% and 20–62% higher in grain yield and dry matter accumulation, respectively, compared to the un-mulched plots. Yield response to phosphorus levels on each tillage–mulch combination was significant for linear and parabolic responses. Maximum yields occurred at 34, 37, 35, and 33 kg P ha^{-1} on the tilled–mulched (TM), tilled–un-mulched (TU), untilled–mulched (UM) and untilled–un-mulched (UU) plots, respectively. Dry matter response to P level was of a quadratic polynomial form and indicated apparent maximum accumulation (at flowering) at 30 kg ha^{-1} rate under the tillage mulch treatments. Apparent maximum accumulation of dry matter was however at 45 kg ha^{-1} P rate for the TM treatment. Phosphorus use efficiency (grain yield per P applied) decreased in the order TM (72.4) > UM (66.6) > TU (48.9) > UU (36.4), where the figures in parenthesis represent phosphorus use efficiency (kg kg^{-1}). The rate of change in available P in mulched plots increased faster compared to the un-mulched plots, with the rate in UM plots being significantly faster than in the other plots at the ninth week. Tissue P did not vary in plants following the tillage–mulch treatment. The results also indicated that the tilled treatments (TM and TU) gave 12.3–34.9% comparatively higher gross margin (profit) when compared to their untilled equivalents (UM and UU), however when the profits were considered against the investment costs, the untilled treatments (UM and UU) gave higher returns per unit investment (189.0–588,800).

1. Introduction

The fast growing population of the world, especially in Africa, has put much pressure on food supply. The available agricultural land has to be cultivated continuously to meet with the food demands, with the deterioration of soil quality as an attendant consequence. The situation is exacerbated by the further loss of agricultural land to infrastructural development. Therefore, to maintain the quality and hence sustain the productivity of the diminishing agricultural land mass, the need for soil conservation becomes pertinent. Research has demonstrated the potential of conservation tillage, especially of no-tillage, for improved soil and water conservation (Lal, 1982; Andraski et al., 1985; Mbagwu, 1990; Aina et al., 1991). For the production of cereal and leguminous crops, several studies have shown that, if weeds can be controlled with herbicides, conventional tillage is unnecessary and is an avoidable component of production cost, since it does not increase yields of crops over those obtained from untilled plots, especially when the problem of soil compaction is alleviated (Soil Conservation Society of America, 1977; USDA, 1999). Some results from the tropics also indicate that zero tillage with mulch and herbicide applications preserved (or even improved) soil productivity and increased maize yields in comparison with the conventional tillage (Baryeh, 1983; Dalal, 1992; Franzluebbers et al., 1994; Alvarez, 2005). In the light of this, zero tillage has been advocated for use on fragile tropical soils.

Lal (1982) observed that nutrient dynamics under a given tillage and cropping management practice differ from one ecological zone to another and between diverse crops. Under low supply of nitrogen, Kang et al. (1982) found that maize yield was higher on conventionally tilled than zero tilled plots. In western Nigeria, seed germination was suppressed where zero tillage was used (Mohamed-Saleam and Fawusi, 1983). On soils

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with penetration resistance >0.5 Mpa, zero tillage produced lower maize and cowpea yields (Anjuwon, 1983). With these varying results, the relevance of this work on the *Ultisol* of south-eastern Nigeria becomes impelling. Therefore, this study is aimed at comparing the effects of four tillage–mulch systems on cowpea yield and phosphorus use efficiency (evaluated by yield response to different phosphorus levels) on an *Ultisol* in south-eastern Nigeria.

2. Materials and methods

This study was conducted in 2009 and 2010 farming seasons on the University of Nigeria, Nsukka Teaching and Research Farm, located by latitude 06°52′N and longitude 07°24′E and at an elevation of 400 m above sea level. Mean annual temperature of this location ranges between 26 and 31 °C. The average annual precipitation is about 1700 mm but the area experiences distinct wet (April–October) and dry (November–March) seasons. Rainfall during the wet season is bi-modally distributed, with peaks in July and September and a short dry spell around mid-August.

The soil is a reddish brown sandy loam *Ultisol* (Oxic Paleustult) belonging to the Nkpologu series and formed from false bedded sandstone parent materials (Nwadialo, 1989). Akamigbo and Igwe (1990) described the soil of the area as highly weathered, coarse to medium textured, granular in structure, acid in reaction and low in N, P and K. Some characteristics of its surface soil are described in Table 1. The site was under natural vegetation fallow, predominantly *Pennisetum purpurem, Mimosa pudica* and *Cynodon dactylon* for about 10 years.

Weed control was done by the application of a post emergence herbicide [2-chloro-2,6-diethyl-N (butoxymethyl) acetanilide]. A factorial combination of two tillage systems, two mulch rates and four phosphorus levels, with three replications was arranged in a split plot format using a randomized complete block design (RCBD). The main plot treatments were tilled–mulched (TM), tilled–un-mulched (TU), untilled–mulched (UM) and untilled–un-mulched (UU); whereas the sub-plot treatments were four rates of phosphorous (0, 15, 30 and 45 kg ha^{-1}). Sub-plots measured 1.0 m × 2.5 m. Tilling was done by traditional hoeing method to about 20 cm depth, while in the no-till treatment, no further soil preparation after residue clearing was done. The mulch material was a mixture of dry grasses (*Penisetum purpurem* and *M. pudica*) applied at two rates (0 and 4 Mg ha^{-1}) in June of each year.

Cowpea (*Vigna unguiculata* L. Walp var. 355) was single cropped in both 2009 and 2010 in the same plots. The planting season lasted from late June to early October. All phosphorus fertilizer doses were applied at planting. Each plot also received a blanket application of 60 kg N ha^{-1} as urea (45% N) and 60 kg K ha^{-1} as muriate of potash (60% K_2O). Sowing was done manually at the rate of two seeds per hole to a depth of 2.5 cm; a spacing of 25 cm within row and 50 cm between rows were done in two rows. The plants were thinned to one plant per stand, one week after germination. Leaf area index, dry matter accumulation and tissue P were determined at flowering while grain yield (90% dry matter) was measured at maturity. Change in available P was monitored at three weeks intervals for nine weeks which is the flowering period for the plant. Tables 2 and 3 show rainfall, temperature and humidity data recorded during the two planting seasons of this experiment.

Table 1
Some characteristics of the surface soil before the experiment.

Year	Parameter	Value
2009	Sand %	68
	Silt %	15
	Clay %	17
	Textural class	Sandy-loam
	pH (1:2.5 H_2O)	4.6
	pH (0.01 MKcl)	3.8
	Organic carbon (%)	1.29
	Total N (%)	0.056
	Exchangeable bases (cmol kg^{-1})	
	Na	0.69
	K	0.02
	Ca	1.12
	Mg	3.16
	Exchangeable acidity (cmol kg^{-1})	
	Al^{+3}	1.20
	H^{+}	2.40
	ECEC (cmol kg^{-1})	8.59
	Available P (mg kg^{-1})	20.60
	Available P (mg kg^{-1})	
	Tilled–unmulched plots	20.00
2010	Untilled–unmulched plots	20.00
	Untilled–mulched plots	22.50
	Tilled–unmulched plots	25.00

3. Results

3.1. Dry matter accumulation

Table 4 shows that mulched treatments accumulated higher dry matter compared to the un-mulched by as much as 62%. Dry matter accumulation among the tillage–mulch treatments followed the order: TM > UM > TU = UU, showing that plants in the un-mulched plots did not vary in dry matter content. Plants in tilled plots tended to show better dry matter accumulation over those grown in untilled plots, especially in the mulched plots where the difference was significant ($p < 0.05$). The UU, TU and UM treatments apparently showed maximum accumulation of dry matter at 30 kg ha^{-1} P but TM treatment showed further increment in dry matter content beyond this P rate.

There was significant interaction ($P < 0.01$) between the tillage–mulch and phosphorus treatments, with the combination of TM and 45 kg P ha^{-1} producing plants with the highest dry matter content. This however, did not vary significantly ($p < 0.05$)

Table 2
Meteorological data during the experimental period (2009/2010 cropping season).

	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March
Total rainfall (mm)	36.32	4.06	103.12	51.05	243.83	213.86	259.60	195.58	190.50	313.94	1.52	0.00	0.00	9.91	121.66
Mean rainfall (mm)	36.32	2.03	25.78	10.21	15.24	13.37	12.36	10.29	7.62	16.52	1.52	0.00	0.00	9.91	15.21
Rain days	1	2	4	5	16	16	21	19	25	19	1	0	0	1	8
Max air temp (°C)	33.16	33.61	33.10	35.53	30.55	29.90	28.65	27.84	28.17	29.94	31.77	32.65	33.29	35.02	35.13
Min air temp (°C)	23.06	23.25	22.84	23.33	21.35	21.20	21.58	20.81	21.33	21.29	18.97	17.90	20.87	22.67	23.19
Relative humidity (%)															
At 10 am	75.27	76.00	73.65	74.83	77.90	77.67	79.68	80.00	79.07	76.94	65.47	57.23	54.55	71.93	69.45
At 4 pm	57.87	59.61	61.65	61.70	71.06	72.23	74.10	74.94	74.47	72.84	56.03	44.77	44.94	50.93	55.68