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Use of Plant Residues for Improving Pod Chemical Composition, Biochemical Quality and Pod Yield of Okra *(Abelmoschus esculentum L.)*

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ABSTRAK

Kesan abu kayu, habuk gergaji, sekam koko, bijian terpakai dan dedak digunakan ke atas lenggai okra, komposisi kimia, kualiti biokimia dan hasil lenggai okra (Abelmoschus esculentum *Moench) kepelbagaian NHAe-47 dikaji. Lima jenis rawatan baja organik dibandingkan dengan baja kimia (1,600kg/ha NPK 15-15-15) dan kawalan yang tidak berbaja dalam empat lapangan eksperimen. Rawatan-rawatan tersebut direplikatkan empat kali dan disusun dalam reka bentuk blok lengkap secara rawak. Komposisi kimia bahan organik, nutrien lenggai, kualiti biokimia dan hasil lenggai okra telah ditentukan untuk rawatan yang berbeza. Keputusan menunjukkan penggunaan 6t/ha sisa tumbuhan secara signifikan (P<0.05) meningkatkan hasil lenggai, N, P, K, Ca, Mg, Na, abu, protein mentah dan hasil lenggai okra berbanding rawatan kawalan. Abu kayu, sekam koko, bijian terpakai merupakan bahan yang paling efektif dalam pembaikan hasil lenggai, status nutrien lenggai dan kualiti biokimia manakala dedak dan habuk gergaji adalah bahan yang paling tidak efektif. Sisa tumbuhan mengeluarkan Ca, Mg dan Na kandungan lenggai dengan lebih baik berbanding rawatan baja NPK 15-15-15. Bijian terpakai meningkatkan Ca, Mg dan Na lenggai okra dengan lebih 98, 94 dan 69% berbanding baja NPK. Hanya bijian terpakai yang meningkatkan lenggai abu berbanding baja NPK. Dalam kalangan sisa tumbuhan, abu kayu mempunyai nilai N, P, K, Ca dan Mg tertinggi, dan diikuti dengan rawatan sekam koko, bijirin terpakai, dedak dan habuk gergaji. Abu kayu meningkatkan N, K, Ca dan Mg lenggai dengan 50, 70, 72 dan 52% berbanding habuk gergaji. Bijian terpakai mempunyai nilai hasil lenggai okra tertinggi, diikuti dengan sekam koko dan abu kayu, manakala kedua-dua habuk gergaji dan dedak mempunyai nilai yang terendah. Bijian terpakai meningkatkan hasil lenggai dengan 50, 49, 65 dan 52% melebihi rawatan habuk kayu, sekam koko, dedak dan habuk gergaji. Baja NPK meningkatkan hasil lenggai dengan 25, 24, 48 dan 48.2% lebih tinggi daripada abu kayu; sekam koko, dedak dan habuk gergaji. Bijian terpakai juga meningkatkan hasil lenggai dengan 33% berbanding baja NPK. Pekali kolerasi (r) di antara hasil lenggai dan lenggai N, hasil lenggai dan abu lenggai, hasil lenggai dan protein mentah adalah 0.81, 0.73 dan 0.64 pada aras 1% ($P \geq 0.01$) manakala pekali regresi (R^2) bagi hubungan antara hasil lenggai okra, komposisi kimia dan kualiti biokimia adalah 0.83. Implikasinya adalah lenggai N, P, K, Ca, Mg, Na, protein mentah dan abu dihitung dengan 83% hasil variasi dalam okra.*

ABSTRACT

The effect of wood ash, saw dust, ground cocoa husk, spent grain and rice bran used ordinarily on the okra pod, chemical composition, biochemical quality and pod yield of okra (Abelmoschus esculentum *Moench) variety NHAe-47 was studied. Five organic fertilizer treatments were compared to a chemical fertilizer (1,600 kg/ha NPK 15-15-15) and unfertilized controls in four field experiments. The treatments were replicated four times and arranged in a randomized complete block design for each experiment. The chemical composition of the organic materials, pod nutrients, biochemical quality, and pod yield of okra were determined for the different treatments. The results showed that the application of 6 t/ha of plant residues significantly (P<0.05) increased the pod yield, N, P, K, Ca, Mg, Na, ash, crude protein and pod yield of okra compared to the control treatment. Wood ash, cocoa husk and spent grain were the most effective in improving pod yield, pod nutrient status and biochemical quality while the rice bran and saw dust were least effective. The plant residues produced better pod Ca, Mg and Na contents than the NPK 15-15-15 fertilizer treatment.*

Spent grain increased okra pod Ca, Mg and Na by 98, 94 and 69% more respectively compared to NPK fertilizer. Only spent grain significantly increased the pod ash compared to NPK fertilizer. Among the plant residues, wood ash had the highest values of pod N, K, Ca and Mg followed by cocoa husk, spent grain, rice bran and saw dust treatments respectively. Wood ash increased pod N, K, Ca and Mg by 50, 70, 72 and 52% more respectively compared to the saw dust. Spent grain had the highest value of okra pod yield followed by cocoa husk and wood ash while both saw dust and rice bran had the least values. The spent grain increased pod yield by 50; 49, 65 and 66% more compared to wood ash, cocoa husk, rice bran and saw dust treatments respectively. NPK fertilizer increased the pod yield by 25, 24, 48 and 48.2% more compared to wood ash; cocoa husk, rice bran and saw dust respectively. Spent grain also increased the pod yield by 33% compared to NPK fertilizer. The correlation coefficients (r) between pod yield and pod N, pod yield and pod ash, pod yield and crude protein were 0.81, 0.73 and 0.64 respectively at 1% level ($P \geq 0.01$) while the regression coefficient (R^2) for the relationship between okra pod yield, chemical composition and biochemical quality was 0.83. The implication is that pod N, P, K, Ca, Mg, Na , crude protein and ash accounted for 83% of yield variation in okra.

INTRODUCTION

Okra *(Abelmoschus esculentum* L.) is an annual herb and fruit vegetable crop which belongs to the family Malvaceae. Okra is grown throughout the tropical and subtropical parts of the world either as a sole crop or intercropped with major staple crops such as yam and maize.

Okra plays an important role in the human diet by supplying additional carbohydrate, protein, fats, minerals and vitamins which are usually deficient in the staple food (Oyenuga, 1968). The nutritional importance of okra has led to renewed interest in bringing the crop into commercial production.

In spite of the above nutritional importance of okra, its optimum yield and the quality have not been attained partly because of continued decline in soil fertility. However, efforts to increase the yields of okra through the use of the inorganic fertilizers have been hampered by acute scarcity, high cost and continued deterioration of soil properties (Adeoye, 1986).

Sanchez *et al.* (1989) reported that an important method to improve nutrient recycling and conserve soil fertility is through the use of applied organic inputs.

This work investigated the effect of plant residues such as wood ash, spent grain, ground cocoa husk, rice bran and saw dust on pod chemical composition, biochemical quality and yield of okra in Akure, South West Nigeria.

MATERIALS AND METHODS

Source and Preparation of the Organic Materials

Cocoa pod husk and wood ash were collected from the cocoa farm plots and cassava processing units of Federal College of Agriculture, Akure. Rice bran was collected from the OS-6 variety processed at the college rice mill while the sorghum based spent grain was collected from the International Breweries Nig. Plc., Ilesa, Osun State, Nigeria.

The saw dust was obtained from the nearby saw mill industry at Akure township, specializing in cutting obeche *(Triplochiton scleroxylon)* log trees into pieces.

The organic materials were processed to allow for decomposition. The dried cocoa pod husk were ground with a hammer mill while the rice bran was chopped into pieces, wetted and allowed to decompose.

The college has 300 ha of cocoa plantation from which quantities of cocoa pod husk were obtained. There is also a 200 ha rice field from which sizeable quantities of rice bran were obtained. The processing of harvested tubers from 250 ha of cassava generated high quantities of woodash derived from fuel wood and planks purchased from the nearly saw mill.

Generally, all the organic residues used were easily available, sustainable and cheap for growing okra commercially.

Field Experiments

The experiments were carried out at Akure, Nigeria in the tropical rainforest zone. The soil is a sandy loan texture and belongs to Akure soil series, Iwo Association and is classified as a skeletal, Kaolinitic Ishohyperthermic Paleustalf (Alfisol) USDA or Ferric Luvisol (FAO) Harpstead (1972).

The soil had pH (H_2O) of 5.1, 0.53% organic matter, 0.02% N, 4.6 mg kg^{-1} Bray P1 extractable P, 0.05 mmol kg^{-1} exchangeable K, 0.1 mmol kg^{-1} exchangeable Ca and 1.12 mmol kg^{-1} exchangeable Mg.

The soil was under arable crops for 10 years. The field experiments were conducted four times between April 6 1998 and August 23 1999 at the same site. Each experiment spanned for four months.

Five organic fertilizer treatments were applied to each crop of okra at the start of the experiment, in-addition, to 400 kg/ha kg^{-1} (1,600 kg ha^{-1} for four experiments) NPK 15-15-15 fertilizer and the control (no manure or fertilizer) treatments.

The five plant residues were wood ash, saw dust, ground cocoa pod husk, rice bran, spent grain (sorghum based brewery waste) and saw dust.

The seven treatments were replicated four times on each of the four consecutive okra crops and arranged in a randomized complete block design. The size of each plot was 16 m^2 (4 m x 4 m) and soils were ploughed and harrowed to maintain good tilth for the okra crop. The residues and NPK fertilizer were incorporated into the soil two weeks before planting using a garden fork to allow better decomposition.

Four seeds of early maturing okra variety (NHAe 47-4) were planted per hole of 2 cm depth and at a spacing of 60 cm x 30 cm (20 kg/ha). There were five vertical rows of okra seeds planted in each plot and germination took place five days after planting. Thinning to one plant per stand was done.

The plots were manually weeded thrice starting from second, fourth and sixth weeks after planting. The insect pests were controlled by spraying Vetox 85 at the rate of 28 g a.i in 9 L of water starting from the second week after planting (WAP).

Twenty six plants were selected and tagged out of 88 plants per plot for sample pod chemical composition, biochemical quality and pod yield determination.

Harvest of mature pods started at 35 days after planting and it continued at every four days interval until senescence. The yields of the remaining 62 plants for okra in each treatment plot were weighed, put into labeled envelopes and oven dried at 70°C for 48 hours. At the end of each experiment, all okra plants were uprooted.

Analysis of the Okra Pods for Nutrients Chemical Composition and Biochemical Quality

The dried okra pods were ashed for 6 hours in a muffle furnace. The chemical composition (P, K, Ca, Mg and Na) in the ashed pods were extracted with water. The % P was determined by using vanado-molybdate solution and it was read on spectronic 20 at 442 um (Udo and and Ogunwale, 1979). The % K, Ca and Na were read on the flame photometer using appropriate element filters (Jackson, 1958). The Mg was determined on atomic absorption spectrophotometer (Novaspec II visible spectrophotometer, manufactured by Pharmacia Biotech (Biochrom Ltd) Cambridge, England).

The crude protein content was determined by multiplying % N N x 6.25 and the total ash was determined by using the formula.

$$\%\ \text{total ash} = \frac{\text{ash weight}}{\text{Sample weight (oven dry)}} \times 100$$

The % N was determined by Microkjedahl method (Jackson, 1964).

Chemical Analysis of Organic Materials

The processed forms of the organic materials were analysed. The determination of nutrients in organic materials were done using wet digestion method based on 25-5-5 ml of NHO_3-

H_2SO_4-$HC10_4$ acids respectively. The filtrates collected were used for the determination of %, P, K, Ca, Mg and Na. The % P was determined using vanado molybdate colorimetry and read on specronic 20 while % K, Ca and Na were read on flame photometer. Mg was read on atomic absorption spectrophotometer. The % N was determined by microkjedahl method (Jackson, 1964).

Statistical Analysis

The mean data for pod nutrients N, P, K, Ca, Mg, Na crude protein, ash content and pod yield of okra crops were subjected to ANOVA F-test and their levels of significance were determined for the residue treatments using Duncan's Multiple range test (DMRT) at 5%. Multiple regression coefficient showing the nutrient use relationship between the okra pod yield, pod nutrients and biochemical quality was calculated.

RESULTS

Table 1 presents the chemical composition of the organic materials used for the cultivation of okra. Among the plant residues, wood ash had the best nutrient status with regards to C, N, K, Ca, Mg and Na while cocoa husk had the highest total P.

Wood ash supplied the highest P while cocoa husk had the highest K. NPK supplied moderate amounts of N, P and K nutrients and very low Ca and Mg to the soil (Table 2).

Effect of Plant Residues on Okra Pod Chemical Composition and Biochemical Quality

The mean percent values of okra pod N, P, K, Ca, Mg, Na, total ash and crude protein for the four crops of okra under the different manure treatments are presented in Table 3. The plant residues increased the okra pod status of N, P, K, Ca, Mg, Na, total ash and crude protein significantly ($P<0.05$) relative to the control. Wood ash increased the okra pod N, P, K, Ca, Mg, Na, total ash and crude protein more by 98, 88, 98, 79, 92, 77, 84 and 98% respectively compared to the control treatment.

The plant residues produces better pod Ca, Mg and Na contents than the NPK 15-15-15 fertilizer treatment. Spent grain increased okra pod Ca, Mg and Na by 98, 94 and 69% more respectively compared to NPK 15-15-15 fertilizer. Only spent grain significantly increased the pod ash compared to NPK fertilizer.

NPK fertilizer had the highest values of pod N, K and crude protein than all residues while pod P values were the highest in cocoa husk and NPK fertilizer treatments.

Among the plant residues, wood ash had the highest values of okra pod N, K Ca, and Mg followed by cocoa husk, spent grain, rice bran and saw dust treatments respectively. Cocoa husk and spent grain had the highest values of pod P and ash respectively. For instance, wood ash increased percent pod N, K, Ca and Mg by 50, 70, 72 and 52% respectively compared to the saw dust.

Rice bran, cocoa husk and wood ash had the highest values of pod Na compared to others while only wood ash and cocoa husk had the highest values crude protein in okra.

Effect of Plant Residues on Pod Yield of Okra

The plant residues and NPK fertilizer increased pod yield (gross) of okra significantly ($P<0.05$) relative to the control treatment (Table 4). Wood ash, cocoa husk, rice bran, spent grain, saw dust and NPK fertilizer increased the okra pod yield by 97, 98, 96, 99, 96 and 98% respectively compared to the control treatment.

Among the plant residues, spent grain had the highest value of pod yield of okra followed by cocoa husk and wood ash while both saw dust and rice bran had the least values. Spent grain increased the pod yield by 50, 49, 65 and 66% compared to wood ash, cocoa husk, rice bran and saw dust treatments respectively. Generally, the residues had cumulative effect on pod yield and chemical composition.

NPK 15-15-15 fertilizer increased okra pod yield compared to plant residues except in

TABLE 1
The chemical composition of the organic materials used in the treatments of okra

Organic Materials	C %	N %	C/N ratio	Total P(mg/kg)	Na	Ca	K	Mg
					Mg/L			
Cocoa husk	16.0	1.44	11.1	100.0	4.41	9.34	20.59	7.10
Wood ash	18.0	1.53	11.76	86.0	8.26	9.40	23.02	8.52
Spent grain	10.0	0.78	12.82	76.0	4.57	0.13	7.86	3.10
Rice bran	14.0	0.60	23.23	56.0	4.43	0.12	6.93	1.80
Saw dust	8.0	0.42	18.96	10.0	4.39	0.10	5.12	1.30

spent grain. NPK fertilizer increased the pod yield by 25, 24, 48 and 48.2% compared to wood ash, cocoa husk, rice bran and saw dust respectively. Spent grain alone increased the pod yield by 33% compared to the NPK fertilizer.

The correlation coefficients (r) between okra pod yield, pod N, P, K, Ca Mg, ash and crude protein were significantly and positively correlated at 1% and 5% levels (Table 5). The r values between pod yield and pod N, pod yield and pod ash, pod yield and crude protein were 0.81, 0.73 and 0.64 respectively at 1% level ($P \geq 0.01$).

The multiple regression analysis showing the relationship between okra fresh pod yield, pod Ca, Mg, Na, K, N, P, ash and crude protein is presented in Table 6. The R^2 value (coefficient of determination) was 0.83 and the implication is that pod N, P, K, Ca, Mg, Na crude protein and ash accounted for 83% yield variation in okra.

DISCUSSION

In the control treatment (no fertilizer and residues), the pod yield of okra was the least compared to those of the five plant residues (cocoa husk, spent grain, rice bran, wood ash and saw dust). This could be due to the initial low soil nutrient status of the field before application of residues. Agboola (1982b) reported poor growth and yield responses in unfertilized soils.

The nutrient contents in the okra pod under the control treatment were very far below the critical level of 0.25% P, 1.19% K, 0.8% Ca and 0.7% Mg as reported by Jones Eck (1973). Thus, the okra plants showed deficiency symptoms of P (purple colouration), K (burnt leaf margin), Ca (stunted root growth) and N (yellow leaf colouration).

Spent grain produced the best pod yield of okra, although, it had lower nutrient status compared to wood ash and cocoa husk. Spent grain also gave relatively low pod nutrient composition in okra. Therefore, the best crop performance associated with the use of spent grain could be attributed to possible improvement in the soil physical properties (bulk density and low porosity). Folorunso (1999) reported that spent grain better reduced the soil bulk density compared to the other plant residues. The reduction in the soil bulk density enhanced root growth and subsequently enhanced uptake of nutrients from the soil for sustainable yield.

Cocoa husk followed spent grain with regards to the enhancement of okra pod yield. It had the least C/N ratio, which implies that it decomposed and released its nutrients faster when compared with the wood ash, rice bran and saw dust. The better effect of cocoa husk on okra pod yield compared with rice bran and saw dust is consistent with the fact that it had better nutrient composition (Table 1).

Cocoa husk had the highest total P among the plant residues and better Ca, K and Mg than rice bran and saw dust. Cocoa husk improved okra pod N, K, Ca, Mg and crude

TABLE 2
The total quantity of residues and amount of nutrients in plant residues sources

Fertilizers	N	P	K	Ca	Mg Kg	Total quantity of residue applied per for each planting	Total quantity of residues applied for the four plantings
NPK fertilizer	240	240	240	16	8	400kg	1600kg
Cocoa husk	346	250	285	638	16	6 Tonnes	24 Tonnes
Rice bran	144	104	119	59	35	6 Tonnes	24 Tonnes
Saw dust	101	93	103	43	30	6 Tonnes	24 Tonnes
Spent grain	187	260	163	158	68	6 Tonnes	24 Tonnes
Wood ash	367	272	262	642	212	6 Tonnes	24 Tonnes

TABLE 3
Effect of plant residues on okra pod chemical composition and biochemical quality

Treatments	Pod N	Pod P	Pod K	Pod Ca	Pod Mg %	Pod Na	Pod ash	Pod crude protein
Control (no fertilizer)	0.031a	0.052a	0.024a	0.22b	0.019b	0.016a	1.142a	0.193a
NPK 15-15-15	2.804g	0.615e	1.50f	0.011a	0.0087a	0.02a	7.262e	17.67f
Wood ash	1.568f	0.418d	1.395e	1.028f	0.233g	0.07d	7.237e	9.80e
Cocoa husk	1.488e	0.603e	1.053d	0.975e	0.152f	0.071d	7.156d	9.304e
Rice bran	0.506b	0.354c	0.433b	0.298c	0.123d	0.072d	6.625c	3.167b
Spent grain	1.357d	0.221b	0.601c	0.609d	0.145e	0.064c	7.345f	8.484d
Saw dust	0.791c	0.212b	0.423b	0.292b	0.113c	0.051b	5.355b	4.945c

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

TABLE 4
Effect of different plant residues on pod yield of okra kg/ha (gross plot)

Treatments	Pod yield (kg/ha)
Control (no fertilizer)	18.72a
NPK 15-15-15	988.58e
Wood ash	746.19c
Cocoa husk	754.56d
Rice bran	512.80b
Spent grain	1483.20f
Saw dust	511.56b

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

TABLE 5
The linear correlation coefficient (r) between the okra pod yield, %, N, P, K, Ca, Mg, Ash and crude protein

Parameters	"r" values
Pod yield vs % pod K	0.50*
Pod yield vs % pod P	0.53**
Pod yield vs % pod Ash	0.73**
Pod yield vs % pod N	0.81**
Pod yield vs % pod crude protein	0.64**
Pod yield vs % pod Ca	0.48*
Pod yield vs % pod Mg	0.43*

* - significant at 5% level
** - significant at 1% level

TABLE 6
Multiple regression coefficient (R^2) between okra fresh pod yield and % Ca, Mg, Ash, Na, K, N, P and crude protein

Amount of residues applied	Regression equation $Y = a+bx_1 + x_2 + x_3 \ldots x_8$	Regression coefficient (R^2)
6tha^{-1}	Y = 13.25 + 18.35x1 + 63.50x2 +6.15x3 – 20.73x4 + 40.28x5 +43.28x6 + 5.94x7 + 10.51x8	0.83

x_1 = %Ca, x_2 = %Mg, x_3 = %Ash, x_4 = %Na,
x_5 = %K, x_6 = %N, x_7 = %P and x_8 = % crude protein.

protein better than the other plant residues except wood ash. Cocoa husk has been found to be good source of K for maize (Adu-Daap *et al*, 1994).

Although, wood ash had the highest macro nutrient contents and a relatively low C/N, it had lower effect on okra yield compared to spent grain and cocoa husk. This might be due to leaching of the easily available nutrients since ash is highly water soluble compared with other plant residues. Ojeniyi (1998) reported that wood ash increased maize yield.

Saw dust and rice bran respectively were least efficient in the supply of nutrients to the okra crops. Accordingly, they had the least values of pod N, P, K, Ca, Mg, crude protein and ash. The low nutrient contents of rice bran and saw dust are consistent with the least values of okra pod yield in the field. The poor performance attributed to saw dust and rice bran could be due to the fact that these residues had the least nutrient contents compared with wood ash, cocoa husk and spent grain.

Saw dust had the least values of C, N, P, K, Ca, Mg and rice bran had relatively low N, Ca and Mg. This might be due to their high C/N ratio which slowed degradation rate and subsequent slow rate of nutrient release to soil.

The increase in pod N, P, K status under NPK fertilizer compared to the plant residues might be due to the fact that N, P and K in the fertilizer were easily available than those supplied by organic sources. The R^2 values of 0.83 showed that pod N, P, K, Ca, Mg, Na, crude protein and ash were responsible for 83% yield variation in okra. This implied that the plant residues were efficient in improving the chemical composition and biochemical quality of okra for human consumption. This observation is supported by Oyenuga (1968) who reported that okra played an important role in the human diet by supplying additional carbohydrate, proteins, fats, minerals (Ca, P and Fe) and Vitamins (Vitamins A, C, thiamine, niacin and folic acid) which are usually deficient in the staple food of Nigeria (Oyenuga, 1968).These are required for body growth, reproduction and maintenance of health.

CONCLUSIONS AND RECOMMENDATIONS

Plant residues such as wood ash, cocoa husk and spent grain are effective sources of nutrients for okra because their addition to the soil enhanced the okra pod nutrients composition, biochemical quality and pod yield. Saw dust and rice bran were less effective.

Therefore, plant residues such as wood ash, spent grain and cocoa husk applied at rates of 6 t/ha are very useful as fertilizer materials for improving the nutrient availability and ensuring sustainable cultivation of okra on low fertility soils in humid tropics as well as improving the nutritional quality of okra.

This is particularly important considering the fact that inorganic fertilizers are scarce and expensive for resource poor farmers who are the producers of vegetable crops in most developing countries. In addition the increasing deep interest in organic farming in developed countries further justifies the recommendation for the use of plant residues for sustainable crop production.

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