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EFFECTS OF HYACINTH RESIDUES ON CHEMICAL PROPERTIES AND PRODUCTIVITY OF DEGRADED TROPICAL SOILS

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ABSTRACT

Water hyacinth (Eichhornia crassipes) is an aquatic weed that has blocked many navigable water-ways in the tropics. Attempts have been made to control or erradicate it to no avail. Its capacity to produce large biomass in a short time could be explored to seek other ways of utilizing it as a biofertiliser. An evaluation of the potential of water hyacinth (WH) residue as a biofertiliser was carried out in the green-house using a split-plot in a Radomized Complete Block Design (RCBD) experiment with three replications of each treatment. Top soil samples taken from an Entisol, Lithic Usorthent, (S1) and an Ultisol, Typic Paleustult, (S2) constituted the main plot treatments, whereas the sub-plot treatments were control (C), inorganic fertilizer (N-P-K-Mg at the rates of 240, 60, 240 and 80 kg/ha) (F), 20 t/ha water hyacinth (WH1), WH1 + F, 40 t/ha water hyacinth (WH2), WH2 + F, WH1 + 20 t /ha rice mill waste (WH1 + RW1), WH1 + 20 t/ha poultry droppings (WH1 + PD1) and WH1 + 10 t/ha RW and 10 t/ha PD (WH1 + RW1 +PD1). All amendments were mixed with the soils and incubated for 10 days before planting. The F treatment was applied at maize planting. Data were collected on maize performance and changes in soil chemical properties. Results showed that exchangeable cations, CEC, OC, total N, available P and pH increased in the WH-amended soils relative to the controls in both S1 and S2. The more fertile S1 benefited from these amendments more than S2 and showed that maize performance during the first cropping was better on S1 than S2, whereas during the residual cropping the crop performed equally well on both soils. Lower maize dry matter yields occurred in the residual than the first cropping. Also the less fertile S2 had higher residual effect of the residues than S1. Generally, WH mixed with either PD or RW or both performed better than when used alone. These results indicate that WH has a lot of potential for use as a biofertilizer on these low-fertile, fragile, tropical soils, especially if mixed with PD or PD+RW.

Key words: Soil chemical properties; Soil fertility improvement; Maize performance; Water hyacinth residues; Poultry manure; Rice mill wastes; Nigeria.

INTRODUCTION

One of the important ways of improving soil nutrient status and enhancing continuous soil productivity is through the use of organic residues. Application of organic residues plays an important role in improving crop yields. To evaluate the agronomic potential of organic wastes on degraded soils, it is essential to consider the positive impact of their use on the chemical properties of such soils. For soils with good structure, improvements in the physical properties are not as primarily important as enhanced chemical properties due to organic waste application (Mbagwu et al., 1994).

Increase in the use of commercial fertilizers had brought about improvements in crop yields (Obi and Molindo, 1995), though problems of soil acidity associated with this use became rampant (Obi and Akinsola, 1995; Blevins et al., 1983). Also increased use of inorganic fertilizers within developing countries posed a considerable financial problem in these areas (FAO, 1983), hence the need to explore other sources of soil amendment. Some of these sources include wastes from agriculture, industries, urban and domestic sewage and aquatic environment.

The aquatic environment is the most unexplored source of organic waste materials. Some weeds in this environment are obnoxious, constituting environmental nuisance. A typical example in the Nigerian aquatic environment is the water hyacinth (*Eichhornia crassipes*) which has persistently caused environmental problems in the coastal waters of Nigeria.

Within the sub-saharan Africa, investigations on the agronomic value of water hyacinth (WH) are scarce. Most of the information on the potential of this weed as a soil amendment had been obtained mainly from Asia where it was observed to improve crop yields due to enhanced nutrient status of the soils (Venkataramanan et al., 1984; Utomo, 1981).

Water hyacinth suppresses other aquatic weeds as it forms green carpets on a large expanse of water surface Irrigation and drainage channels are clogged, hydroelectric installations are blocked and fisheries are seriously affected whereever this weed invades (Rady, 1997). Other than the ordinary nuisance, the WH poses some environmental health hazards by providing ideal breeding ground for mosquitoes, other kinds of insects and snails. These insects are carriers of diseases such as malaria and yellow fever. The snails are important in the life cycles of blood and liver flukes which are vectors of diseases such as schistosomiasis and fascioliasis (Rady, 1979).

The ability of WH to produce large biomass in a short time could be beneficial to mankind (Center and Durden, 1986; Kay and Haller, 1986; Rosemond et al., 1984; Haller and Tag El-Seed, 1977). The objective of this preliminary investigation was to characterize WH residue chemically and determine to what extent its use would improve the chemical properties and maize growth and yield on two degraded soils when it is used alone or combined with inorganic fertiliser, poultry manure and/or rice mill waste. It is hoped that the results of this study, if validated in the field, would help to solve the problems of use of the huge amounts of WH residues produced annually in Nigeria for crop production.

MATERIALS AND METHODS

Sample Collection

Top soil (0-15 cm) samples of a clay Entisol (*Lithic Usorthent*, S1) and a loamy sand Ultisol (*Typic Paleustult*, S2) were used for this study. Both soils are degraded due to less than optimum soil physical and chemical properties (Mbagwu, 1992). Both soil samples and poultry droppings (PD) were collected from the University of Nigeria at Nsukka. Water hyacinth (WH) was collected from a lagoon within the Lagos area of Nigeria where it abounds and rice mill waste (RW) from Adani, near Nsukka. A local variety of maize (*Zea mays* L.) was used as the indicator crop.

Experimental Design

The layout for this experiment was a split-plot in a Randomized Complete Block Design (RCBD) with each treatment replicated three times. This investigation examined the influence of application rates of WH, with and without inorganic fertilizer (F), RW and PM on soil chemical properties and on yield of maize. The soil samples (S1 and S2) were the main plot treatments whereas the amendments were the sub-plot treatments which were made up of the following:

(1) C.......Control
(2) F.......Inorganic fertiliser, (N, P, K and Mg at 240, 60, 240 and 80 kg/ha, respectively)
(3) WH1......20 t/ha water hyacinth residues
(4) WH1+F...20 t/ha WH+inorganic fertilizer
(5) WH2......40 t/ha water hyacinth residues
(6) WH2+F....40 t/ha WH+inorganic fertilizer
(7) WH1+RW1...20 t/ha WH+20 t/ha rice mill wastes (RW)
(8) WH1+PD1... 20 t/ha WH+20 t/ha poultry droppings (PD), and
(9) WH1+RW0.50+PD0.50...20 t/ha WH+10 t/ha RW+10 t/ha PD.

Experimental Procedure

The soil samples and the poultry droppings (PD) were air-dried at about 25°C and passed through a 2 mm sieve. The water hyacinth (WH) was cut to small pieces after oven-drying at 55°C for 48 h. while RW which needed no sieving was also dry enough for the study.

In both experiments, WH (with or without conditionig with F, RW and PM) was mixed with 2 kg of the soil samples and incubated at field capacity (FC) moisture content for 10 days in perforated 4 kg-capacity clay pots. The incubation was needed to detoxify any harmful materials produced during WH decomposition. Thereafter, eight (8) maize grains were planted per pot and thinned down to three (3), seven days after germination (7 DAG). Germination counts were taken daily from the first day of germination to the 7th day, by which time germination had ceased in all the treatments. Plant hieghts were recorded weekly from the 7th day of germination for six (6) weeks at the end of which the plants were harvested. On each treatment dry matter yield of maize shoot was recorded in g/pot. The second planting followed immediately using the same procedure as the first planting to ascertain the residual effects of WH (straight or mixed) treatments on maize growth and dry matter yields and on soil chemical properties.

Laboratory Analyses

Detailed chemical characterisation of the soil samples and WH, RW and PD were carried out by the methods of Anderson and Ingram (1993). The soil/amendment mixtures were air-dried after first cropping with careful removal of plant roots in preparation for laboratory analyses. These analyses included pH in 1:2.5 soil/water ratio. Cation exchange capacity (CEC) was determined by the NH_4OAc displacement method (Jackson, 1958) and exchangeable acidity by the titrimetric method after extraction with 1.0 M KCl (McLean, 1965). After extraction with neutral NH_4OAc solution, the Ca and Mg in the leachate were determined by Atomic Absorption Spectrophotometry (AAS) whereas the Na and K were obtained by flame photometry. Total N was determined by the macro Kjedahl digestion method (Bremner and Mulvaney, 1982) while OC was

Table 1: Some chemical properties of the 0-20 cm of the two soils.

Property	Value	
	Entisol (S1)	Ultisol (S2)
Sand (%)	34.0	84.0
Silt (%)	18.0	2.0
Clay (%)	48.0	14.0
Texture	Clay	Loam sand
pH (1:2.5 H_2O)	4.92	5.98
OC (%)	2.07	0.20
Total N (%)	0.18	0.02
Avail P (Bray II, ppm)	14.7	7.36
CEC (Cmol(+)/kg)	7.0	3.0
Exch.bases(Cmol(+)/kg		
Na	0.04	0.05
K	0.20	0.30
Mg	1.40	0.40
Ca	3.67	2.00
Al+H	1.00	0.60
Total Fe (%)	10.93	2.64
Total Al (%)	0.98	0.20
Total Mn (%)	0.013	0.003
C/N ratio	11.78	10.00
Saturation water (%)	72.6	5.1

measured by the Walkley and Black (1934) wet oxidation method and converted to OM by multiplying by 1.724. Available P was determined by the Bray II method of Bray and Kurtz (1945). These determinations were also made on the WH, RW and PD. Some of the characteristics of the soils are shown in Table 1. The characteristics of these amendements are given in Table 2 whereas the nutrients contained in each treatment are shown in Table 3.

Table 2: Some chemical properties of water hyacinth residue, rice mill waste and poultry droppings

Property	Value[1]		
	WH	RW	PD
pH (1:10 H_2O)	5.89	5.76	7.22
OC (%)	31.92	32.11	22.94
Total N (%)	2.55	0.73	2.86
Total P (%)	0.24	0.055	0.182
Total Mg (%)	4.30	0.92	1.28
Total Na (%)	0.43	0.20	0.35
Total K (%)	0.47	0.80	1.80
Total Ca (%)	0.16	1.08	2.56
C:N ratio	12.52	43.99	8.02
C:P ratio	13.30	58.38	12.60
N:P ratio	1.06	1.33	1.51

1. WH = water hyacinth; RW = rice mill waste; PD = poultry droppings.

Data Analysis

Measured data were analyzed according to the procedure for the split-plot in a Randomized Complete Block Design (RCBD) as outlined by Little and Hills (1978).

Table 3: Total amount of major nutrients (mg/kg) contained in each treatment.

Treatment	N	Na	P	K	Mg	Ca	OC
Entisol (S1)							
C	1800	9.20	7.36	78	168	734	20700
F	1920	9.20	37.36	198	208	734	20700
WH1	2055	52.2	31.36	125	598	750	23892
WH1+F	2175	52.2	61.36	245	638	750	23892
WH2	2310	95.2	55.36	172	1028	766	27084
WH2+F	2430	95.2	85.36	292	1068	766	27084
WH1+RW1	2128	72.2	36.86	205	690	830	27103
WH1+PD1	2341	87.2	49.56	305	726	1290	26186
WH1+ RW0.5+ PD0.5	2235	79.7	43.21	225	708	1060	26645
Ultisol (S2)							
C	200	11.5	14.7	117	48	400	2000
F	320	11.5	44.7	237	88	400	2000
WH1	455	54.5	38.7	164	478	416	5192
WH1+F	575	54.5	68.7	284	518	416	5192
WH2	710	97.5	62.7	211	908	432	8384
WH2+F	830	97.5	92.7	331	948	432	8384
WH1+RW1	528	74.5	44.2	244	570	496	8403
WH1+PD1	741	89.5	56.9	344	606	956	7486
WH1+ RW0.5+ PD0.5	635	82.0	50.6	294	588	726	7945

The LSD test was used to detect differences between treatment means (Obi, 1988). The per cent dry matter yield increase over the control (PI) was calculated for each treatment thus:

$$PI = (Ya/Yc - 1) \times 100 \qquad (1)$$

where Ya is yield due to amendment and Yc is yield in control.

The per cent reduction in yield during the second cropping over the first cropping (PR) was calculated as follows:

$$PR = \{1-(Ys/Yf) \times 100\} \qquad (2)$$

where Yf is yield during the first cropping and Ys is yield during the second cropping. The per cent residual effect of the amendments during the second cropping (RE) is given as:

$$RE = (Ys/Yf) \times 100 \qquad (3)$$

where Ys and Yf are as defined in Eq. 2.

RESULTS AND DISCUSSION

Changes in Soil Chemical Properties

Soil Exchange Properties

Application of WH increased the CEC and exchangeable bases of the two soils as shown in Table 4. The WH residue is an important source of these bases which contributed to the relatively high CEC of the soils. The S1 and S2 are dominated by kaolinite (a 1:1 clay mineral) (Mbagwu and Abeh, 1998). Therefore, the observed improvement in CEC was mainly due to increased OC

Table 4: Exchange properties (Cmol(+)/kg) of two soils treated with organic and inorganic amendments.

Soils	Treatments	Na	K	Mg	Ca	CEC	Al+H
Entisol (S1)	C	0.17	0.06	0.6	3.7	6.5	1.0
	F	0.13	0.80	0.6	3.3	7.0	1.0
	WH1	0.20	1.20	0.8	4.7	8.0	0.6
	WH1+F	0.17	1.10	0.8	3.9	8.5	0.8
	WH2	0.20	1.40	0.9	4.1	9.5	0.6
	WH2+F	0.27	1.80	1.2	4.6	10.0	0.6
	WH1+RW1	0.20	1.00	1.0	3.8	10.0	0.6
	WH1+PD1	0.25	1.70	2.0	7.6	13.0	0.6
	WH1+RW0.5+ PD0.5	0.17	1.00	3.5	3.1	8.0	0.6
Means		0.20	1.18	1.27	4.30	8.83	0.71
Ultisol (S2)	C	0.11	0.05	0.6	1.4	3.0	0.6
	F	0.11	0.30	0.5	1.3	3.0	0.6
	WH1	0.11	0.40	0.7	1.6	4.0	0.6
	WH1+F	0.13	0.60	0.8	1.8	4.5	0.4
	WH2	0.13	0.60	0.8	2.0	5.0	0.6
	WH2+F	0.13	0.60	0.9	2.0	5.0	0.4
	WH1+RW1	0.13	0.60	0.7	1.4	5.5	0.6
	WH1+PD1	0.11	0.40	0.6	3.5	9.5	0.4
	WH1+RW0.5+ PD0.5	0.10	0.40	1.4	2.2	8.0	0.6
Means		0.12	0.44	0.78	1.91	5.17	0.53
LSD (0.05):	Soils (S)	0.03	0.26	0.18	0.85	1.30	0.07
	Amendments (A)	0.01	0.07	0.14	0.23	0.46	0.03
	SxA	0.01	0.08	0.12	0.27	0.47	0.03

resulting from application of ordinary or mixed WH. This was expected because OM more than inorganic clay colloids contributes to the CEC of soils that are low in OM and clay contents (Mbagwu et al., 1994; Asadu et al., 1997). The pH of the F treatment increased in S1 but decreased in S2 as shown in Table 5. This result emphasizes the differential performance of inorganic fertilizer on soils and suggests that certain characteristics of the soils may be implicated in this response. On both soils the highest increase in pH was obtained in the WH1+PD1 treatment, which implies that this treatment which also had the highest amounts of Ca (Table 3), acted as a liming material in these soils.

The increased exchange properties were due to mineralization of applied WH residue with consequent release of nutrients. In both soils, improvements in exchange properties reflected in the increasing rate of WH application. However, in S1 for WH+F treatment, Na, K, Ca and CEC values were lower than those for the preceeding WH1 alone treatment. This trend also reflected in the exchangeable acidity (Al^{3+} + H^{+}) which was higher in the WH1+F than WH1 alone treatments. Perhaps, on the one hand, the inorganic fertilizer in this treatment might have induced slight increase in acidity which possibly affected microbial activities during mineralization, thus keeping the exchangeable bases low. On the other hand, the inorganic fertilizer might have induced more rapid mineralization, the nutrients of which were utilized by the maize plants as was suggested by Mbagwu (1992) and confirmed by the observed yield increases (Tables 6, 7, 8, and 9).

Table 5: Residual OC, total N, available P and pH levels of the two soils treated with organic and inorganic amendments.

Soils	Treatments	OC (%)	Avail P (ppm)	Total N (%)	pH (H_2O)
Entisol S1)	C	2.51	4.8	0.21	4.97
	F	2.83	9.7	024	5.07
	WH1	3.19	17.7	0.27	5.34
	WH1+F	2.91	17.7	0.26	5.18
	WH2	2.95	27.4	0.26	5.19
	WH2+F	3.23	32.2	0.28	5.17
	WH1+RW1	2.55	64.4	0.23	5.40
	WH1+PD1	3.43	16.1	0.28	6.04
	WH1+ RW0.5+ PD0.5	3.59	27.4	0.31	5.74
Means		3.02	24.4	0.26	5.34
Ultisol (S2)	C	0.36	6.4	0.036	5.99
	F	0.32	9.7	0.033	5.86
	WH1	0.64	24.4	0.068	6.71
	WH1+F	0.72	29.0	0.068	6.22
	WH2	0.64	37.0	0.068	6.55
	WH2+F	0.56	38.6	0.055	6.25
	WH1+RW1	1.08	25.8	0.095	6.20
	WH1+PD1	0.84	120.8	0.080	6.77
	WH1+ RW0.5+ PD0.5	0.64	56.4	0.062	6.24
Means		0.64	38.7	0.063	6.31
LSD (0.05):					
Soils (S)		1.68	10.25	0.140	0.69
Amendments (A)		0.11	9.13	0.010	0.10
SxA		0.42	9.14	0.030	0.18

Similarly, when WH was mixed with PD in S2 it did not improve the exchangeable Na content and also decreased exchangeable K and Mg. Furthermore, as was the case with WH+F treatment in S1, probably, there was rapid mineralization with consequent utilization of released nutrients by the maize crop as reflected in yield increases shown in Tables 6, 7, 8 and 9. Mbagwu (1992) had shown that RW and PM had rapid mineralization rates (0.00189 and 0.00297 per day, respectively) which would ensure that where they are mixed with WH, improvements in mineralization rate of WH would result.

Improvements in exchangeable properties of soils due to organic residue application were also reported by Mbagwu (1992). With application of WH on the acidic S1, exchangeable acidity decreased relative to the control, possibly due to removal of Al^{+} from the soil exchange sites by OM from decomposing WH. This agrees with the observations of Hargrove and Thomas (1981). The reduction may also be due to the neutralization of Al^{3+} by Ca and Mg released by the decomposing WH residues as observed with other decomposing wastes (Mbagwu et al., 1994).

Changes in OC, total N available P and pH

Increasing rates of mixed or straight WH in both soils improved their OC, total N and available P relative to

Table 6: Influence of organic and inorganic fertilizer on maize performance on two soils during the first cropping.

Trts[1]	Germination (%)			Plant height (cm)			DMY[2](g/pot)		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
C	95.8	87.5	91.7	22.5	23.7	23.1	2.64	1.96	2.30
F	95.8	91.7	93.8	33.7	30.5	32.1	5.08	3.50	4.29
WH1	95.8	83.3	89.6	48.3	46.9	47.6	12.04	7.17	9.61
WH1+F	87.5	83.3	85.4	54.7	45.9	50.3	14.71	7.60	11.12
WH2	87.5	91.7	89.6	54.0	45.4	49.7	14.17	8.33	11.25
WH2+F	83.3	95.8	89.6	53.4	36.0	44.7	12.73	8.46	10.60
WH1+ RW1	87.5	91.7	89.6	51.8	35.9	43.9	10.69	6.60	8.65
WH1+ PD1	95.8	95.8	95.8	52.9	42.5	47.2	13.17	8.49	10.83
WH1+ RW0.5+ PD0.5	75.0	95.8	85.4	51.0	40.5	45.7	13.00	6.63	9.82
Mean	89.3	90.7	-	46.9	38.6	-	10.91	6.53	-
LSD (0.05)									
Soils(S)	NS			5.11			3.16		
Amendments (A)	10.2			8.09			1.97		
SxA	NS			NS			2.65		

NS = not significant

1. Symbols as explained in the text; S1 = Entisol; S2 = Ultisol.
2. DMY = dry matter yield of maize shoot.

Table 7: Influence of organic and inorganic fertilizer on maize performance on two soils during the second cropping.

Trts[1]	Germination (%)			Plant height (cm)			DMY[2](g/pot)		
	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
C	75.0	91.7	83.3	20.1	24.3	22.2	2.26	1.62	1.94
F	75.0	91.7	83.3	19.1	26.4	22.8	1.96	1.89	1.93
WH1	87.5	87.5	87.5	24.8	30.9	27.8	3.43	3.49	3.46
WH1+F	66.7	100.0	83.3	26.3	28.4	27.3	3.75	3.68	3.72
WH2	87.5	91.7	89.6	29.8	32.6	31.2	4.77	4.65	4.71
WH2+F	79.2	95.8	87.5	32.2	29.4	30.8	5.16	4.18	4.64
WH1+ RW1	100.0	91.7	95.8	35.7	37.6	36.6	4.53	3.52	4.03
WH1+ PD1	100.0	91.7	95.8	44.9	39.9	42.4	6.70	5.13	5.92
WH1+ RW0.5+ PD0.5	100.0	91.7	95.8	44.1	37.8	40.9	5.52	4.39	4.96
Mean	85.7	92.2	-	30.8	31.9	-	4.23	3.62	-
LSD (0.05)									
Soils(S)	5.06			NS			0.38		
Amendments (A)	4.93			3.25			0.52		
SxA	NS			NS			NS		

NS = not significant

1. Symbols as explained in the text; S1 = Entisol; S2 = Ultisol.
2. DYM = dry matter yield.

Table 8: Dry matter yield increase (%) over the control and reduction during the second cropping (%) following organic and inorganic amendments.

Trt[1].	First cropping		Second cropping		Per cent reduction	
	S1	S2	S1	S2	S1	S2
C	-	-	-	-	14.4	17.3
F	92.4	78.6	-13.3	-16.7	61.4	46.0
WH1	356.1	265.8	51.8	115.4	71.5	51.3
WH1+F	457.2	287.8	65.9	127.2	74.5	51.6
WH2	436.7	325.0	111.1	187.0	66.3	44.2
WH2+F	382.2	331.6	128.3	158.0	59.5	49.8
WH1+RW1	304.9	236.7	100.4	117.3	57.6	46.7
WH1+PD1	398.9	333.2	96.5	216.7	49.1	39.6
WH1+ RW0.5+ PD0.5	392.4	238.3	144.2	204.3	57.5	33.8
Mean	352.6	262.1	98.1	138.7	56.9	42.3
LSD (0.05)	28.8	21.0	16.0	18.5	4.2	2.6

1. As explained in the text. S1 = Entisol; S2 = Ultisol.

the control (Table 5). In comparison to that before planting, pH increased in both soils with WH application, although no significant differences were observed between the values of these treated soils and the control. The F treatment recorded the least value in both soils, a trend that was also observed in exchangeable acidity (Table 4). The highest increases in these properties occurred when WH was mixed with RW and PD. This shows that mixing WH with these agricultural wastes improved these soil parameters more than increasing the application rate of WH.

Relative to the control, improvements in OC and total N were higher on the Ultisol (S2) than on the Entisol (S1) because S1 contains higher levels of these nutrients (Table 5). Improvements in OC in S1 and S2 over the controls were 43% and 20%, respectively, and in total N, 47.6% and 163.9%, respectively. For similar reasons, relative improvements in available P and soil pH levels were higher on S1 than S2. This observation corroborates similar findings by Mbagwu et al. (1994), Mbagwu et al. (1991), Mbagwu and Piccolo (1990) and Bernal et al. (1992) who used organic residues from other sources as soil amendments.

SOIL PRODUCTIVITY

Maize Germination

As shown in Tables 6 and 7, the average percent germinations of 89.3 and 90.7 in S1 and S2, respectively during the first cropping and 85.7 and 92.2, respectively during the second cropping were very good. However, they contrasted with an earlier study by Ahmed et al. (1982) in which they observed that germination and growth of raddish seedlings were inhibited by aqueous extracts of WH leaves and rhizomes. This may imply that using dehydrated WH is better than using the aqueous extracts of WH leaves and rhizomes as biofertilizers. During the second cropping, shown in Table 7, no regular pattern was observed in the germination count in S1 and during both croppings in S2.

On S2 the residual cropping was better than the first by only 1.7% in germination count while on S1 the first cropping was better than the residual cropping by 4.2% (Tables 6 and 7). Generally, germination was very good on both soils since these differences are not significant. However, there was significant difference ($P<0.05$) between the two soils during the second cropping (Table 7). The S2 performed better than S1 because S2 is generally better aerated because of its sandy texture (Table 2).

The effects of WH mixed with RW and PD on maize performance are also shown in Tables 6 and 7. No sequential order in germination was observed on S1 during the first cropping and differences were not significant at $P<0.05$. During the residual cropping on the same S1, all treatments but the control (75%) had 100% germination. On S2, during the first and residual croppings, no significant effects were observed on germination counts. Although WH amendment did not outperform the control in germination, it neither retarded nor inhibited germination.

Crop Growth

Water hyacinth (WH) residues stimulated maize growth as was observed during plant height measurements shown in Tables 6 and 7. Similar results were recorded by others (Roy, 1979; Chakraverty, 1984; Utomo, 1981). Overall, the tallest plant of 54.7 cm at harvest was recorded in the WH1+F treatment during the first cropping while the shortest one of 19.1 cm was observed in the F treatment during the second cropping (Tables 6 and 7).

In mixing WH with RW and PD also shown in Tables 6 and 7, there were no observable regular patterns in plant heights in both soils, though all treatments performed better than the controls during both croppings. Generally, there were significant treatment effects ($P<0.05$) in all cases, even though the F and control treatments had similar heights. No significant interactions were observed in all cases but there was significant difference between the soils, with S1 outperforming S2 during the first cropping (Table 6). This implies that the effect of WH on maize growth is soil-specific. In all these cases, except for the increasing rates of WH during the second cropping (Table 7), the tallest plants were observed on S1 which is more fertile than S2 (Table 3).

Dry Matter Yield of Maize Shoots

Maize shoot dry matter yields were better on the more fertile S1 than S2 (Tables 6 and 7). With increasing rate of WH, there was no significant difference between the two soils during the second cropping. In all other cases, there were significant differences ($P<0.05$) in dry matter yields between the two soils. The treated soils (except F) performed significantly better than the controls. However, during the first cropping, the F treatment on S1 was lower than the other treatments but slightly higher than the control. There was no observable sequence in improvements in yield over the control as WH rates increased during the first cropping. Here, the highest yield was obtained in WH+F treatment. During the second cropping, increases in maize dry matter yields with increased rate of WH reflected a regular pattern on S1 except on the F treatment which performed less than the control. Here, the highest yield was observed in the WH2+F treatment. The less fertile S2 reflected a near complete regular pattern of yield increases over the control as the treatment rates increased during both the first and second croppings.

Using WH mixed with RW and PD during the first cropping in the two soils did not give as much dry matter yield as with increasing rates of WH although there were significant yield increases over the control. The WH1+PD treatment recorded the highest yield on both soils during the two croppings. These improvements in yields were most likely as a result of enhanced nutrient status of the soils due to the WH amendments (Table 3). Similar results were observed by Mbagwu et al. (1994) when they used dehydrated swine waste to improve the productivity of similar soils. Also Chakraverty (1984),

Table 9: Estimate of residual effect (%) of water hyacinth conditioned with inorganic fertilizer, rice mill waste and poultry dropping on two degraded soils in Nigeria.

Amendments	S1 (Entisol)	S2 (Ultisol)
C	85.6	82.7
F	38.6	54.0
WH1	28.5	48.7
WH1+F	25.5	48.4
WH2	33.7	55.8
WH2+F	40.5	49.4
WH1+RW1	42.4	53.5
WH1+PD1	50.9	60.4
WH1+RW0.5+PD0.5	42.7	66.2
Mean	43.2	57.7
LSD (0.05)	4.2	2.6

Mohan (1984), Kondap et al. (1981) and Utomo (1981) recorded yield increases with WH as soil amendment. Lower yields on F treatments in comparison to others (except the control) may be due to the incapacity of the inorganic fertilizer to ameliorate degraded soil physical properties as well as low nutrient status of soils treated with inorganic fertilizer (Table 3).

The WH might have released some organic compounds (especially polysaccharides and microbial gums) during decomposition and mineralization which were capable of improving degraded soil physical and chemical fertility (Spaccini et al., 2002). Although two times the locally recommended rate of inorganic fertilizer for maize production was used in this study, the results have shown that there is still need for addition of organic amendments to improve the chemical properties of these degraded soils.

The per cent dry matter increases over the control shown in Table 8 indicated that increases were higher on S1 than S2 during the first cropping whereas S2 recorded higher yield increases over the control than S1 during the residual cropping. This meant that the residual effect of WH (Table 9) was more obvious on the less fertile S2 than S1. Except for the control, the per cent yield reduction during the residual cropping in both soils was higher in the more fertile S1 than S2. It also indicated higher residual effect due to WH on S2 than S1. These results may be explained by the higher inherent fertility of S1 than S2.

CONCLUSION

The following conclusions can be drawn from these results: (1) Water hyacinth (WH) is a useful soil amendment; (2) It performs best when mixed with rice mill waste and poultry droppings; (3) The essential plant nutrients contained in WH are released during mineralization to the extent that they supported plant growth; and (4) Optimum rate of application for maximum maize yield is soil-dependent but when conditioned with PD, lower rates of about 20 t/ha produced more yields than higher rates. It is suggested that such a study be carried out in the field to validate these greenhouse results.

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