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Determination of Soil Nutrient Levels for Maximum Yield of Okra (*Abelmoschus esculentum*) Using Sole and Amended Plant Residues

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ABSTRACT

The determination of critical or optimum level of nutrients for a particular crop (i.e. soil calibration) is very important. An investigation was carried out in Akure rainforest zone of Southwest Nigeria to determine the critical soil nutrient levels for pH, organic matter (OM), N, P, K, Ca and Mg for okra crop using sole plant residues, wood ash, cocoa husk, spent grain, rice bran and saw dust amended with pig, goat and poultry manure. Twenty organic fertilizer treatments were compared to control (no treatment) and a reference treatment 400kg/ha NPK 15-15-15 fertilizer in four experiments. Application of sole and amended plant residues at 2,4,6,8 and 10 t ha-^{1} to soil increased soil N, P, K, Ca, Mg, Na, pH and OM, growth and pod weight of okra relative to the control. The wood ash, spent grain and cocoa husk were the most effective in improving soil nutrient contents for okra crop. The NPK fertilizer decreased soil OM, pH, Ca and Mg. The pod weight increased up till 6 t/ha under the different plant residues with R^2 value of 0.907 and decreased at 8 and 10 t ha^{-1}. Spent grain + poultry manure treatment gave the best performance in increasing all soil properties as well as yield and leaf area. For instance spent grain + poultry manure treatment had the highest okra yield (4555.5 kg ha-^{1}) with critical or optimum nutrient combination 5.2% N, 51.03 mg kg^{-1} P, 0.78 mmol kg^{-1} soil K, 0.43 mmol kg^{-1} soil Ca, 0.0 mmol kg^{-1} soil Mg, 2.96 mmol kg^{-1} soil Na, 3.2% soil OM and 6.9 for soil pH respectively.

Keywords: Soil calibration, level of nutrients, *Abelmoschus esculentum*

INTRODUCTION

The efficacy of soil testing as a means for predicting the nutrient needs of crops to be grown has been established. Olson *et al.* (1982) reported that three major concepts were used by various organizations in U.S.A. and Britain doing soil testing programmes and they are, sufficiency level arising from soil calibration studies (soil critical level), maintenance concept and cation ratio concept.

However, soil calibration test refers to the determination of a relationship between laboratory soil test values and yield responses to fertilizer application and indicates at which soil test values responses are expected. Different scientists have worked on the determination of critical P levels in Southwest Nigeria. Agboola and Corey (1973) worked on the determination of critical P level (10 mg kg^{-1}P) for maize using Bray P_1 method, while Okeya (1977) obtained levels of 17 and 12 ug ml^{-1} for Bray P_1 and Olsen modified methods from green house calibration studies. Adeoye (1980) established critical range of 10-16 ppm for P, 2.0-2.6 meq/100g for Ca, 0.35 meq/100g for K, 3.0 mg kg^{-1} Zn and 12.0 mg kg^{-1} for Cu for maize on sedimentary soils of Southwest Nigeria.

The determination of critical or optimum levels is very useful and it is defined as the soil test value about which response is not expected and below which a large yield response can be obtained with adequate supply of a particular nutrient.

Folorunso *et al.* (1995) reported that using fractional recovery modified $NaHCO_3$ multi-purpose extractant, a critical level of 0.20 mmol kg^{-1} K was established for south west Nigeria using muriate of potash fertilizer. It is interesting to note that the determination of soil critical or

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nutrient levels for crop responses has been based on inorganic fertilizer elements from Single Superphosphate, Urea and $ZnSO_4$ for N, P, K and Zn nutrients respectively.

Therefore, the high cost of fertilizer purchases, scarcity of fertilizer to farmers and the degradation of soils on continuous use of inorganic fertilizers had necessitated the need to use cheap available organic residues by farmers; hence, this has created the need to establish critical levels for soil nutrients and crop responses for different organic residues. However, research information on the soil critical levels for N, P, K, Ca and Mg for okra crop using different plant residues is lacking.

Waugh *et al.* (1973) reported the use of multiple regression equations as a tool for establishing meaningful soil nutrient availability, while Monsoon and Nelson (1973) also reported that multiple regression analysis could be used to relate crop yields and soil test values.

The objective of this paper is to report soil critical levels for pH, OM, N, P, K, Ca, Mg Na for okra crop (*Abelmoschus esculentum* L) using various sole plant residues or amended with manures on Alfisols soil in Southwest Nigeria.

MATERIALS AND METHODS

Four field experiments were conducted for okra between 1998 and 1999 respectively on the same site in Akure (7° N 5 10 E) in the rainforest zone of South west Nigeria. The site had been continuously cropped for ten years.

The soil is sandy loam texture and belongs to Akure series, (Iwo Association) and is classified as an Alfisol (Oxic tropudalf), (Harpstead, 1972). The underlying geology is basement complex (Durotoye, 1972).

The surface (0-15cm, depth) soil had a pH_{water} of 5.1, organic matter 0.53%, N 0.2%, 4.6 mg kg^{-1} extractable P, 0.08 mmol kg^{-1} exchangeable K, 0.11mmol kg^{-1} exchangeable Ca and 1.12 mmol kg^{-1} exchangeable Mg (Folorunso, 1999).

There were twenty plant residue treatments namely wood ash (sole), wood ash + goat dung, wood ash + pig dung, wood ash + poultry manure, cocoa husk (sole), cocoa husk + goat dung, cocoa husk + pig manure, cocoa husk + poultry manure, rice bran (sole), rice bran + goat dung, rice bran + pig dung, rice bran + poultry manure, spent grain (sole), spent grain + goat dung, spent grain + pig dung, spent grain + poultry manure, saw dust (sole) sawdust + goat dung, sawdust + pig dung, sawdust + poultry manure, plus 400 kg ha^{-1} NPK 15-15-15 fertilizer as reference treatment and control (no treatment) applied to the soil. The rates of plant residues (wood ash, spent grain, sawdust, rice bran and cocoa husk) applied were at 2,4,6,8 and 10 t ha^{-1} as sole. Each rate of plant residues was amended with goat, pig and poultry manures at the rate of 1,2,3,4 and 5 t ha^{-1} (1.1 ratio plant residue: manure).

All treatments were replicated three times at the same site and arranged in a randomized complete block design. The size of each plot was 4 m x 4 m (16 m^2). The fertilizer and manure were incorporated into soil ten days before planting. Before planting, the residues and animal manures were processed to speed up decomposition in the soil and analysed for their chemical composition.

Two seeds of okra (NHAe 47-4 variety) were planted per stand at spacing of 60 x 30cm, germination took place five days after planting, and thinning to one plant per stand was done. The plots were hand weeded thrice starting from second, fifth and seventh weeks after planting. The insect pests were controlled by spraying Vetox 85 at a rate of 28g a.i in 9 L of water at second week after planting and this was repeated at the third and fourth weeks after planting.

The total plant population per 16 m^2 plot was eighty-eight (88) and 26 plants were randomly selected and tagged. At 2, 4 and 6 weeks after planting, measures of plant height (cm), leaf area (cm^2) and stem girth (cm) were carried out. Harvest of mature pods stated 40 days after planting. The fresh pod weight (yield) was recorded per treatment plot and the harvest continued at four days interval till senescence period. The total harvest of the fresh pod weight per 16m^2 plot was recorded in kg ha^{-1} for the different treatments.

At the end of each field experiment, composite soil samples were collected to 15cm depth in each plot. The soil samples were air dried and passed through 2mm sieve for chemical analysis.

The soils were extracted by a multi-purpose extractant modified $NaHCo_3$ pH 8.5 for P, K, Ca and Mg. The P in solution was determine using Murphy and Riley (1962) blue the exchangeable bases (K, Ca and Na), and Mg in solution were determined using flame photometer and atomic absorption spectrometer respectively (Jackson, 1964).

The okra pod weights data recorded for the three replicates were averaged for the 2, 4, 6, 8 and 10 t ha^{-1} of sole and amended plant residues. The same procedure was applied for plant height, leaf area and stem girth. The data were subjected to ANOVA F-test and their means were separated and compared using Duncan Multiple Range Test (DMRT) at 5% level. The soil critical level determination was done using multiple regression and linear correlation between the okra pod and soil test values of N, K, Ca, Mg, soil pH and OM under different rates of plant residues added (2, 4, 6,8 and 10 t ha^{-1}).

RESULTS AND DISCUSSION

The plant residues (sole and amended) and NPK fertilizer increased okra pod weight (Table 1), leaf area (Table 2), plant height (Table 3), stem girth (Table 4), soil N (Table 5), soil P (Table 6), soil K (Table 7) and soil Ca (Table 8) significantly ($P<0.05$) relative to control.

The amendment of cocoa husk, rice bran, spent grain, wood ash and saw dust with goat, pig and poultry manures increased soil Mg (Table 9), soil Na (Table 10) and soil pH (Table 11) compared to NPK fertilizer. However, NPK fertilizer resulted in better plant height, leaf area and stem girth than wood ash, saw dust, rice bran and cocoa husk amended with goat, pig and poultry manure except for the amended spent grain + poultry manure which resulted in the best values of okra pod weight followed by wood ash, cocoa husk, rice bran and saw dust amended with poultry manures respectively.

Okra pod weight increased with number or rate of application till 6 t ha^{-1} residue and decreased slightly at 8 and 10 t ha^{-1} residues. The plant residues had cumulative effect on soil OM, N, P, K, Ca and Mg which increased with manure addition from 2 to 10 t ha^{-1}. The mean pod weight of okra for soil treated with sole and amended plant residences at 2, 4, 6, 8 and 10 t ha^{-1} were 1597, 1950.55, 2493.58, 2308.31 and 2199.8 kg ha^{-1} respectively. The equivalent values for soil OM were 2.86, 3.0, 3.12, 3.16 and 3.21

TABLE 1
The effect of different levels of plant residues plus manure on the fresh pod yield (kg ha^{-1}) of Okra

Treatments	2	4	6	8	10 t ha^{-1}
Woodash	594.56d	901.25d	1450.75d	1300.75d	1262.75d
Woodash + Goat dung	1801.44 l	2101.75m	2500.80m	2325.50n	2275.00o
Woodash + Pig dung	1944.69m	2170.25o	2831.25o	2516.75p	2490.75p
Woodash + Poultry manure	2195.63r	2281.00q	3301.25q	2532.00r	2751.75r
Cocoa husk	666.56h	932.00f	1450.50d	1403.75e	1395.50f
Cocoa husk + Goat dung	1747.06j	2123.00n	2781.50n	2282.00m	2267.00n
Coca husk+ Pig dung	2004.44p	2185.75p	3202.00p	2829.75q	3152.25q
Cocoa husk + Poultry manure	2223.88s	2448.50r	3775.25s	3300.00t	3152.25s
Rice bran	644.56f	781.00b	1050.75b	1025.75b	1002.33b
Rice bran + Goat dung	1960.63k	1978.00 l	2110.75h	2026.51j	2000.75
Rice bran + Pig dung	1972.81n	1995.25k	2150.50 l	2126.00k	2026.0k
Rice bran + Poultry manure	1563.69o	1981.50j	21.87.75j	2196.25 l	2070.25m
Spent grain	1923.75i	2450.25s	2475.25 l	2400.75o	2050.75 l
Spent grain + Goat dung	2481.38t	3001.75t	3502.00r	3275.00s	3201.25t
Spent grain + Pig dung	2532.69u	3750.75u	4253.00t	4051.75u	3575.25u
Spent grain + Poultry manure	3007.19v	4251.00v	4551.50u	4313.25v	4038.25v
Saw dust	624.38b	853.75c	1206.50c	1131.00o	1078.25c
Saw dust + Goat dung	613.44c	906.75e	1472.75e	1427.00 l	1325.25e
Saw dust + Pig dung	704.25e	939.50g	1676.25f	1625.75g	1552.00g
Saw dust + Poultry manure	731.75g	978.00h	1950.25g	1777.25h	1750.75h
Control (no fertilizer)	47.00a	47.00a	46.75a	46.75a	46.75a
NPK 15-15-15	2013.00q	2062.75 l	2420.25k	1962.75 l	1920.00 l

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 2
The effect of plant residues plus manure on leaf area (cm^2) of Okra

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	60.45e	67.44c	91.66de	122.76gh	130.5 i
Woodash + Goat dung	79.33ij	70.84cd	102.22f	137.33 l	140.1h
Woodash + Pig dung	80.07j	84.34g	117.08j	137.04 l	140.9h
Woodash + Poultry manure	101.25m	90.46h	144.20m	139.76j	141.5h
Cocoa husk (sole)	61.99ef	83.50fg	101.70f	120.34g	123.3g
Cocoa husk + Goat dung	76.19i	102.74i	129.26k	137.89 l	140.5h
Coca husk+ Pig dung	94.96 l	128.17k	144.67m	149.89k	150.3j
Cocoa husk + Poultry manure	120.73o	178.38m	186.14o	161.23m	176.1k
Rice bran (sole)	54.58cd	73.45c	86.24cd	92.79c	94.1c
Rice bran + Goat dung	64.44fgh	80.30f	104.37fg	110.23e	117.2f
Rice bran + Pig dung	75.61 l	83.97fg	106.20gh	115.16f	119.16f
Rice bran + Poultry manure	87.62k	87.59gh	110.85hi	119.12fg	122.12g
Spent grain (sole)	115.46n	121.39j	130.11kl	147.77 l	151.77j
Spent grain + Goat dung	125.45pq	165.97 l	172.38n	180.75n	185.75 l
Spent grain + Pig dung	127.35qr	178.50m	193.89p	179.52no	184.52m
Spent grain + Poultry manure	131.90rs	185.55n	198.01qr	189.68o	192.10n
Saw dust (sole)	27.27b	37.95b	49.36b	73.04b	75.9b
Saw dust + Goat dung	53.39c	75.35de	82.67c	93.12c	97.12d
Saw dust + Pig dung	59.78e	82.28fg	87.75d	99.42d	19.42e
Saw dust + Poultry manure	63.22fg	88.71gh	92.29e	110.73e	126.37h
Control (no fertilizer)	8.27a	9.71a	9.78a	9.53a	9.32a
NPK 15-15-15	121.96op	167.20 l	196.48pq	146.99 l	158.16r

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 3
The effect of different levels of plant residues plus manure on the plant height (cm) of Okra

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	23.09f	34.73hij	36.16gh	39.90ij	40.5hi
Woodash + Goat dung	30.25n	40.04n	43.09 l	47.60 l	48.2 l
Woodash + Pig dung	32.02o	41.13o	45.24lm	48.09lm	49.5m
Woodash + Poultry manure	35.29r	43.01p	48.08no	49.14mn	51.14n
Cocoa husk (sole)	20.56d	29.45e	30.48d	32.48d	34.2d
Cocoa husk + Goat dung	27.73j	32.10g	35.32fg	36.12fg	38.1f
Cocoa husk+ Pig dung	28.68m	34.05h	37.80i	38.52hi	36.8e
Cocoa husk + Poultry manure	32.56op	38.81m	39.22jk	40.65jk	39.8g
Rice bran (sole)	16.14b	22.45b	24.38b	25.41b	27.1b
Rice bran + Goat dung	22.82e	30.24f	35.16fg	37.10g	39.1g
Rice bran + Pig dung	24.99hi	34.49hi	37.28hi	38.42hi	42.4j
Rice bran + Poultry manure	26.64k	37.01kl	38.77ij	38.99l	45.2k
Spent grain (sole)	27.53l	36.08k	38.68ij	41.62j	43.6j
Spent grain + Goat dung	32.88pq	43.33pq	46.05mn	49.10mn	52.1o
Spent grain + Pig dung	35.84rs	45.81r	48.23no	51.03o	56.0p
Spent grain + Poultry manure	38.32t	47.01s	52.56p	54.58p	60.6q
Saw dust (sole)	18.78c	24.97c	26.37c	27.90c	29.9c
Saw dust + Goat dung	22.90e	27.32d	30.75de	34.75e	36.9e
Saw dust + Pig dung	23.57fg	28.36de	34.84f	35.20ef	38.2f
Saw dust + Poultry manure	24.77h	37.26kl	37.60l	37.92gh	40.6hi
Control (no fertilizer)	11.22a	9.11a	9.21a	9.20a	9.69a
NPK 15-15-15	43.83u	65.75t	67.33q	66.67q	70.1r

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 4
The effect of different levels of plant residues plus manure on the stem girth (cm) of Okra

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	1.63e	2.61e	5.32i	4.26f	4.5e
Woodash + Goat dung	2.20h	3.51i	6.35n	5.08hi	5.2gh
Woodash + Pig dung	2.40i	3.73j	5.47jk	4.47g	4.6ef
Woodash + Poultry manure	3.13m	3.85k	6.48o	6.48no	6.6m
Cocoa husk (sole)	1.37c	2.19c	4.55f	4.06d	4.2d
Cocoa husk + Goat dung	2.23h	3.44h	5.13h	5.19I	5.3 l
Cocoa husk+ Pig dung	2.67j	4.18 l	5.44j	5.44j	5.6k
Cocoa husk + Poultry manure	3.28n	5.20o	6.30n	6.30n	6.6m
Rice bran (sole)	1.34c	2.12bc	3.28c	3.42c	3.6c
Rice bran + Goat dung	1.53cd	2.43d	4.06d	4.16e	4.4e
Rice bran + Pig dung	1.76ef	2.83f	4.31e	4.31f	4.6ef
Rice bran + Poultry manure	2.17k	3.51	5.04gh	5.04h	5.4ij
Spent grain (sole)	1.67e	2.64ek	4.28de	4.28f	4.7ef
Spent grain + Goat dung	2.84kl	4.56m	6.14 l	6.14 l	6.3 l
Spent grain + Pig dung	3.11m	5.04n	6.24m	6.24m	6.7m
Spent grain + Poultry manure	3.44o	5.51p	6.54p	6.54o	6.8m
Saw dust (sole)	1.14b	2.06b	2.90b	2.90b	3.2b
Saw dust + Goat dung	1.58d	2.56de	4.28e	4.28f	4.6ef
Saw dust + Pig dung	1.80f	2.82f	4.92g	4.92h	5.0g
Saw dust + Poultry manure	1.96g	3.06g	5.08gh	5.07hi	5.1g
Control (no fertilizer)	0.51a	0.51a	0.52a	0.52a	0.52a
NPK 15-15-15	2.78k	4.53m	5.51k	5.57k	5.6k

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 5
The effect of different levels of plant residues plus manure on the soil Nitrogen (%) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	0.136c	0.157bc	0.242c	0.367e	0.420g
Woodash + Goat dung	0.236e	0.252ef	0.315e	0.420g	0.446hi
Woodash + Pig dung	0.252ef	0.275f	0.378gh	0.430h	0.489j
Woodash + Poultry manure	0.315gh	0.331h	0.436i	0.483k	0.520k
Cocoa husk (sole)	0.131c	0.168c	0.26cd	0.3I5d	0.331cd
Cocoa husk + Goat dung	0.247ef	0.273f	0.373gh	0.420g	0.430h
Cocoa husk+ Pig dung	0.273f	0.315f	0.394h	0.446hi	0.451i
Cocoa husk + Poultry manure	0.331h	0.367j	0.451j	0470ij	0.509jk
Rice bran (sole)	0.121b	0.163c	0.210bc	0.260c	0.315c
Rice bran + Goat dung	0.189cd	0.220d	0.325ef	0.367ef	0.393e
Rice bran + Pig dung	0.193d	0.242e	0.341f	0.393f	0.399e
Rice bran + Poultry manure	0.294g	0.304fg	0.357g	0.399fg	0.409f
Spent grain (sole)	0.273f	0.273f	0.289d	0.315d	0.341d
Spent grain + Goat dung	0.304gh	0.336h	0.378gh	0.425gh	0.446hi
Spent grain + Pig dung	0.325h	0.357i	0.390h	0.451i	0.483i
Spent grain + Poultry manure	0.378 l	0.430j	0.450j	0.483k	0.499j
Saw dust (sole)	0.199d	0.147b	0.189b	0.215b	0.268b
Saw dust + Goat dung	0.199d	0.220d	0.267c	0.320d	0.341d
Saw dust + Pig dung	0.215de	0.252ef	0.289d	0.341de	0.357d
Saw dust + Poultry manure	0.273f	0.325h	0.346f	0.373ef	0.394e
Control (no fertilizer)	0.017a	0.017a	0.017a	0.017a	0.017a
NPK 15-15-15	0.26ef	0.282f	0.420k	0.478j	0.499j

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 6
The effect of different levels of plant residues plus manure on soil available P (mg kg^{-1}) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	29.25c	28.13b	38.25cd	47.25g	50.07ef
Woodash + Goat dung	38.25i	41.07i	47.82 l	52.50h	43.88cd
Woodash + Pig dung	46.13k	51.75m	61.32k	63.00j	66.38gh
Woodash + Poultry manure	63.00o	72.00p	79.32o	83.25m	85.50i
Cocoa husk (sole)	35.45h	38.82h	41.63g	47.75g	44.45de
Cocoa husk + Goat dung	47.25 l	50.63 l	60.20k	61.32j	61.88g
Cocoa husk+ Pig dung	50.09m	56.82n	65.25m	66.38k	69.75h
Cocoa husk + Poultry manure	57.38n	69.20o	77.82n	80.45 l	87.75i
Rice bran (sole)	28.13b	30.08d	35.45c	36.57bc	38.25bc
Rice bran + Goat dung	29.82c	32.63f	38.25d	41.63de	44.45de
Rice bran + Pig dung	31.63e	34.32g	40.50f	43.88f	47.25ef
Rice bran + Poultry manure	34.34g	37.70h	43.88h	47.82g	51.20f
Spent grain (sole)	32.63f	32.34e	40.50f	43.88f	47.25ef
Spent grain + Goat dung	34.34g	38.25h	51.20j	57.38i	63.57g
Spent grain + Pig dung	38.05i	44.45j	64.13i	66.38k	70.88h
Spent grain + Poultry manure	39.95j	46.13k	86.63p	88.88n	93.95j
Saw dust (sole)	28.13b	29.25c	34.32b	35.45b	36.57b
Saw dust + Goat dung	29.82c	3.95de	35.45c	38.25c	40.50bcd
Saw dust + Pig dung	30.38d	30.38d	38.82d	41.07de	43.88cde
Saw dust + Poultry manure	32.53f	34.32g	39.95e	40.32d	45.57def
Control (no fertilizer)	2.10a	2.13a	2.12a	2.18a	2.16a
NPK 15-15-15	130.0p	141.50	146.50q	151.50o	101.82k

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 7
The effect of different levels of plant residues plus manure on the soil K (mmol kg^{-1}) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	1.064m	0.80n	1.001m	0.920 l	0.928jk
Woodash + Goat dung	0.80k	0.88o	1.120m	1.04m	1.08k
Woodash + Pig dung	0.960 l	1.040q	1.200n	1.16n	1.160 l
Woodash + Poultry manure	1.120n	1.160r	0.84k	1.20n	1.24m
Cocoa husk (sole)	0.72j	0.761m	1.00m	0.88kl	0.92j
Cocoa husk + Goat dung	0.88kl	0.96p	0.975 l	1.04m	1.08k
Cocoa husk+ Pig dung	1.040m	1.120r	1.240p	0.64 l	1.320n
Cocoa husk + Poultry manure	1.120n	1.240s	1.320q	1.32q	1.320n
Rice bran (sole)	0.192c	0.24dc	0.28d	0.32d	0.32c
Rice bran + Goat dung	0.288ef	0.32f	0.360ef	0.72f	0.38e
Rice bran + Pig dung	0.332f	0.34g	0.368ef	0.38fg	0.384ef
Rice bran + Poultry manure	0.34g	0.372h	0.40f	0.44g	0.48f
Spent grain (sole)	0.360h	0.52i	0.50g	0.56h	0.64g
Spent grain + Goat dung	0.360h	0.60j	0.64h	0.72j	0.76h
Spent grain + Pig dung	0.64 l	0.64k	0.72i	0.80k	0.82i
Spent grain + Poultry manure	0.72j	0.74 l	0.760j	0.84k	0.82i
Saw dust (sole)	0.120b	0.132b	0.140b	0.168b	0.20b
Saw dust + Goat dung	0.20cd	0.22c	0.248c	0.28c	0.32c
Saw dust + Pig dung	0.24d	0.28d	0.30e	0.32d	0.36d
Saw dust + Poultry manure	0.260e	0.30e	0.32df	0.34e	0.38e
Control (no fertilizer)	0.013a	0.013a	0.013a	0.012a	0.012a
NPK 15-15-15	1.132a	1.146t	1.320n	1.21o	1.24m

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 8
The effect of different levels of plant residues plus manure on the soil Ca (mmol kg^{-1}) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	0.246g	0.30g	0.45j	0.54h	0.54h
Woodash + Goat dung	0.30j	0.45j	0.54k	0.69j	0.75j
Woodash + Pig dung	0.39jk	0.54kl	0.60 l	0.75k	0.790 l
Woodash + Poultry manure	0.45k	0.60 l	0.69m	0.78 l	0.780k
Cocoa husk (sole)	0.45k	0.54k	0.60 l	0.63 I	0.75j
Cocoa husk + Goat dung	0.57 l	0.75m	0.78mn	0.81j	0.84m
Cocoa husk+ Pig dung	0.60 l	0.84n	0.84n	0.87k	0.87mn
Cocoa husk + Poultry manure	0.69m	0.87o	0.90o	0.98m	0.90o
Rice bran (sole)	0.075c	0.09c	0.120c	0.150c	0.150b
Rice bran + Goat dung	0.09d	0.150d	0.195d	0.210d	0.213d
Rice bran + Pig dung	0.150e	0.195ef	0.210e	0.24e	0.243e
Rice bran + Poultry manure	0.150e	0.21f	0.225f	0.255f	0.258f
Spent grain (sole)	0.180f	0.180de	0.195d	0.210d	0.216d
Spent grain + Goat dung	0.270h	0.30g	0.36h	0.45g	0.456g
Spent grain + Pig dung	0.285i	0.39h	0.42i	0.54h	0.56h
Spent grain + Poultry manure	0.30j	0.410i	0.54k	0.63 l	0.69 l
Saw dust (sole)	0.06b	0.09c	0.150d	0.156c	0.168bc
Saw dust + Goat dung	0.15e	0.18de	0.210e	0.216d	0.225e
Saw dust + Pig dung	0.15e	0.190e	0.225fd	0.24e	0.24ef
Saw dust + Poultry manure	0.180f	0.210h	0.240g	0.25f	0.267f
Control (no fertilizer)	0.01a	0.010a	0.010a	0.01a	0.01a
NPK 15-15-15	0.020a	0.024b	0.028b	0.020ab	0.20ab

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

(Table 15). The values of soil N were 0.24, 0.27, 0.32, 0.38 and 0.41. Soil P values were 37.83, 41.46, 51.03, 54.11 and 56.55 mg kg^{-1} . Exchangeable K values were 0.58, 0.63, 0.68, 0.70 and 0.75 mmo1 kg-1 respectively.

These results implied that okra pod weight responded positively to soil fertility and there were positive and significant ($P<0.05$) relationships between okra pod weight and N, P, K, Ca, Mg, Na and OM (Table 12).

Table 13 presents multiple regression analysis showing the relationship between okra pod weight and soil K, Ca, Mg, Na, N, P and OM. The regression coefficients of determination (R^2) values were significant ($P<0.05$) and high for the okra pod yield and soil properties for different application rates of plant residues.

For instance, R^2 values at 2, 4, 6, 8 and 10 t ha^{-1} plant residue were 0.828, 0.83, 0.907, 0.804 and 0.80 respectively. This implied that soil nutrient Na, K, Ca, Mg, OM., N, P, and pH accounted for 82.8, 83, 90.7, 80.4 and 80% yield variation in okra for different plant residues respectively.

Spent grain + poultry manure generally produced the best performance in increasing all soil properties as well as yield and leaf area. For-instance, to obtain highest okra yield (4555.5 kg ha^{-1}) for spent grain + poultry manure using the regression equation (Table 13), the following gave the best nutrient combination: 5.2% N, 51.03 mg/kg P, 0.78 mmol kg-1 soil K, 0.43 mmol kg^{-1} soil Ca, 0.0 soil Mg, 2.96 mmol kg^{-1} soil Na, 3.2% soil OM and 6.9 for soil pH respectively.

The increases in growth, pod weight of okra and soil nutrients content due to application of sole and manure amended plant residues is consistent with the initial soil organic matter content which was much lower than the critical values of 2% (Agboola and Corey, 1973) recommended for soils in Southwest Nigeria. The soil was quite acidic for good performance of okra (Aduayi, 1980). The application of wood ash, saw dust, spent grain, rice bran and cocoa husk increased soil K, Ca, Mg, Ca, OM, N, P, and pH which is consistent with the fact that the organic materials are sources of all plant nutrients

TABLE 9
The effect of different levels of plant residues plus manure on the soil Mg (mmol kg^{-1}) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	0.28c	0.30bc	0.325c	0.362c	0.40c
Woodash + Goat dung	0.55a	0.58d	0.62de	0.63e	0.662ef
Woodash + Pig dung	0.615f	0.66e	0.70ef	0.718f	0.718f
Woodash + Poultry manure	0.675fg	0.70ef	0.775f	0.812gh	0.812g
Cocoa husk (sole)	0.287c	0.32bc	0.33c	0.362c	0.40c
Cocoa husk + Goat dung	0.32cd	0.38bc	0.40c	0.437cd	0.445c
Cocoa husk+ Pig dung	0.362d	0.385bc	0.41c	0.418cd	0.441c
Cocoa husk + Poultry manure	0.40de	0.411bc	0.437c	0.47d	0.51cd
Rice bran (sole)	0.676fg	0.70ef	0.762f	0.66ef	0.737f
Rice bran + Goat dung	0.587e	0.60e	0.662e	0.70f	0.775fg
Rice bran + Pig dung	0.625f	0.62e	0.775f	0.775fg	0.775fg
Rice bran + Poultry manure	0.55e	0.587d	0.68e	0.775fg	0.825g
Spent grain (sole)	0.587e	0.52d	0.605de	0.625e	0.651ef
Spent grain + Goat dung	0.70g	0.80f	0.70ef	0.662ef	0.737f
Spent grain + Pig dung	0.775h	0.81f	0.85g	0.85g	0.887gh
Spent grain + Poultry manure	0.675fg	0.77ef	0.812g	0.8l2gh	0.812g
Saw dust (sole)	0.475de	0.51bc	0.55d	0.65e	0.587d
Saw dust + Goat dung	0.51de	0.54bc	0.587d	0.587de	0.625e
Saw dust + Pig dung	0.55e	0.587d	0.617de	0.62e	0.636e
Saw dust + Poultry manure	0.587e	0.60d	0.625de	0.625e	0.660ef
Control (no fertilizer)	0.0023a	0.023a	0.023	0.023	0.023a
NPK 15-15-15	0.0625b	0.066b	0.070b	0.071b	0.0775b

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 10
The effect of different levels of plant residues plus manure on the soil Na (mmol kg^{-1}) of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	0.293b	0.309b	0.37b	0.43b	0.52c
Woodash + Goat dung	0.67ef	0.77fg	0.80ef	0.806ef	0.88de
Woodash + Pig dung	0.813ij	0.88ij	0.86fg	0.87fgh	0.78de
Woodash + Poultry manure	0.813ij	0.78fgh	1.03hi	1.07kl	1.09gh
Cocoa husk (sole)	0.28b	0.37c	0.376b	0.43b	0.35b
Cocoa husk + Goat dung	0.43c	0.43d	0.45c	0.49b	0.52c
Cocoa husk+ Pig dung	0.43c	0.43d	0.50cd	0.47b	0.53c
Cocoa husk + Poultry manure	0.450c	0.46d	0.53d	0.60c	0.65c
Rice bran (sole)	0.86kj	0.92j	0.89fg	0.95hij	0.99efg
Rice bran + Goat dung	0.763hi	0.80gh	0.88fg	0.86fgh	1.05fgh
Rice bran + Pig dung	0.793i	0.82hi	1.01hi	1.03jkl	1.05fgh
Rice bran + Poultry manure	0.68ef	0.77fg	0.97h	1.05kl	1.11gh
Spent grain (sole)	0.73gh	0.79fgh	0.82efg	0.823ef	0.88d
Spent grain + Goat dung	0.906k	0.88ij	0.86fg	0.84fg	0.88efg
Spent grain + Pig dung	1.013 l	1.09 l	1.06i	1.10m	1.16h
Spent grain + Poultry manure	0.860jk	1.013k	1.07i	0.99ijk	1.05fgh
Saw dust (sole)	0.60d	1.61e	1.75e	0.71d	0.82d
Saw dust + Goat dung	0.66e	0.62e	0.77e	0.73def	0.86de
Saw dust + Pig dung	0.71fg	0.75f	0.77e	0.823ef	0.86de
Saw dust + Poultry manure	0.77hi	0.77fg	0.82efg	0.80ef	0.92def
Control (no fertilizer)	0.018a	0.018a	0.020a	0.021a	0.020a
NPK 15-15-15	0.788i	0.88ij	0.86fg	0.92ghi	1.07gh

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 11
The effect of different levels of plant residues plus manure on the soil pH_{water} of Okra plot

Treatments	2	4	6	8	10 t ha^{-1}
Woodash (sole)	7.10h	7.10 l	7.40 l	7.30k	7.20h
Woodash + Goat dung	7.20 l	7.30k	7.50m	7.40 l	7.30 l
Woodash + Pig dung	7.30j	7.40 l	7.50m	7.20j	7.40j
Woodash + Poultry manure	7.40k	7.50m	7.10 l	7.30k	7.60 l
Cocoa husk (sole)	7.20i	7.20j	7.20j	7.20j	7.30 l
Cocoa husk + Goat dung	7.30j	7.30k	7.40 l	7.30k	7.40j
Cocoa husk+ Pig dung	7.10h	7.40 l	7.30k	7.40 l	7.50k
Cocoa husk + Poultry manure	7.40k	7.50m	7.50m	7.50m	7.60 l
Rice bran (sole)	5.80b	5.90b	5.90c	6.00c	5.80c
Rice bran + Goat dung	6.10c	6.10c	6.30d	6.30d	6.50e
Rice bran + Pig dung	6.30d	6.30e	6.30d	6.40e	6.50e
Rice bran + Poultry manure	6.40e	6.20d	6.50e	6.60g	6.60c
Spent grain (sole)	6.10c	6.10c	6.30d	6.50f	6.30d
Spent grain + Goat dung	S7.10h	7.10 l	7.10 l	7.20j	7.30 l
Spent grain + Pig dung	7.20i	7.30k	7.20j	7.40 l	7.50k
Spent grain + Poultry manure	7.50 l	7.50m	7.40 l	7.50m	7.60 l
Saw dust (sole)	6.10c	5.90b	5.80b	5.80b	5.880c
Saw dust + Goat dung	6.60f	6.40f	6.60f	6.60g	6.80f
Saw dust + Pig dung	6.70g	6.60g	6.80g	6.80h	7.10g
Saw dust + Poultry manure	6.70g	6.70h	6.90h	6.90 l	7.10g
Control (no fertilizer)	5.30a	5.30a	5.32a	5.29a	5.29b
NPK 15-15-15	5.35ab	5.32a	5.34a	5.30a	5.10a

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

TABLE 12
Correlation coefficients (r0 values between the yield parameters of okra and soil N, P, K, Ca, Mg, Na OM and pH at different levels of plant residues plus manures

Parameters	2	4	6	8	10 t ha^{-1}
Fresh pod yield vs soil OM.	0.473**	0.51**	0.55**	0.48**	0.48**
Fresh pod yield vs soil K	0.66**	0.543**	0.541**	0.52**	0.587**
Fresh pod yield vs soil Ca	0.47**	0.48**	0.48**	0.46**	0.472**
Fresh pod yield vs soil N	0.832**	0.875**	0.90**	0.856**	0.818**
Fresh pod yield vs soil P	0.433**	0.524**	0.64**	0.667**	0.825**
Fresh pod yield vs soil pH	0.408**	0.404**	0.46**	0.48**	0.51**
Fresh pod yield vs soil Na	0.216*	0.245*	0.26*	0.37*	0.38*
Fresh pod yield vs soil Mg	0.36*	0.54**	0.6**	0.63**	0.68**

** - Significant at 1% level.
* - Significant at 5% level.

(Table14) which NPK fertilizer can not supply (Swift and Anderson, 1993).

The poultry, pig and goat manures resulted in higher values of N and P nutrients and least C/N ratio of 6.93, 6.72 and 7.93 respectively compared to the agricultural by products (wood ash) spent grain, rice bran, saw dust and cocoa husk). The wood ash had the highest K, Ca and Mg followed by cocoa husk and spent grain while rice bran and Na with the highest C/N ratio of 23.3 and 19.05 respectively (Table 14). The increase in growth parameters, such as plant height, leaf area and stem girth by NPK fertilizer could be associated with quick release of the nutrients for assimilation (Ojeniyi, 1984).

TABLE 13
Standardized regression coefficients between soil properties and okra yield under different levels of plant residues

Levels of plant residues	Regression equation	R^2
	$Y = abo + b_1 x_1 + b_2 x_2 + b_3 x_3$ ....$+ b_8 x_8$	
t ha^{-1}		
2	$Y = 1206.383 + 0.612 x_1 + 0.447 x_2 + 1.174 x_3$	0.828
	$+ 0.561 x_4 + 0.642 x5 - 0.555 x_6 + 0.750 x_7$	
	$+ 0.528 x_8$	
4	$Y = 2111.963 + 0.240 x_1 + 1.239 x_2 + 0.408 x_3$	0.834
	$+ 0.197 x_4 + 0.629 x_5 + 0.199 x_6 + 0.443 x_7$	
	$+ 0.750 x_8$	
6	$Y = -2737.64 + 0.190 x_1 + 0.508 x_2 + 0.064 x_3$	0.907
	$+ 0.292 x_4 + 0.422 x_5 + 0.170 x_6 + 0.393 x_7$	
	$+ 0.708 x_8$.	
8	$Y = -1268.803 - 0.483 x_1 - 0.217 x_2 + 0.735 x_3 + 0.576 x_4$	0.804
	$+ 0.771 x_5 + 0.128 x_6 + 0.206 x_7 + 0.792 x_8$	
10	$Y = -2998.745 + 0.086 x_1 + 1.695 x_2 + 0.691 x_3$	
	$- 0.720 x_4 - 0.120 x_5 + 0.644 x_6 + 0.386 x_7 - 0.924 x_8$	0.80

X_1 = Soil Na, X_2 = Soil K, X_3 = Soil Mg, X_4 = Soil Ca, X_5 = % OM, X_6 = Soil pH, X_7 = Soil P and X_8 = % Soil N.

TABLE 14
Chemical characteristics of organic fertilizers used for the field experiments

Organic materials	% C	%N	C/N ratio	Available P (mg kg^{-1})	Na	Ca	K	Mg	Fe	Mn	Cu	Zn
					%					mg kg^{-1}		
Poultry manure	30.0	4.33	6.93	385.0	5.65	3.20	9.72	4.1	37.85	1.66	0.15	1.26
Pig manure	25.0	3.72	6.72	312.0	5.22	3.10	14.45	4.8	34.0	1.62	0.17	1.34
Goat manure	20.0	2.52	7.93	167.5	6.30	2.90	9.97	4.5	34.5	1.60	0.16	1.30
Cocoa pod Husk	16.0	1.44	11.1	100.0	4.41	9.34	20.59	7.1	50.4	8.64	0.55	1.69
Wood ash	18.0	1.53	11.76	86.0	8.26	9.40	23.02	8.52	65.51	11.92	0.66	1.83
Spent grain (Brewery waste)	10.0	0.78	12.82	76.0	4.57	0.13	7.86	3.10	3.39	0.99	0.1	0.7
Rice bran	14.0	0.6	23.33	56.0	4.43	0.12	7.93	1.8	6.25	1.78	0.18	0.49
Saw dust	8.0	0.42	18.96	10.0	4.39	0.10	5.12	1.3	4.01	1.69	0.16	0.40

The continuous use of NPK fertilizer for okra decreased soil pH, OM., Ca, Mg and Na nutrients and this could be traced to the ammonium (NH_4^+) component which reduced soil uptake. Besides, the high P and K contents of NPK could lead to nutrient imbalance P/Mg, K/Mg, K/Ca and K/Na (Bear, 1950).

The effectiveness of amended plant residues with manures compared to the sole treatments could be adduced to their high N, P, K, Ca, Mg, Na contents and lower C/N ratio of the manure which would aid decomposition and release of nutrients.

However the inferior performance of rice bran and saw dust in improving the soil pH could be due to their high C/N ratio and consequent immobilization of soil nutrients especially cations. The best crop performance associated with the use of spent grain is also attributed to possible improvement in other attributes of soil, such as bulk density for all the plant residues (Folorunso, 1999).

TABLE 15
The effect of different amount of plant residues plus manure on soil organic matter (%) of okra plot

Treatments	2	4	6	8	10 t ha-1
Wood ash (sole)	2.80k	2.86k	2.90g	2.96h	3.00f
Wood ash + goat dung	3.13o	3.24k	3.79l	3.68jk	3.72i
Wood ash + pig dung	3.20p	3.75n	3.81lm	3.90l	3.85j
Wood ash + poultry dung	3.31q	3.82o	3.88n	3.91l	3.99j
Cocoa husk (sole)	2.67h	2.73f	2.82f	2.98hi	2.94e
Cocoa husk + goat dung	3.38s	3.46l	3.64k	3.71k	3.75i
Cocoa husk + pig dung	3.32r	3.44kl	3.87m	3.93m	3.98j
Cocoa husk + poultry manure	3.59t	3.67m	3.80l	3.97n	4.06k
Rice bran (sole)	2.24d	2.33d	2.35cd	2.40d	2.45cd
Rice bran + goat dung	2.63g	2.68ef	2.70de	2.76ef	2.80de
Rice bran + pig dung	2.70i	2.76f	2.87fg	2.90g	3.02f
Rice bran + poultry manure	2.73j	2.80fg	2.99h	3.04i	3.17g
Spent grain (sole)	2.36e	2.43de	2.60d	2.63e	2.72d
Spent grain + goat dung	2.97l	3.00h	3.13j	3.20j	3.25h
Spent grain + pig dung	3.03m	3.10i	3.21j	3.15	3.18g
Spent grain + poultry manure	3.07n	3.20j	3.30jk	3.22j	3.29hi
Saw dust (sole)	2.19c	2.22c	2.29c	2.34c	2.40c
Saw dust + goat dung	2.53f	2.67e	2.70de	2.73ef	2.78d
Saw dust + pig dung	2.53f	2.66e	2.76e	2.80f	2.80de
Saw dust + poultry dung	2.70i	2.78f	2.99h	3.03i	2.97ef
Control (no fertilizer)	0.27a	0.28a	0.28a	0.27a	0.28a
NPK 15-15-15	0.43b	0.41b	0.40b	0.42b	0.39b

Treatment means within each group of column followed by the same letters are not significantly different from each other using DMRT at 5% level.

The responses of okra to the application of plant residues, which ranged from 2 t ha^{-1} to 6 t ha^{-1} could be attributed to the initial soil fertility. At 8 and 10 t ha^{-1} residues or residues plus manure application okra pod formation was retarded and flowering delayed. This is also consistent with the R^2 values in Table 13 where the highest R^2 values (0.907) were obtained at 6 t ha^{-1}. This implied that 90.7% of the okra pod weight variation was adduced to the soil nutrients and okra could respond positively to soil fertility. The above observation corroborates that of Rehim *et al.* (1981) who noted that the P, K, Ca, Mg, Na concentrations in crops decreased with the amount of applied organic fertilizers. The reduction was of plant nutrients dilution resulting from increased starch formation especially at 8 and 10 t ha^{-1} residues application. Above the 6 t ha^{-1} of treatment application and the associated soil nutrient levels of N, P, K, Ca, Mg, Na, soil OM and pH, the principle guiding the law of diminishing returns in fertilizer use was applied (Yayock, 1986). He reported that further addition to the soil above the soil critical level, would lead to little or no addition in crop yield and it should be discontinued.

The implication is that at 6 t ha^{-1} of residues or residue + manure application, the optimum yield of okra has been attained and soil nutrient status (N, P, K, Ca, Mg, Na, OM) had been built up to support the growth of the crop. Therefore by discontinuing application of these treatments to the soil, they will also release sufficient nutrients for crops such as yam, maize, cassava and others to be grown in rotation with okra in future (residual effect).

This is the philosophy of soil fertilization (i.e. adding fertilizers to soils before planting) that supports multiple cropping systems of peasant farmers in the tropics. The observation was supported by the work of Folorunso *et al.* (2000), which emphasized the use of three fertilizer models to evaluate the residual effects of P and K fertilizers for maize growth. They noted that soil exchange sites still released nutrients to crops after application of fertilizers to soil was stopped.

Excessive application of fertilizers to the soil especially at 8 and 10 t ha^{-1} would lead to nutrient imbalance and subsequently poor uptake of essential nutrients for crop growth.

The soil critical levels for N, P, K, Ca, Mg, Na and OM. differed slightly from the earlier ones developed by Agboola and Corey (1973) and Adeoye (1980) signifying the importance of updating research on soil calibration for these nutrients. Besides, the study helps to provide a framework for soil critical levels using applied plant residues or residues + manure which are presently adopted by farmers.

CONCLUSIONS

Plant residues (sole and amended forms) were effective as fertilizer and sources of nutrients for okra crop. Their application enhanced crop growth and pod weight of okra. Amendment of residues with pig, goat and poultry manures improved their effects on the pod weight of okra. The research showed that soil nutrient or critical levels and okra pod weight at 6 t ha^{-1} residue or residues + manure gave the best yield response and above which at 8 and 10 t ha^{-1} crop responses decreased.

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