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Incorporation of Agro-Industrial Biomass and Their Effects on Growth and Nutrient Content of Four Successive Crops of Amaranthus

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ABSTRAK

Satu kajian telah dijalankan di Akure, barat daya Nigeria ke atas kesan habuk kayu, sisa kulit koko, sisa bijian, habuk gergaji dan dedak padi, sama ada mentah atau ditambah dengan baja najis haiwan pada pertumbuhan, kandungan nutrien daun dan hasil empat tanaman Amaranthus viridis *(L). Dua puluh kombinasi biojisim industri pertanian telah digunakan ke atas tanah bersama satu rawatan dengan baja NPK dan satu petak yang tidak dirawat. Biojisim industri pertanian telah digunakan pada t/ha atau bergabung dengan baja najis kambing, khinzir dan ayam itik pada kadar 3tha-1 (nisbah 1:1). Dua puluh dua (22) rawatan yang direplikasi empat kali ke atas setiap empat tanaman secara berturutan menggunakan satu reka bentuk blok lengkap terawak. Keputusan menunjukkan bahawa penggunaan biojisim industri pertanian ke atas tanah meningkatkan N, P, K, Ca daun, abu Mg, protein kasar, ketinggian tumbuhan, kawasan daun, lilitan batang dan penghasilan daun amaranthus secara signifikannya ($P<0.05$) berbanding rawatan kawalan. Penggunaan sisa bijian, kulit koko dan habuk kayu lebih efektif dalam meningkatkan pertumbuhan, N, P, K daun, abu dan protein kasar, dan penghasilan daun amaranthus dibandingkan dengan dedak padi dan habuk gergaji. Rawatan sisa bijian meningkatkan N, P, K, Ca, Mg daun, abu dan protein kasar amaranthus kepada masing-masing 32.4%, 22%, 30%, 21%, 15.3%, 32% dan 6% berbanding penggunaan dedak padi sahaja. Penggabungan baja najis haiwan dan biojisim industri pertanian meningkatkan penghasilan daun. Habuk kayu + rawatan baja najis ayam itik meningkatkan penghasilan daun amaranthus kepada 67%, 50%, 35% dan 34% masing-masing pada tanaman 1, 2, 3 dan 4 berbanding penggunaan sisa bijian sahaja. Rawatan dengan biojisim industri pertanian memberikan lebih tinggi kandungan K, Ca, dan Mg pada daun berbanding baja NPK kecuali penghasilan daun. Tambahan pula, penambahan sisa bijian dengan baja najis ayam itik juga meningkatkan N, P, K, Ca, Mg daun, protein kasar dan abu atau amaranthus kepada masing-masing 12%, 34%, 17.40%, 96.30%, 93% 48% dan 26% berbanding rawatan NPK. Penambahan habuk kayu, sisa kulit koko, dedak padi, sisa bijian dan habuk gergaji dengan baja najis ayam itik meningkatkan kepanjangan akar amaranthus kepada masing-masing 47%, 42%, 41.58%, 53% dan 27% berbanding rawatan baja NPK. Penambahan biojisim industri pertanian sama ada tanpa atau digabungkan dengan baja najis ayam itik meningkatkan kandungan nutrien pada daun dan penghasilan amaranthus secara progresifnya melebihi empat musim tanaman. Hubungan nlai-nilai R^2 di antara penghasilan daun amaranthus dan N, P, K, Ca, Mg daun, protein kasar dan abu adalah 0.90, 0.92, 0.94 dan 0.98 dalam tanaman 1, 2, 3 dan 4. Implikasinya ialah nutrien daun menjelaskan variasi 90%, 92%, 94% dan 98% dalam penghasilan daun amaranthus.*

ABSTRACT

A study was conducted in Akure, South West Nigeria on the effect of wood ash, ground cocoa husk, spent grain, saw dust and rice bran, either raw or amended with animal manure on the growth, leaf nutrient contents and yield of four crops of Amaranthus viridis *(L). Twenty combinations of agro-industrial biomass were applied to the soil together with one treatment with NPK fertilizer and a control which received no treatments. The agro-industrial biomass was applied at t/ha or individually combined with goat, pig and poultry manures at the rate of 3tha-1 (1:1 ratio). The twenty two (22) treatments were replicated four times on each of the four consecutive* *crops using a randomized complete block design. Results showed that the application of agro-industrial biomass to the soil increased the leaf N,P,K,Ca, Mg ash, Crude protein, plant height, leaf area, stem girth and leaf yield of amaranthus significantly ($p<0.05$) compared to the control treatment. Application of spent grain, cocoa husk and wood ash was more effective in increasing growth, leaf N, P, K, ash and crude protein, and leaf yield of amaranthus than the rice bran and sawdust. The spent grain treatment increased the leaf N, P, K, Ca, Mg, ash and crude protein of amaranthus by 32.4%, 22%, 30%, 21%, 15.3%, 32% and 6% respectively compared to the rice bran (sole) application. Incorporation of animal manure with agro-industrial biomass further increased the leaf yield. Wood ash + poultry manure treatment increased the amaranthus leaf yield by 67%, 50%, 35% and 34% respectively in crops 1, 2, 3 and 4 compared to the sole application of spent grain. Treatments with agro-industrial biomass gave higher leaf K, Ca, and Mg contents compared to NPK fertilizer except the leaf yield. In addition, amendment of spent grain with poultry manure also increased the leaf N, P, K, Ca, Mg, crude protein and ash or amaranthus by 12%, 34%, 17.40%, 96.30%, 93%, 48% and 26% respectively compared to the NPK treatment. The amended wood ash, cocoa husk, rice bran, spent grain and sawdust with poultry manure increased the root length of amaranthus by 47%, 42%, 41.58%, 53% and 27% respectively compared to NPK fertilizer treatment. Addition of agro-industrial biomass either alone or incorporated with animal manure increased the nutrient content in the leaf and yield of Amaranthus progressively over the four cropping seasons. The R^2 values of the relationship between amaranthus leaf yield and leaf N,P, K, Ca, Mg, Na, crude protein and ash were 0.90, 0.92, 0.94 and 0.98 in crops 1, 2, 3 and 4 respectively. The implication is that leaf nutrients accounted for 90%, 92%, 94% and 98% variations in leaf yield of amaranthus.*

INTRODUCTION

Vegetable farmers in humid tropical countries use the same piece of land continuously and after some years, the crops suffer from nutrient deficiency and low yield (Aweto and Ayuba 1993). In areas where NPK fertilizer is commonly used, the crops suffer from nutrient deficiency such as Ca and Mg. Due to the problems of scarcity and high cost of chemical fertilizer, there is a need to investigate into locally available and cheap sources of organic fertilizers for vegetable production.

Unlike the animal manures, use of agro-industrial biomass organic fertilizers in vegetable production has not received research attention. Decomposing plant residues release important and appreciable amount of nutrients into the soil (Ayanlaja and Sanwo 1991).

Amaranthus viridis L is a common vegetable in the humid tropics grown for its edible leaves. In this study, plant residues such as wood ash, ground cocoa husk, rice-bran, spent grain and sawdust, applied sole or amended with animal manure were tried as fertilizers on four crops of amaranthus. Their effects on growth parameters, nutrient composition and leaf yield of amaranthus were investigated.

MATERIALS AND METHODS

Source and Preparation of Organic Materials

Cocoa pod husk, wood ash, poultry, goat and pig dropping were obtained from the cocoa farm plots, cassava processing unit and livestock section of the Federal College of Agriculture, Akure.

Rice bran was obtained from the 05-6 varieties of rice processed at College rice-mill. Sorghum based spent grain was collected from the International Breweries Nigeria and the sawdust from a nearby sawmill industry at Akure township.

The organic materials were processed to allow decomposition. The dried cocoa pod husks were ground into powdery form using hammer mill while the wood ash was sieved mechanically with 2 mm sieve to remove foreign materials such as charcoal and wood remnants. The rice bran, spent grain and sawdust were each thoroughly wetted with water and composted separately to reduce the high C/N ratio. The poultry, pig and goat manures were heaped separately to allow for quick mineralisation and were placed under shade.

The processed individual agro-waste was added separately to the soil at 6tha^{-1} while the amended forms of the agro-wastes, involves mixing the agro-wastes together with each animal manure (pig, goat and poultry manures) and allowed to compost before adding to the amaranthus plants. The amended forms (agro wastes + manures) were added at 3tha^{-1} each (1:1). The animal manures were not applied to the soils individually but mixed with agro-wastes.

Chemical Analysis of the Organic Materials Used

Two grammes each of the processed forms of the organic materials used, were analysed.

The nitrogen content was determined by kjedahl method (Jackson 1964) while the determination of other nutrients such as P, K, Ca, Mg, Na, Fe, Zn, Cu and Mn was done using the wet digestion method based on 25-5-5 ml of HNO_3-H_2SO_4-$HC10_4$ acids respectively (A.O.A.C., 1970). The K, Ca and Na elements were read on flame photometer while Mg, Fe, Zn, Cu and Mn were read on atomic absorption spectrophotometer. The P content was developed into colouration with vanado-molybdate solution and read on spectronic 20 at 442 Um.

The organic carbon (%) was determined by wet oxidation method through chromic acid digestion (Walkley and Black 1934).

Field Experiment

The experiments were carried out at Akure in the rain forest zone of South West Nigeria on a sandy loam soil, skeletal, kaolinitic, isohyperthermic oxic paleustalf (Alfisol) or Ferric Luvisol (FAO). The surface soil (0-15 cm) had pH (water) of 5.1, organic matter 0.56%, 0.02% nitrogen, 4.3 mg/kg extractable P, 0.11 mmol/kg exchangeable Mg and 0.08 mmol/kg exchangeable K (Folorunso 1999).

The soil had been cropped for 10 years. The four field experiments were conducted between April 1998 and July 1999. Twenty agro-industrial biomass treatments, sole and amended, were applied to the amaranthus. Additional treatments included NPK fertilizer at 400 kg/ha and the control (no manure, no fertilizer). The five agro-industrial biomass were wood ash, ground cocoa pod husk, rice bran, brewery spent grain and sawdust.

The materials were applied sole at $6tha^{-1}$ and each agro-industrial biomass was combined with goat, pig and poultry manure at the rate of $3tha^{-1}$.

The twenty two (22) treatments were replicated four times on each of the four consecutive amaranthus crops at the same time using randomized complete block design. The size of each of the 88 plots was 16 m^2 (4 m x 4 m) and the soils were ploughed and harrowed to maintain good tilth for the amaranthus crops. The sole and amended residues and NPK fertilizer were incorporated into the soil seven days before planting.

Seeds of amaranthus (NHAC – 35) were hand drilled in rows that were 30 cm apart (13 rows per plot) at the rate of 7.5 kg/ha. Seeds were mixed with equal volumes of sand for even spreading. Ten days after planting, seedlings were thinned to a population of 535, 332 plants per hectare (i. e. 212 plants per plot).

The plant height (cm), leaf area (cm^2) and stem girth (cm) were measured at the second, third and fourth week after planting. Vetox 85 at in the rate of 28 g a.i. in 9 L of water was sprayed in the second and fourth weeks after planting. Thirty-five days after planting, the plants were harvested and weighed. The root length (cm) was measured for each crop of amaranthus.

Analysis of the Amaranthus Leaves for Chemical Composition

Sub samples of the plant were dried at 70°C for three days. The % N was determined by microjedahl method (Jackson 1964). P was determined by using vanado-molybdate solution and it was read on spectronic 20 at 442 Um. The % K, Ca and Na were read on the flame photometer using appropriate filters. The Mg was determined on atomic absorption spectrophotometry.

The crude protein content was determined by multiplying % N X 6.25 and the % total ash was also determined as reported by the Association of Analytical Chemists (AOAC 1970).

Statistical Analysis

The mean data for amaranthus growth parameters; plant height, leaf area, stem girth and root length, leaves % N, P, K, Ca, Mg, ash and crude protein and leaves' yields for each of the four crops were presented. They were subjected to ANOVA F-test and their levels of significance were determined for the sole and manure amended treatments using Duncan Multiple Range Test (DMRT) at a level of 5%.

RESULTS

Analysis of the Organic Material Used

Table 1 presents the chemical composition of the organic material used for the cultivation of amaranthus. Among the agro-industrial biomass, the wood ash had the highest nutrient status with regards to C, N, Ca, K, Mg, Fe, Mn, Cu and Zn. Wood ash and cocoa husk were relatively

TABLE 1
Analysis of the organic fertilizers used for the field experiments

Organic fertilizer	C %	N %	C/N ratio	Available P(mgkg)	Na	Ca mg/kg	K mg/kg	Mg	Fe	Mn mg/kg	Cu mg/kg	Zn
Poultry manure	30.00	4.33	6.93	385.00	5.65	3.20	9.72	4.10	37.85	1.66	0.15	1.26
Pig manure	25.00	3.72	6.72	312.00	5.22	3.10	14.45	4.80	34.00	1.62	0.17	1.34
Goat dung	20.00	2.52	7.93	167.50	6.30	2.90	9.97	4.50	34.50	1.60	0.16	1.30
Cocoapod husk	16.00	1.44	11.11	100.00	4.41	9.34	15.59	7.10	50.40	8.64	0.65	1.69
Wood ash	18.00	1.53	11.76	86.00	8.26	9.40	23.02	8.52	65.51	11.92	0.66	1.83
Spent grain (Brewery waste)	1.00	0.78	12.82	76.00	4.57	0.13	7.86	3.10	3.39	0.99	10.10	0.70
Rice bran	14.00	0.60	23.33	56.00	4.43	1.12	7.93	1.80	6.25	1.78	0.18	0.49
Sawdust	9.00	0.12	75.00	10.00	4.39	0.10	5.12	1.30	4.01	1.69	0.16	0.40

high in K, Ca, and Mg. The spent grain is also high in available P, K, and Mg generally; the sawdust and rice bran had the least nutrient status. The rice bran had C/N ratio of 1:23 while the sawdust C/N ratio was usually very high 1:75.

Among the types of animal manure used for amending the agro-industrial wastes, poultry manure had the highest values of % N, P, Ca, Fe and Mn compared to pig and goat manure. The manure had lower C/N ratio ranging from 6.72 to 7.93 and higher P status compared with the agro-industrial wastes.

It is therefore expected that mixing the animal manure with the agro-industrial wastes will enhance the effectiveness of improving nutrient availability.

Effect of Agro-Industrial Biomass on Amaranthus Leaf Chemical Composition

The sole and amended agro-industrial biomass increased the leaf N, P, K, Ca, Mg crude protein and ash content of amaranthus significantly ($p<0.05$) compared to the control treatment (Table 2).

Wood ash, spent grain, rice bran and sawdust incorporated with animal manure further increased the leaf N, P, K, Ca, Mg crude protein and ash. The sole and amended plant residues produced higher values of leaf Ca, Mg, P and K than the NPK fertilizer.

The spent grain treatment increased the values of amaranthus leaf Ca, Mg, P by 26%, 30% and 47% respectively compared to the wood ash treatment. Spent grain + poultry manure treatment increased the amaranthus leaf N, P, Ca, Mg, crude protein and ash by 56%, 33%, 14%, 26% and 18% respectively compared to the rice bran + poultry manure treatment.

Spent grain + poultry manure increased the leaf N, P, K, Ca, Mg, crude protein and ash of amaranthus by 12%, 34%, 17.40%, 96.3% 93%, 48% and 26% respectively compared to the NPK fertilizer treatment. It also increased the same parameters (N,P, K, Ca, Mg, crude protein and ash) by 98.9%, 94.4%, 98.0%, 93%, 93.10%, 98.7% and 92.4% respectively compared to the control treatment.

Generally, the rice bran and sawdust had the least values of leaf N, P, K, Ca, Mg, crude protein, and ash compared to the spent grain, wood ash and cocoa husk treatments.

The values of leaf P, Ca and Mg increased progressively throughout the four crops. There were high ratios of leaf K/Ca, K/Mg, P/Mg, in the amaranthus leaves: 1:35, 1:35 and 1:29 respectively under the NPK fertilizer treatment signifying nutrient interaction which could affect the amaranthus leaf quality in terms of nutrient utilization as noted by Bear (1950).

Effect of Agro-Industrial Biomass on the Growth and Yield Parameters of Amaranthus

The sole and amended agro-industrial biomass increased the plant height, leaf area, stem girth and root length (Table 3) and leaf yield of amaranthus (Table 4) significantly ($P<0.05$) compared to the control treatment.

The amendment of wood ash, cocoa husk, spent grain, rice bran and sawdust with animal manure increased the leaf area, plant height, stem girth, root length and leaf yield of amaranthus. However, agro-industrial wastes amended with pig and poultry manure increased the growth and yield parameters more than the amendment with goat manure. For example, the

TABLE 2
Effect of agro-industrial wastes plus manure on the leaf nutrient contents under the four crops of amaranthus

Treatment	N	P	K	Ca	Mg	Crude Protein	Ash content	Na
	%	%		%		%		%
Control (no fetilizer)	0.0286a	0.012a	0.019a	0.010b	0.005a	0.180a	1.143a	0.01a
NPK 15-15-15	2.3401	0.143d	0.8182e	0.005a	0.005a	8.652gk	16.275d	0.02b
Wood ash (sole)	1.379jk	0.145ef	1.7978q	0.864de	0.397de	8.620jk	18.16hi	0.06f
Wood ash + goat dung	2.423m	0.144de	1.1258p	0.0951fg	0.0357cd	15.140m	19.6731	0.04e
Wood ash + Pig dung	2.81no	0.1439de	0.7058b	0.11991m	0.604ij	15.51no	22.586t	0.04e
Wood ash + Poultry manure	2.529p	0.1951mn	0.8502h	0.0847d	0.033c	15.810p	20.43p	0.38d
Cocoa husk (sole)	1.184i	0.180l	0.9264i	0.0642c	0.0272b	7.400l	19.733m	0.06f
Cocoa husk + goat dung	2.474n	0.1584gh	0.8332fg	0.1064q	0.065kl	15.460n	21.01o	0.33c
Cocoa husk + pig dung	2.928tu	0.212p	1.3519u	0.1234m	0.063j	18.300tu	21.701r	0.09i
Cocoa husk + poultry manure	2.912t	0.214o	0.9536j	0.997gh	0.0652kl	18.200t	20.647n	0.06f
Rice bran (sole)	0.707c	0.122c	0.8315f	0.0929f	0.048f	4.420c	15.952c	0.04e
Rice bran + goat dung	0.967d	0.1682jk	0.9632j	0.1039i	0.60ij	6.040d	17.790f	0.06f
Rice bran + pig dung	1.011e	0.1661i	0.995m	0.1078ij	0.055gh	6.32e	17.966fg	0.07g
Rice bran + Poultry manure	1.173h	0.1449d	1.1018r	0.118k	0.054g	7.330h	18.114h	0.08h
Spent grain (sole)	1.046ef	0.1565g	1.1818t	0.11731	0.0567i	6.540ef	16.844e	0.06f
Spent grain + goat dung	2.587qr	0.1922m	1.2645t	0.1376o	0.082o	16.17qr	18.506j	0.08h
Spent grain + pig dung	2.56q	0.2343r	0.7877d	0.125mn	0.064jk	16.170qr	23.644u	0.04e
Spent grain + poultry manure	2.665s	0.2159p	0.99071o	0.1371o	0.0727m	16.660s	22.038s	0.07g
Sawdust (sole)	0.682b	0.1071b	0.990t	0.10451	0.0544g	4.260b	14.457b	0.07g
Sawdust + goat dung	1.007e	0.2235q	1.099n	0.1171	0.273p	6.290e	16.250d	0.08h
Sawdust + pig dung	1.089fg	0.1675ij	0.99m	0.139op	0.080n	6.810fg	18.873k	0.04e
Sawdust + poultry manure	1.332j	0.1781	1.1952o	0.1390p	0.072m	8.330j	21.236q	0.06f

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

cocoa husk + poultry manure treatment increased the plant height, leaf area, stem girth and root length by 35%, 19.40%, 29% and 7% respectively compared to the cocoa husk + goat dung treatment.

The NPK fertilizer increased the plant height and stem girth of amaranthus by 58.5% and 40% respectively compared to the wood ash (sole) treatment. However, spent grain + poultry manure treatment increased the leaf area and root length of amaranthus by 72% and 53% respectively compared to the NPK fertilizer. The leaves of amaranthus in the third and fourth crops of amaranthus under NPK fertilizer were showing signs of marginal burn.

The amended wood ash, cocoa husk, rice bran, spent grain and sawdust with poultry manure increased the root length of amaranthus by 47%, 42%, 41.58%, 53% and 27% respectively compared to NPK fertilizer treatment.

The spent grain (sole) treatment increased the amaranthus leaf yield by 39%, 79%, 64.2% and 59% in crops 1, 2, 3 and 4 respectively compared to rice bran treatment. Wood ash + poultry manure increased the leaf yield by 67%, 50%, 35% and 34% respectively in crops 1, 2 3 and 4 amaranthus compared to the sole application of spent grain.

Spent grain + poultry manure treatment increased the leaf yield of amaranthus in crops 1, 2, 3 and 4 by 3%, 13%, 2.2% and 2% compared to NPK fertilizer treatment. The spent grain + poultry manure increased the leaf yield of amaranthus by 98% and 99% in crops 1, 2, 3 and 4 respectively compared to the control treatment.

Generally, the spent grain, wood ash and cocoa husk treatments increased the leaf yield of amaranthus two times higher than that of rice bran and sawdust treatments.

The multiple regression analysis showing the relationship between amaranthus fresh leaf yield and nutrient contents of N, Mg, Na, P, K ash, crude protein and Ca for the four crops of

TABLE 3
The effect of agro-industrial wastes plus manure on the growth parameters of amaranthus four cropping

Treatments	Plant Height (cm)	Leaf Area (cm2)	Stem Girth (cm)	Root Length (cm)
Control (no fertilizer)	4.49a	2.51a	0.15a	3.47a
NPK 15-15-15	44.54v	21.20i	1.741p	13.47d
Wood ash (sole)	18.48f	18.6g	1.043f	16.81e
Wood ash + Goat dung	27.71o	25.131	1.063fg	18.63f
Wood ash + pig dung	26.80n	28.64p	1.40f	19.41h
Wood ash + poultry manure	33.80q	30.84r	1.326l	25.25pq
Cocoa husk (sole)	22.19hi	17.24f	1.173h	20.36i
Cocoa husk + goat dung	25.221	26.41n	1.253jk	21.58kl
Cocoa husk + pig dung	30.36p	30.29q	1.425no	23.45no
Cocoa husk + poultry manure	38.68st	32.78s	1.758pq	23.12n
Rice bran (sole)	13.55c	9.76b	0.785b	12.88b
Rice bran + goat dung	22.03h	15.70d	0.822c	20.45i
Rice bran + pig dung	23.31j	22.34j	1.383m	22.25m
Rice bran + poultry manure	24.78k	25.611m	1.038ef	23.02n
Spent grain (sole)	25.471m	27.95o	0.945d	24.35p
Spent grain + goat dung	35.05r	50.77t	1.063fg	25.92r
Spent grain + pig dung	38.02s	58.19u	1.028ef	28.20s
Spent grain + poultry manure	41.41u	74.72v	1.014e	28.90t
Sawdust (sole)	12.77b	11.40c	1.035ef	13.01c
Sawdust + goat dung	14.35d	16.03de	1.235l	18.82fg
Sawdust + pig dung	16.93e	19.21h	1.241ij	20.63ij
Sawdust + Poultry manure	18.97fg	22.78jk	1.415n	21.29k

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

TABLE 4
The effect of agro-industrial wastes plus manure on the fresh leaf yield (t/ha) under four cropping of amaranthus

Treatments	Crop 1	Crop 2	Crop 3	Crop 4	Mean
Control (no fertilizer)	0.15a	0.12a	0.123a	0.131	0.131a
NPK 15-15-15	7.50q	10.10u	11.63u	12.40u	10.40t
Wood ash (sole)	2.50ef	4.50j	6.40jk	6.98kl	5.095ij
Wood ash + goat dung	4.951	6.53m	8.28m	8.90m	7.115m
Wood ash + pig dung	6.95p	8.10p	9.88op	10.30p	8.808op
Wood ash + poultry manure	7.60s	8.98q	9.83o	10.53r	9.235pqr
Cocoa husk + (sole)	3.15k	4.70k	6.15i	6.43i	5.108ijk
Cocoa husk + goat dung	5.45n	6.70n	9.03n	9.45n	7.658mn
Cocoa husk + pig dung	6.55o	9.18r	9.93pq	10.48q	9.035pq
Cocoa husk + poultry manure	6.95p	9.28s	10.58s	11.25s	9.515qrs
Rice bran (sole)	1.40c	2.05c	2.38b	2.83b	2.165b
Rice bran + goat dung	2.50ef	3.13e	4.15e	4.55e	3.583de
Rice bran + pig dung	2.05d	2.80d	3.98d	4.33d	3.29d
Rice bran + poultry manure	2.95j	3.40f	4.90g	5.35g	4.145g
Spent grain (sole)	2.85h	3.68gh	6.651	6.93k	5.028i
Spent grain + goat dung	5.35m	7.45o	10.00r	9.85o	8.1639
Spent grain + pig dung	9.35t	9.85t	11.38t	12.23t	10.68tu
Spent grain + poultry manure	7.53qr	11.63v	11.90v	12.60v	10.915tuv
Sawdust (sole)	0.63B	1.38B	3.23C	3.45C	2.173BC
Sawdust + goat dung	2.88hi	4.23i	5.33h	5.60h	4.51gh
Sawdust + pig dung	2.45e	3.63g	4.53f	4.57f	3.84ef
Sawdust + poultry manure	2.78g	5.331	6.53j	6.55j	5.253ijkl

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

TABLE 5

Multiple regression equation showing relationship between amaranthus fresh leaf yield, the nutrient composition of % N, Mg, Na, P, K, ash, crude protein and Ca under four crops of amaranthus

Amount of residues	Regression equation	R2 Regression Coefficient
Crop 1	Y = 0.081 + 1.475x1 – 6.8442 + 6.782x3 + 0.266x4 + 0.252x5 + 0.041x6 + 1.638x7 + 3.41x8	0.90
Crop 2	Y = 0.44 + 1.09x1 + 7.084x2 + 0.573x3 + 2.180x4 + 1.78x5 + 1.07x6 + 0.669x7 + 4.41x8	0.92
Crop 3	Y = 0.53 + 1.84x1 + 0.07x2 + 0.08x3 + 0.12x4 + 1.29x5 + 2.06x6 + 1.06x7 + 4.38x8	0.94
Crop 4	Y = 0.184 +0.839x1 + 2.037x2 + 3.78x3 + 0.30x4 + 0.22x5 + 0.05x6 + 2.152x7 + 3.56x8	

Note : X_1 = %N, X_2 = %Mg, X_3 = Na, X_4 = p, X_5 = %k, X_6 = %ash, X_7 = %Ca and X_8 = Crude protein

amaranthus is presented in Table 5. The R2 values for crops 1, 2, 3 and 4 were 0.90, 0.92, 0.94 and 0.98 respectively. The implication is that leaf nutrient contents accounted for 90, 92, 94 and 98% in the yield variations of amaranthus respectively.

The bar graphs showing the effect of the sole agro-industrial biomass on leaf Mg, N, leaf area and leaf yield of amaranthus under the four crops were presented in *Figs. 1, 2, 3,* and *4* respectively. The graphs also revealed that there was a progressive increase in these parameters from crop 1 to crop 4 of amaranthus respectively.

DISCUSSION

The agro-industrial biomass such as wood ash, rice bran, cocoa husk, spent grain and sawdust were lower in plant nutrients such as N, P, K, Ca, Mg, Na, Fe, Zn, Cu and Mn compared to the animal manure such as poultry, pig and goat dung. Hence, they have a high C:N ratio and were expected to decompose more slowly. Thus, the combination of the animal manure with low C:N was also expected to improve the effectiveness of the agro-industrial wastes as a source of plant nutrients.

Rice bran and sawdust have relatively high C:N ratios compared to cocoa husk, spent grain and wood ash and this could be responsible for their greater resistance to decomposition and being less efficient in returning plant nutrients for the use of crops.

The agro-industrial biomass such as cocoa husk, wood ash and spent grain had relatively high N, P, K, Ca and Mg contents; hence, they were more effective in improving the leaf nutrients growth and yield of amaranthus. The generally low leaf status of N, P, K, Ca and Mg ash content and crude protein and poor growth parameters such as plant height, stem girth, leaf area and root length recorded for the control (no fertilizer; no manure) treatment might be traced to the initial poor soil fertility and continuous cultivation which had affected the leaf and application of agro-industrial wastes to enhancement of crop productivity in the tropics (Agboola 1982c).

Spent grain, wood ash and cocoa husk gave the best yield of amaranthus, this was consistent with the fact that spent grain had the best Ca and Mg contents of amaranthus leaf. Wood ash had relatively low C:N (11.76) and the highest Ca, K, Mg, Fe, Mn, Cu, Zn contents compared with other agro-wastes and it was also reflected in the best values of leaf N, K, crude protein and ash of amaranthus.

Cocoa husk had the least C:N (11.11) which implies that it decomposes faster and makes its nutrients more easily available compared with spent grain, rice bran and saw dust. Cocoa husk had the best leaf P and fairly high leaf N, K, Ca, Mg crude protein and ash contents. Cocoa husk has been found to be a good source of K for maize (Adu-Daaph *et al.* 1994).

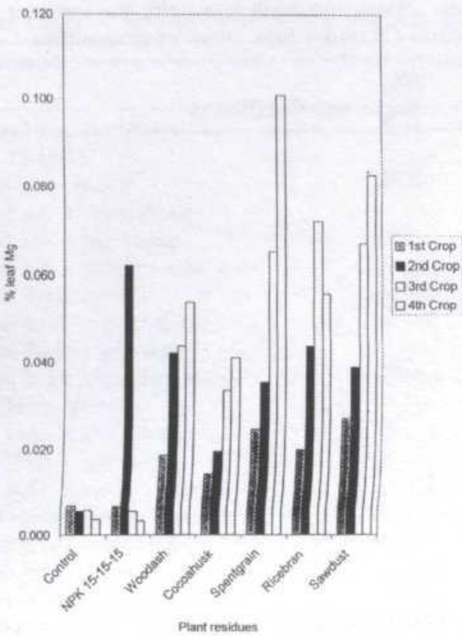

Fig. 1: The effect of plant residues on % leaf Mg under four crops of amaranthus

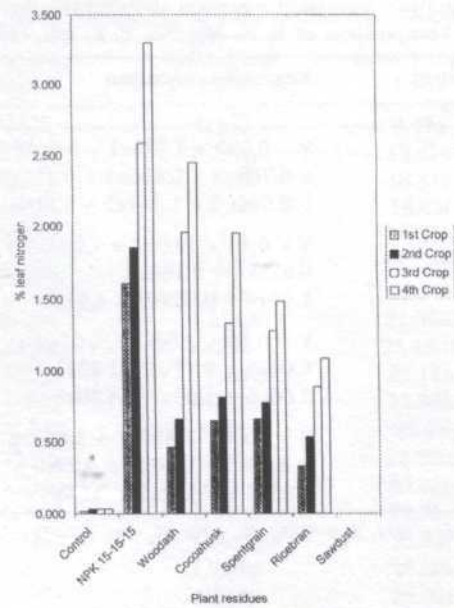

Fig. 2: The effect of plant residues on % leaf nitrogen of amaranthus under four crops

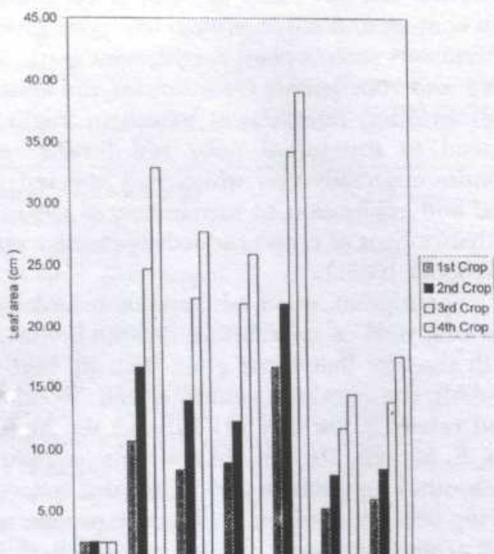

Fig. 3: The effect of plant residues on leaf area (cm^2) of amaranthus under four crops

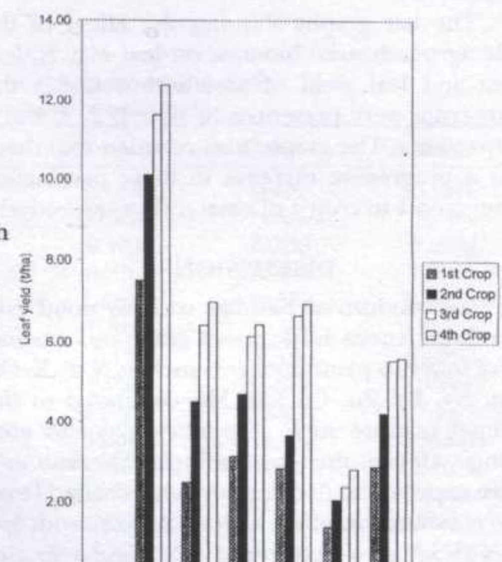

Fig. 4: The effect of plant residues on amaranthus leaf yield (t/ha) gross plot under four crops

amaranthus

crop. Accordingly, the amaranthus crop grown with sawdust and rice bran had the least yield, N, K, Ca, ash P, Mg contents and growth parameters. The poor performance attributed to sawdust and rice bran agreed with the fact that these residues had the least nutrient contents compared with wood ash, cocoa husk and spent grain. Sawdust had the least values of N, P, K, Ca, Mg and Zn while rice bran had relatively low N, Ca, Mg and Zn contents. Both sawdust and rice bran had C/N ratios of 75 and 23 respectively which would have reduced their rate of decomposition and nutrient release to crops.

The finding that the amendment of spent grain with pig and poultry manure gave the better values of amaranthus leaf yield in the four crops than NPK fertilizer, amended forms of wood ash, cocoa husk, rice bran and saw dust, could be attributed to the enhancement of its nutrient nutrients contents. This was also reflected in having the best leaf P, K, Ca, Mg and ash contents and these observations agreed with the work of Folorunso (1999) which reported that spent grain amended with pig and poultry manure gave the best yield of kora and amaranthus. He attributed this performance to the fact that spent grain reduced most soil bulk density which would have enhanced root growth, nutrient and water uptake. Besides, the high nutrient supplying power of spent grain + poultry manure to the crop was also mentioned as a contributory factor. The fact that amendment of spent grain, wood ash, cocoa husk, rice bran and sawdust with animal manure improved the plant height, leaf area, stem girth, root length, leaf nutrient status and leaf yield of amaranthus better than their sole forms agreed with the work of Titilayo (1982) which reported the nutrients' superiority of organically amended fertilizers over their sole forms.

Furthermore, Olayinka (1980) reported that amendment of sawdust with poultry manure increased maize plant height, dry matter yield, soil organic matter and uptake of N, P, K, Ca and Mg. Olayinka and Adebayo (1984) had also found that amendment of sawdust with dairy manure enhanced its decomposition.

The performance of NPK fertilizer in the improvement of growth parameters of amaranthus plant is consistent with the fairly high contents of leaf N, P and K.

The N, P, and K in the fertilizer are expected to be more readily available than those supplied by organic sources. Nitrogen is known to be mainly responsible for plant growth and protein synthesis (Ojeniyi 1984). Shortage of P is associated with reduction in plant growth and K is essential for carbon hydrate formation, synthesis of protein and promotion of mersitematic tissue (Tisdale and Nelson 1966).

However, as a result of continuous use of NPK fertilizer, the leaves of amaranthus were marginally burnt especially in the third and fourth crops and this could be adduced to an increased high ratio of K/Ca, K/Mg and P/Mg that resulted in nutrient interaction. It also agreed with the observation of Ojeniyi (1984) and Folorunso *et al.* (1995) who indicated that the continuous use of inorganic fertilizers might lead to nutrient imbalance, hidden hunger in crops and poor nutrient uptake.

The high R^2 values showing the relationship between the amaranthus leaf yield and leaf nutrient contents justified the fact that the use of agro industrial biomass encouraged increased harvest of leaf yield and this is of great importance to the amaranthus producers who will realise more income from the produce.

CONCLUSION

Application of wood ash, ground cocoa husk, rice bran, spent grain and sawdust increased availability of nutrients to amaranthus, thereby increasing its leaf yield. Wood ash, spent grain and cocoa husk were more effective while the amendment of the residues with animal manure increased their effectiveness as sources of plant nutrients.

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