Response By Pearl Millet To Soil Incorporation Of Waterhyacinths[1]

JOSE V. PARRA[2] AND CHARLES C. HORTENSTINE

Graduate Assistant and Professor, Soil Science Department, University of Florida, Gainesville, Florida 32611

ABSTRACT

Fresh waterhyacinths [*Eichhornia crassipes* (Mart.) Solms.] were spread on field plots of Wachula fine sand at rates of 0, 15,000, and 30,000 kg/ha (dry matter) and after 4 weeks were incorporated to a depth of 15 cm during land preparation. Pearl millet [*Pennisetum americanum* (L.) K. Shum, CV. Pearlex 21] was grown as the indicator crop. Fertilizer rates were 0-0-0, 30-13-25, and 60-26-50 kg/ha of N-P-K. After the first harvest, 80 kg/ha of N were applied to all treatments. The millet was harvested twice for yields and nutrient uptake analysis. Pearl millet yields were higher on all waterhyacinth treatments than on fertilizer-only treatments. In the second harvest, mineral fertilizer depressed yields and nutrient uptake on plots amended with waterhyacinths. The level for maximum yield was 27,000 kg/ha of waterhyacinths. Carbon, N, P, K, Ca, Mg, Zn, Mn, and Cl content and effective cation exchange capacity of Wachula fine sand were all increased by incorporation of waterhyacinths.

[1]Contribution from the Soil Science Department, Florida Agricultural Experiment Station, Gainesville, as Journal Series No. 8022. This study was supported in part by a Florida Department of Natural Resources Research Grant.

[2]Research Scientist, Standard Fruit Company, Limon, Costa Rica.

INTRODUCTION

Organic sources of nutrients, particularly organic-N compounds and organic chelates of heavy metals, may have unique value in plant nutrition under some circumstances because of their solubility or because of their steady release of available forms of nutrient elements (2, 4, 7, 32, 37). The benefits to be derived from incorporation of organic matter (OM) into the soil have been well documented (5, 15, 38). These become of paramount importance in sandy soils, which are low in OM and void of most plant nutrients. Waterhyacinths contain fairly high concentrations of plant nutrients as compared to other species and would be very desirable green manures (10, 20, 22). The objective of this study was to determine the response of pearl millet to field incorporation of fresh waterhyacinths, and the resulting change in soil chemical conditions from a plant nutrition point of view.

MATERIAL AND METHODS

The experiment was established on a Spodosol classified as Wachula fine sand (Ultic Haplaquod). The experimental area (480 m^2) was sampled to a depth of 15 cm for physical and chemical analyses prior to land preparation. On 19 March 1974 the area was limed with 138 kg each of dolomitic and calcitic limestone. After disking, plots 2 by 5 m were marked. During the period of 31 April to 31 May 1974 fresh waterhyacinths removed from Lake Alice on the University of Florida campus were allowed to dehydrate and decompose partially before being incorporated on 4 June. The experimental design was a factorial with three rates of mineral fertilizer application (1=0-0-0, 2=30-13-25, and 3=60-26-50 kg/ha of N-P-K), and three rates of waterhyacinths 1=0, 2=15,000, and 3=30,000 kg/ha, dry weight). The treatments were arranged in a randomized complete-block design with four replications. Fertilizer used was from commercially available sources formulated with micronutrients (1% FTE503). Pearl millet was broadcast on 4 June 1974 and harvested 6 weeks later on 19 July. After the first harvest, composite soil samples were collected from each plot and prepared for chemical analyses and 80 kg/ha of N as NH_4NO_3 were broadcast on all plots. The second and last harvest was on 4 September 1974.

All soil samples were air-dried and sieved through a 2-mm screen prior to analyses. Carbon was determined by the Walkley-Black wet oxidation procedure (3). Total N was determined by the salicylic acid modification of the Kjeldahl method (8). Phosphorus, K, Ca, Mg, Cu, Mn, Fe, and Zn were extracted with Mehlich's solution (30). Phosphorus was analyzed colorimetrically by the phosphomolybdate method (18). Potassium determinations were made by flame spectrophotometry (17). Soil pH, NO_3, NH_4, and Cl were determined with specific ion electrodes (12, 42). Effective cation exchange capacity (ECEC – which is the exchange capacity available at field conditions where pH dependent sites are involved as opposed to CEC measured at pH 7.0 or 8.3) was determined with 1.0 *N* $CaCl_2$ as the saturating solution (11, 13) and 1.0 *N* NH_4Cl as the displacing solution. For cation exchange capacity (CEC) determinations, 1.0 *N* CaOAc (pH 7.0) was used as the saturating solution (11) and corrections for salt trapping in these determinations were made (34). Particle size distribution was determined according to Bouyoucos (6).

Oven dried (70 C) plant material was used for all chemical analyses. Plants were ground in a stainless steel Wiley mill to pass a 20-mesh screen prior to ashing. For ash determination, 0.20 to 0.25 g of sample was ignited at 500C for 8 hrs, cooled and dissolved in 0.1 *N* HCl. Phosphorus, K, Ca, Mg, Cu, Zn, Mn, and Fe were determined by the same procedure used in soil analyses. Boron was determined on waterhyacinths only by the curcumin method (18) with a standard curve prepared as recommended by Wear (41). Total S in waterhyacinths was determined by a turbidimetric method reported by Volk (39). Nitrogen was determined by the same procedure used for the soil samples. Electrical conductance of water extracts of waterhyacinths was determined by a sensitive ohmmeter in combination with a Pt-glass conductivity cell (12).

RESULTS AND DISCUSSION

Partial mineral composition of the waterhyacinths is given in Table 1. The amount of water-soluble materials is an important factor to consider when OM is to be added as a soil amendment, as the plant nutrients immediately equilibrate with the soil solution and the exchange complex (1, 36). Half of the total P, most of the Na and K, and half of the total Mg content were water soluble. Increasing the water to dry weight ratio to 100:1 did not result in increased solubility for Fe, Zn, and Mn. Solubility of P, K, Ca, and Mg apparently decreased, although the differences in concentration as compared with the lower composition at the 5:1 ratio were attributed to sample heterogeneity. Chlorides were high, thus caution must be exercised when amending soils to be cropped with plants sensitive to Cl. The electrical conductance of waterhyacinths in water suspension indicated that crops susceptible to salt injury should not be planted immediately after heavy amendment with waterhyacinths. Similar to some municipal compost materials (15, 16) and feedlot waste products (24, 25, 33), the waterhyacinths contained appreciable amounts of soluble salts. On a dry-weight basis, waterhyacinths compared favorably in their nutrient content with other farm manures (33). However, with only 5% dry matter waterhyacinths would be at a disadvantage as compared to animal manures when spread fresh as a soil amendment.

The waterhyacinths used here compared favorably with the average elemental composition of other waterhyacinths collected from various areas in Florida except that the N content was slightly lower (31). Total S and B contents of Lake Alice waterhyacinths were 0.46% and 31 ppm on dry-weight basis.

The Wachula fine sand consisted of 90.8% sand, 6.7% silt, 2.5% clay, and contained 1.40% total C and 7.8 ppm total N. Soil pH in water was 4.00 and 3.60 in 1.0 *N* KCl. Exchange capacity at field pH was 2.15 me/100g and 5.30

Table 1. Chemical constituents of oven-dry (70C) Lake Alice waterhyacinths.

	Ash	C	N	P	K	Ca	Mg	Na	Cl	Cu	Zn	Fe	Mn	Al	Pb	EC
	%									ppm						mhos/cm
Total	18.32	38.60	1.15	0.41	3.56	2.41	0.78	0.52	——	10	45	1002	366	1244	10	——
Water soluble																
5:1 (H_2O:WH)	——	——	——	0.19	4.60	.24	0.54	.47	3.82	2	8	9	46	0	0	3.58
100:1 (H_2O:WH)	——	——	——	0.15	3.65	0.17	0.39	——	——	5	9	10	40	0	0	——

me 100g at pH 7.00. Extractable nutrients were 11 ppm P, 18 ppm K, 90 ppm Ca, 19 ppm Mg, 0.6 ppm Cu, 1.2 ppm Zn, 19 ppm Fe, 0.4 ppm Mn, and 42 ppm Al.

The recommended fertilizer aplication is 90-48-90 kg/ha of N-P-K for pearl millet grown as a forage on most mineral soils in Florida and micronutrient additions are advised (19, 27, 28). Also, dolomitic lime is required on Wachula soils to reduce exchangeable Al, to raise the soil pH in water to 5.5 to 6.0, and to provide a better root environment.

Yields and nutrient uptake by two pearl millet harvests are given in Table 2. Waterhyacinth applications increased yields in the first harvest; however, no effects from fertilizer alone were observed. Leaching (26), denitrification (9, 14), or unfavorable conditions for nutrient absorption caused by excessive soil moisture (29) from heavy rainfall (465 mm) during May and June probably negated the effect of mineral fertilizer on millet yields.

Nitrogen, P, Ca, Mg, and micronutrients recovered in the foliage of pearl millet were increased by waterhyacinth incorporation in the soil. These results agreed with those obtained in the greenhouse on Leon fine sand (31). Recovery of applied plant nutrients was almost nonexistent when the soil was amended with lime. As an organic fertilizer, waterhyacinths proved more satisfactory in providing plant nutrients to pearl millet than did mineral fertilizer. This was attributed to increased supply and availability of plant nutrients derived from waterhyacinths. Also, it was observed that plots amended with waterhyacinths had a less compacted soil surface which may have effected an improved root environment. Increased microbial activity due to high energy carbonaceous compounds of waterhyacinth origin likely contributed to diminished leaching losses of plant nutrients as noted in a review by Black (5).

In the second harvest, yields were greater than in the first harvest as the result of additional N applied to all plots and reduced rainfall (191 mm) in the last 2 months of the growing season. Here again waterhyacinth soil amendments resulted in increased yields above control and

Table 2. Yields and nutrient uptake by two pearl millet cuttings on Wachula fine sand.

Treatment Wh[b]	Treatment F[c]	Yield[a]	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
		kg/ha						g/ha			
						First Harvest					
1	1	1189	14	6	48	4	3	5	40	207	94
1	2	1288	14	6	43	5	3	6	29	192	97
1	3	1225	13	6	43	5	3	5	30	156	96
2	1	1765	23	14	94	6	4	8	52	262	116
2	2	2674	37	19	122	10	6	17	82	374	227
2	3	1940	25	15	115	8	5	10	70	348	140
3	1	2229	31	18	125	8	6	9	79	281	192
3	2	3017	43	24	187	11	8	19	111	383	298
3	3	2733	33	20	170	12	7	13	108	421	260
Overall mean[d]		2007	26	14	105	8	5	10	67	292	169
Std. dev.		919	14	9	75	4	3	6	49	136	103
1	1	3245	29	15	100	11	13	27	108	150	176
1	2	3030	29	14	72	12	15	25	104	122	216
1	3	3954	37	14	125	16	20	58	121	164	333
2	1	6330	61	26	176	22	27	71	240	253	374
2	2	3530	38	18	109	14	16	63	142	193	254
2	3	2935	34	13	53	11	11	20	117	147	178
3	1	8774	80	34	250	26	32	71	247	331	450
3	2	5845	68	33	233	22	22	105	215	295	309
3	3	3821	46	22	130	16	15	84	144	208	253
Overall mean[d]		4607	47	21	139	17	19	58	160	207	283
Std. Dev.		2185	21	11	75	7	8	46	79	88	137

[a] Each value is an average of four observations.
[b] Waterhyacinth level (1 = 0, 2 = 15000, and 3 = 30000 kg/ha).
[c] Fertilizer level (1 = 0-0-0, 2 = 30-13-25, and 3 = 60-26-50 kg/ha N-P-K.
[d] Each value is an average of 36 observations.

TABLE 3. CHEMICAL PROPERTIES OF WACHULA FINE SAND AFTER AMENDMENT WITH WATERHYACINTHS AND ONE PEARL MILLET ME/100G HARVEST.

Treatment Wh[b]	Treatment F[c]	C[a]	N	P	K	Ca	Mg	Cu	Zn	Fe	Mn	Cl	NO_3	NH_4	Al Exch.	ECEC	pHH_2O	pHKCl
		%	ppm													meq/100		
1	1	1.24	618	22	111	653	123	0.3	1.2	43	4	18	6	6	6	3.97	6.36	6.27
1	2	1.31	610	12	42	592	113	0.2	0.9	25	2	12	4	5	5	3.94	6.30	5.95
1	3	1.22	549	17	62	581	118	0.3	1.4	22	3	11	5	5	8	3.50	6.30	5.88
2	1	1.51	714	36	188	618	128	0.4	1.6	21	6	12	5	6	4	4.67	6.39	6.15
2	2	1.47	759	38	192	800	134	0.2	1.5	21	6	22	5	6	7	4.82	6.37	5.72
2	3	1.41	663	38	168	699	140	0.5	2.0	37	5	32	6	6	5	4.40	6.36	6.34
3	1	1.40	779	37	201	689	155	0.2	1.4	16	6	24	5	6	7	4.94	6.33	5.97
3	2	1.60	848	59	377	862	224	0.2	2.2	26	8	81	8	6	5	5.68	6.68	6.34
3	3	1.55	759	58	259	998	176	0.3	2.2	40	7	68	8	5	5	5.17	6.38	6.40
Overall mean[d]		1.42	700	35	178	721	146	0.3	1.6	28	5	31	6	5	6	4.57	6.39	6.11
Std. dev.		0.24	139	20	110	231	58	0.2	0.7	17	3	29	2	1	3	0.84	0.21	0.49

[a] Each value is an average of four observations
[b] Waterhyacinth level (see Table 2)
[c] Fertilizer level (see Table 2)
[d] Each value is an average of 36 observations

mineral fertilized plots. Fertilizer applications prior to the first harvest evidently depressed yields and nutrient uptake of millet on waterhyacinth treatments in the second harvest. Opposite effects were reported by Boyd (7) when using farmyard manures. There was a significant interaction between waterhyacinths and fertilizers in the Mg uptake by pearl millet in the second harvest. The high level of fertilizer reduced Mg uptake and this was considered to be the cause of depressed yields when fertilizers were applied to waterhyacinth-amended plots. Magnesium concentrations in the plant tissues were adequate at harvest time, but the possibility of interference with Mg absorption by K or NH_4 at earlier stages or growth was possible (21, 23, 35, 36).

The effects of added waterhyacinths in May 1974 on some chemical properties of Wachula fine sand in July 1974 are given in Table 3. Carbon, N. P, K, Ca, Mg, Zn, Mn, and Cl contents were increased in the soil by addition of waterhyacinths. Effective CEC was increased significantly by addition of waterhyacinths. No significant effects were observed on Fe, Cu, NO_3, NH_4, and Al contents.

LITERATURE CITED

1. Adams, F. 1974. Soil solution, pp. 441-481. *In* E. W. Carson (ed.) The Plant Root and Its Environment. University Press of Virginia, Charlottesville, VA.
2. Allaway, W. H. 1971. Feed and food quality in relation to fertilizer use, pp. 533-556. *In* R. C. Dinauer (ed.) Fertilizer Technology and Use. Soil Sci. Soc. of Amer., Madison, WI.
3. Allison, L. E. 1965. Organic carbon, pp. 1367-1378. *In* C. A. Black (ed.) Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, Agronomy 9. Amer. Soc. Agron. Madison, WI.
4. Anderson, M.S. 1957. Farm manure, pp. 229-237. In Soil USDA Yearbook of Agriculture U. S. Government Printing Office, Washington, DC.
5. Black, C. A. 1968. Soil-Plant Relationships. Second edition. John Wiley and Sons, Inc. New York, NY. 792 p.
6. Bouyoucus, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54:464-465.
7. Boyd, D. A. 1959. The effect of farmyard manure on fertilizer response. J. Agr. Sci. 52:384-391.
8. Bremner, J. M. 1965. Total Nitrogen, pp. 1149-1178. *In* C. A. Black (ed.) Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties. Agronomy 9. Amer. Soc. Agron., Madison, WI.
9. Broadbent, F. E., and F. Clark. 1965. Denitrification, pp. 347-359. *In* W. V. Bartholomew and F. E. Clark (eds.) Soil Nitrogen. Agronomy 10, Amer. Soc. Agron. Madison, WI.
10. Easley, J. F. and R. L. Shirley. 1974. Nutrient elements for livestock in aquatic plants. Hyacinth Contr. J. 12:82-85.
11. Fiskell, J. G. A. 1970. Cation exchange capacity component variations of soils of Southeastern USA. Soil Sci. Soc. Amer. Proc. 34:723-727.
12. Fiskell, J. G. A., F. G. Martin, J. NeSmith, and H. L. Breland. 1970. Correlation between soil test and saturated extract determinations. Soil and Crop Sci. Soc. Fla. Proc. 30:288-298.
13. Fiskell, J. G. A., and L. W. Zelazny. 1971. Acidic properties of some Florida soils. I. pH-Dependent cation exchange. Soil and Crop Sci. Soc. Fla. Proc. 31:145-149.
14. Greenwood, D. J. 1962. Nitrification and nitrate dissimilation in soil. II. Effect of oxygen concentration. Plant and Soil. 17:378-391.
15. Hortenstine, C. C., and D. F. Rothwell. 1969. Evaluation of composted municipal refuse as a plant nutrient source and soil amendment on Leon fine sand. Soil and Crop Sci. Soc. Fla. Proc. 29:312-319.
16. Hortenstine, C. C., and D. F. Rothwell. 1973. Pelletized municipal refuse compost as a soil amendment and nutrient source for sorghum. J. Environ. Qual. 2:343-345.
17. Isaac, R. A., and J. D. Kerber. 1971. Atomic absorption and photometry; Techniques and uses in soil, plant, and water analysis, pp. 17-37. *In* L. M. Walsh (ed.) Instrumental Methods for Analysis of Soils and Plant Tissue. Soil Sci. Soc. Amer., Inc. Madison, WI.
18. Jackson, M. L. 1960. Soil Chemical Analysis. Prentice-Hall, Inc. Englewood Cliffs, N. J. 489 p.
19. Jones, D. W., and J. T. Johnson. 1973. Micronutrients for forage crops. Agron. Fact Sheet 11A. Fla. Coop. Ext. Serv., IFAS, U of Fla. 2 p.
20. Kamal, I. A., and E. C. S. Little. 1970. The potential utilization of waterhyacinth for horticulture in the Sudan. PANS. 16:488-496.
21. Kamprath, E. J., and C. D. Foy. 1971. Lime-fertilizer-plant interactions in acid soils, pp. 105-151. *In* R. C. Dinauer (ed.) Fertilizer Technology and Use. Soil Sci. Soc. of Amer. Inc. Madison, WI.
22. Knipling, E. B., S. H. West, and W. T. Haller. 1970. Growth characteristics, yield potential. and nutritive content of waterhyacinths. Soil and Crop Sci. Soc. Fla. Proc. 30:51-68.
23. Martin, J. P., and A. L. Page. 1965. Influence of high and low exchangeable Mg and Ca percentages at different degrees of base saturation on growth and chemical composition of citrus plants. Plant and Soil 22:65-80.
24. Mathers, C. A., and B. A. Stewart. 1970. Nitrogen transformations and plant growth as affected by applying large amounts of cattle feedlot wastes to soil, pp. 207-214. *In* Relationship of Agriculture to Soil and Water Pollution. Cornell U. Conf. on Agr. Waste Mgmt., Rochester, NY.
25. Mathers, A. C., and B. A. Stewart. 1971. Crop production and soil analyses as affected by applications of cattle feedlot waste, pp. 229-231. *In* Livestock Waste Management and Pollution Abatement. Proc. Int. Symp. on Livestock Wastes. Amer. Soc. Agr. Eng. St. Joseph, MI.

26. Munson, R. D., and W. L. Nelson. 1963. Movement of applied potassiums in soils. J. Agr. Food Chem. 11:193-201.
27. NeSmith, J., D. W. Jones, J. T. Johnson, and B. B. Whitty. 1972. Liming for production of field and forage crops. Agron. Facts 20. Fla. Coop. Ext. Serv., IFAS, U. of Fla. 4 p.
28. NeSmith, J., J. T. Johnson, D. W. Jones, and E. B. Whitty. 1972. Fertilization of field and forage crops. Agron. Facts 21. Fla. Coop. Ext. Serv., IFAS, U. of Fla. 11 p.
29. Oliver, S., and S. A. Barber. 1966. An evaluation of the mechanisms governing the supply of Ca, Mg, K, and Na to soybean root (*Glycine max*). Soil Sci. Soc. Proc. 30:82-86.
30. Page, N. R. 1965. Procedures used by state soil-testing laboratories in the southern region of the United States. Bull. 102. Southern Cooperative Series. 49 p.
31. Parra, J. V., and C. C. Hortenstine. 1974. Plant nutritional content of some Florida waterhyacinths and response by pearl millet to incorporation of waterhyacinths in three soil types. Hyacinth Contr. J. 12:85-90.
32. Perkins, H. F., M. B. Parker, and M. L. Walker. 1964. Chicken manure—its production, composition and use as a fertilizer. Georgia Agr. Exp. Sta., Bull. N.S. 123. 24 p.
33. Peterson, J. R., T. M. McCalla, and G. E. Smith. 1971. Human and animal wastes as fertilizers, pp. 557-596. *In* R. C. Dinauer (ed.) Fertilizer Technology and Use. Soil Sci. Soc. Amer., Inc. Madison, WI.
34. Rich, C. I. 1962. Removal of excess salt in cation exchange capacity determinations. Soil Sci. 93:87-94.
35. Schuffelen, A. C. 1954. The absorption of potassium by the plant. Potassium Symp. p. 169-181.
36. Thomas, G. W. 1974. Chemical reactions controlling soil solution electrolyte concentration, pp. 482-506. *In* E. W. Carson (ed.) The Plant Root and Its Environment. University Press of Virginia, Charlottesville, VA.
37. Thornton, G. D. 1971. Composting why and how. Soil Fact Sheet No. 2. Know Florida Soils. Fla. Coop. Ext. Serv., IFAS, U. of Fla. 4 p.
38. Thurman. P. C., and F. A. Pokorny. 1969. Relationship of several amended soils and compaction rates on vegetative growth, root development and cold resistance of "Tifgreen" bermudagrass. J. Amer. Soc. Hort. Sci. 94:463-465.
39. Volk, G. M., and G. C. Horn. 1972. Responses of Tifway bermudagrass to sulfur on sandy soil. Agron. J. 64:359-361.
40. Vomocil, J. A., and W. J. Flocker. 1961. Effect of soil compaction on storage and movement of soil, air, and water. Trans. Amer. Soc. Agr. Eng. 4:242-246.
41. Wear, J. I. 1965. Boron, pp. 1059-1063. *In* C. A. Black (ed.) Methods of Soil Analysis. Part 2. Agronomy 9. Amer. Soc. Agron., Inc. Madison, WI.
42. Zelazny, L. W., and J. G. A. Fiskell. 1971. Acidic properties of some Florida soils. II. Exchangeable and titratable acidity. Soil and Crop Sci. Soc. Fla. Proc. 31:150-154.