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AGRICULTURE

OBSERVATIONS ON PALM BUNCH ASH EFFECTS ON COWPEA GROWTH AND CHARACTERISTICS OF A GHANA ACID SOIL

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ABSTRACT

Oil palm bunch ash is a locally available material in Ghana with the potential of being used as fertilizer. A pot-experiment was conducted in a roofless open-air planthouse to study the effects of palm bunch ash on cowpea dry matter yield, tissue nutrient content and soil characteristics. Airdry palm bunch ash (with pH 10.6 and 26% K, 6.8% Ca, 5.8% Mg, 4.0% P, on ovendry weight basis) was applied to cowpea in Ofin soil (a loamy sand, classified as aquic Ustifluvent) at the rates 0.0 (T_0), 0.42, 0.83, 1.67, 2.50, 3.33 and 4.17 g kg.$^{-1}$ soil (T_6). Plants were harvested 41 days after planting and shoot and root dry matter (DM) yields were measured. Whole plant tops were analysed for elemental contents. Ash application resulted in significant increases in DM yields steadily from T_0 to T_6. ShootDM increased from 5.6 (at T_0) to 30.3 g pl[illegible] T_6), and root DM from 0.9 (at T_0) to 3.3 g plant[illegible] Ash application significantly increased cowpe[illegible] rom 1.2% (at T_0) to 10.6% (at T_6) and P from [illegible] T$_0$) to 0.51% (at T_0) to 0.51% (at T_6), but had no significant effect on tissue Ca and Mg. Soil analysis after harvest showed that ash application increased soil pH from 4.7 (at T_0) to 7.2 (at T_6), available P from 0.7 (at T_0) to 5.3 mg kg^{-1} (at T_6), exchangeable K from 0.05 (at T_0) to 1.3 cmol kg^{-1} (at T_6), and exchangeable Ca from 0.52 (at T_0) to 2.17 cmol kg^{-1} (at T_6), but decreased soil total N from 2.8 (at T_0) to 0.7 g kg^{-1} (at T_6) and soil exchangeable Mg from 0.76 (at T_0) to 0.10 cmol kg^{-1} (at T_6). A palm bunch ash application of 0.83 g kg^{-1} soil was found to be optimum for the growth of cowpea in the Ofin soil. The study showed that oil palm bunch ash has properties that can be exploited as a fertilizer particularly on acid soils.

Keywords: acid soil, cowpea, Ghana soil, palm bunch ash, tropical soil.

INTRODUCTION

Among the three primary agricultural inputs (seed, water and fertilizer), fertilizer is the most critical especially in a rain-fed farming system. Fertilizer use involves the greatest investment made by both the individua farmer and the nation. Commercial fertilizers used in most developing countries, including Ghana, are imported and very expensive. The high cost of fertilizers is a major drawback in the use of this vital input in agricultural production. In situations of limited financial resources, attention should be focussed on locally available materials with the potential of being used as fertilizers.

There appears to be an increasing awareness of the beneficial effects of the application of agricultural and agro-industrial residues on crop production [1, 3, 18, 20]. The oil palm bunch refuse, the part that is discarded in the stripper, is one of such local residues with the potential of being used as fertilizer. It may be applied in the form of raw refuse, composted refuse or bunch ash. For reasons of cost, convenience and ease of application, palm bunch refuse is generally used in the form of the ash.

Palm bunch ash derived from the incineration of empty oil palm bunch waste is very hygroscopic, extremely basic (pH 10-12) and contains, on dry weight basis, 25-34% K, 3.6-5.5% Ca, 1.6-3.6% Mg, 0.5-1.7% P and about 0.1% N [5, 18, 20]. In view of such properties of oil palm bunch ash and in line with Ghana's

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search for locally available materials that can effectively serve as fertilizer, this work was undertaken to study the effects of oil palm bunch ash on the growth of cowpea and the chemical characteristics of an acid soil.

MATERIALS AND METHODS

A pot-experiment was conducted in the planthouse of the Department of Crop Science of the University of Science and Technology, Kumasi, Ghana (located at longitude 01° 36' W and latitude 06° 43' N). The planthouse (roofless, with plants exposed to the natural atmosphere) operated under natural daylight of 12 h duration and at mean temperature and mean humidity for the day/night, respectively, of 30/22°C and 60.95% R.H.

The soil used was sampled from the surface (0-18 cm) of Ofin series. The series is the bottom member of a catena developed over Cape Coast granite parent material, under a semideciduous forest vegetation, and in a zone receiving a mean annual rainfall of 1375-1625 mm. The soil is classified as Aquic Ustifluvent (USDA-Soil Taxonomy) or Dystric Fluvisol (FAO/UNESCO system) with loamy sand texture, pH(H_2O) 4.8, sand, silt and clay contents of 856, 62 and 82 g kg^{-1} soil respectively, total N content of 1.8g kg^{-1} soil, available P (Bray P1) of 2.0 mg kg^{-1} soil, and exchangeable Ca, Mg and K, respectively, of 1.68, 1.79 and 0.064 cmol kg^{-1}, soil.

The oil palm bunch ash was obtained from the Ghana Oil Plam Development Corporation (GOPDC) oil mill at Kwae in the Eastern Region of Ghana. It was sieved through 1-mm sieve to remove debris.

The experiment consisted of seven treatments, which were the rates of applied palm bunch ash (PBA): 0.0 (T_0), 0.42 (T_1), 0.83 (T_2), 1.67 (T_3), 2.50 (T_4), 3.33 (T_5) and 4.17 g PBA kg^{-1} (T_6). The treatments were each replicated thrice and arranged in a completely randomized design. The ash levels were chosen based on the recommended fertilizer-P requirement for cowpea of 0.13 g P $plant^{-1}$ (or about 21 kg P ha^{-1} of 166, 666 plants) and PBA analysis of 4% P. (The P recommendation was estimated from that made by the Ghana/CIDA Grains Development Project, 1992).

Large wooden pots were each filled with 12 kg of soil, which was watered to about 20% by weight. (Twelve kg of soil is approximately the quantity of soil exploited by cowpea plant in the field in a population of 166,666 plants ha^{-1}.) Four seeds of cowpea (Vigna unguiculata L. Walp, variety IT 82E-32) were sown to a pot at a depth of 4 cm. The appropriate amount of ash was applied in a ring about 5 cm away from the seed and about 8 cm below the soil surface. Plants were thinned to one pot^{-1} ten days after planting (DAP). Plants received natural rainfall and were also artificially watered when necessary. Pre-flowering insect pests were controlled with Ripcord insecticide.

Plants were harvested 41 DAP, at flowering stage, by cutting the plant tops at soil level. The roots were carefully removed from the soil, washed to remove adhering soil particles and air-dried. The plant top and root for each pot were oven-dried at 70 °C for 72 h and weighed. The plant tops were ground and ashed at 450 °C overnight. The ash was taken up in 2 M HCl and filtered through No 42 Whatman filter paper. Total plant tissue K, P, Ca and Mg in the filtrate were measured.

The pH of the PBA was measured in paste and at an ash:water ratio of 1:2.5 using a Pye Unicam Model 290 Mk 2 pH Meter equipped with a combination electrode. The moisture content of PBA was determined by drying at 105 °C for 72 h. The PBA was dissolved in 2 M HCl, heated for 10 minutes on a hot plate, diluted with distilled water, filtered and analysed for total K, P, Ca and Mg. Total P in cowpea tissue and PBA filtrates was measured by the colorimetric (phospho-vanadomolybdate, yellow complex) method, K by the flame photometer, and Ca and Mg by the Versenate (EDTA) titration.

At the end of the experiment, the soil in each pot was thoroughly mixed and subsamples taken and prepared for chemical analysis. The soil samples before and after the experiment were analysed for pH, total N, exchangeable K, Ca and Mg, and available P contents. Soil total N was determined by the macro-Kjeldahl method. Soil available P was extracted by Bray P1 method [6] and measured by the stannous chloride-molybdate blue method [8] on a Bausch and Lomb Spectronic 20 spectrophotometer. Exchangeable cations were extracted with 1.0 M ammonium acetate solution at pH 7.0. Soil pH(H_2O), and K, Ca and Mg in solution were measured as earlier described for palm bunch ash analysis.

Statistical analysis of data were done, using the Duncan's Multiple Range Test for means separation.

RESULTS AND DISCUSSION

Analysis of the oil palm bunch ash used in the study showed that it had pH 10.6 both in paste and water, 32% moisture content, 26% K, 6.8% Ca, 5.8% Mg and 4.0% P, on oven-dry weight basis. The K content (26%) was low compared with that (34%) reported by Toh et al [20], but within the range (25-29%) reported by Arokiasamy [5]. The Ca, Mg and P contents of the present palm bunch ash (PBA), on the other hand, were higher than those earlier reported [5, 18, 20]. The elemental composition of PBA is source-dependent, reflecting the nutritional status of the soil supporting the oil palm tree that produced the bunch.

The plants that received no PBA (T_0) shed their basal leaves, an observation that in an earlier study had been attributed to P deficiency [11]. The dry matter (DM) yields of these control (T_0) plants were low (Table 1) apparently as a result of high acidity and low fertility of the soil. High soil acidity may depress growth of annual legumes by affecting the host plant nutrition, rhizobial survival and multiplication, the nodulation process, or the symbiotic N_2-fixation [6]. The poor nutrient status of the unamended soil was also shown by low level of soil exchangeable K (0.064 cmol kg^{-1} soil) as compared with the level (0.22 cmol kg^{-1} soil) generally

Table 1: Shoot and root dry matter yields (g plant^{-1}) of cowpea plants at 41 days after planting as influenced by oil plam bunch ash application on Ofin soil

Treatment	Palm bunch ash applied (g pot^{-1})	Palm bunch ash applied (g kg^{-1} soil)	Shoot DM	Root DM
T_o	0	0.0	5.6	0.93
T_1	5	0.42	8.6	1.53
T_2	10	0.83	14.3	2.30
T_3	20	1.67	17.3	2.33
T_4	30	2.50	19.3	2.53
T_5	40	3.33	22.6	2.96
T_6	50	4.17	30.3	3.33
LSD (5%)			1.7	0.21
LSD (1%)			2.5	0.32

DM: Dry matter

Table 2: Plant tissue concentration (%) of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) in cowpea shoots 41 days after planting as influenced by oil palm bunch ash application on Ofin soil.

Treatment	Palm bunch ash applied (g pot^{-1})	Palm bunch ash applied (g kg^{-1} soil)	P	K	Ca	Mg
T_o	0	0.0	0.09	1.2	0.82	0.54
T_1	5	0.42	0.18	6.2	0.96	1.29
T_2	10	0.83	0.27	7.5	1.22	1.40
T_3	20	1.67	0.37	8.9	1.39	1.68
T_4	30	2.50	0.41	9.6	1.53	1.98
T_5	40	3.33	0.46	10.2	2.13	2.21
T_6	50	4.17	0.51	10.6	2.35	2.48
LSD (5%)			0.02	0.7	NS	NS
LSD (1%)			0.03	1.1	NS	NS

NS: Not significant

Table 3: Some chemical properties of Ofin soil (after harvest of 41-day old cowpea plants) as influenced by oil palm bunch ash application.

Treatment code	Bunch ash applied (g kg^{-1})	pH(H_2O) 1:2.5	Total N (g kg^{-1})	Avail. P (mg kg^{-1})	Exchangeable cations (cmol kg^{-1}) K	Ca	Mg	K/Mg* ratios
T_o	0.0	4.7	2.8	0.7	0.05	0.52	0.76	0.07
T_1	0.42	5.3	2.2	1.9	0.43	0.70	0.52	0.83
T_2	0.83	5.7	1.7	2.6	0.48	0.83	0.40	1.20
T_3	1.67	6.1	1.6	3.5	0.64	1.49	0.23	2.80
T_4	2.50	6.3	1.5	4.1	0.81	1.74	0.16	5.06
T_5	3.33	6.7	1.4	5.6	1.22	2.00	0.13	9.38
T_6	4.17	7.2	0.7	5.3	1.30	2.17	0.10	13.00
LSD (5%)		0.16	0.3	0.2	0.33	0.02	0.06	
LSD (1%)		0.24	0.4	0.3	0.49	0.08	0.08	

* K/Mg ratios have been computed on equivalent basis.

considered adequate for most field crops (including cowpea) in loamy sands [9] . Palm bunch ash application resulted in very significant steady increases (P = O . 01) in shoot and root dry matter yields (Table 1), from the control treatment (T_o) to the treatment of the highest ash level, 4.17 g PBA kg $^{-1}$ soil (T_6). The shoot DM yield of 30. 3 g plant $^{-1}$ for 41-day old plants in this study is comparable to that (45. 6g plant $^{-1}$) reported by Eaglesham et al [10] for 48-day old plants. It was also observed that PBA application caused increases in plant height, number of leaves and branches, and stem thickness (data not presented) . There are conflicting reports of the effects of potassium on seed yield of cowpea. Kumar and Pillai [12] reported that K application did not increase seed yield, while Chesney [7] demonstrated that P and K are necessary for nodulation and optimum yield of cowpea. Notwithstanding such conflicting reports, the good growth of the plants treated with PBA in this study resulted from the improvement by the PBA in the pH and general fertility of the soil.

Palm bunch ash application resulted in significant increases in cowpea tissues K (from 1. 2 at T_o to 10. 6% at T_6)and in tissue P (from 0.09% at T_o to 0.51% at T_6). Ash application, however, had no significant effect on tissue Ca and Mg though these tended to increase steadily with increase in ash application. At PBA application of 0.83g kg^{-1} soil (T_2) tissue P was 2. 27% (Table 2), which agrees with the sufficiency level of P in soybean in the Ofin-Akroso-Kumasi soil association reported by Ankomah and Osei Kofi [4] . On the assumption that the tissue P sufficiency level for soyabean would equally apply to cowpea, a PBA application of 0.83g kg^{-1} soil could be selected as the optimum rate for cowpea on the Ofin soil. A cowpea tissue P sufficiency level of 0. 27% also agrees with the range of 0. 20-0. 35% proposed as 'the sufficiency values for groundnut (upper stems and leaves) at early pegging [17] . Again, on the assumption that the K nutritional need of cowpea would not be much different frcm that of groundnut, the groundnut tissue K sufficiency range of 1. 7%-3 . 0% proposed by Small and Ohlrogge [17] could also apply to cowpea. On this basis, the cowpea tissue K level of 1. 2% in the unamended soil (Table 2) was not adequate for good growth of the crop, and thus emphasizes the fact that the unamended soil exchangeable K was inadequate. However, an application of only 0.42 g PBA kg^{-1} soil (T_1) resulted in a cowpea tissue K concentration of 6 . 2% (Table 2), which is far greater than the adopted sufficiency values (1.7%-3.0%). Thus, even at the PBA application rate of 0.83 g kg $^{-1}$ soil (T_2), taken in this study as the optimum rate, the ccwpea tissue K of 7 . 5% (Table 2) could be considered as a "luxury consumption" .

The non-significant effect of the PBA on Mg content of cowpea tissue might be explained by the fact that generally the Mg content of plant organs is adversely influenced by K^+ nutrition as a result of cation competition or antagonism [14] . This was caused by the unfavourably high K/Mg ratios in the soil (Table 3), especially at PBA application rate greater than 0. 83 g k^{1}· soil (T_2), resulting from the very high K content of the ash. Sugiyono [18] also reported that while PBA application had no significant effects on maize tissue P, N and Ca, it significantly adversely affected tissue Mg content. Loue [13], studying the interaction of plant nutrients in leaves of maize, also found a negative correlation between leaf K on one hand and Ca and Mg on the other. It is worth noting that while relatively high K uptake adversely affects tissue Mg of maize, a monocot [13, 18], the Mg content of cowpea (a dicot) tissue in this study was not adversely affected by PBA, per se; in fact, the cowpea tissue Mg levels tended to increase with increase in ash application, except that such increases were not significant. It would appear that high K/Mg ratios affect Mg uptake in maize (monocot) more severely than in cowpea (dicot).

Soil analysis after harvest indicated that PBA application resulted in significant increases in soil pH, available P, and exchangeable K and Ca, but caused decreases in soil total N and exchangeable Mg (Table 3).Soil pH increased from 4.7 (at T_o) to 7.2 (at T_6). The increase in soil pH with ash application is not surprising since the ash is basic and the soil, being sandy, has a low buffering capacity. Teoh et al [19] reported that equal rates of application of limestone and PBA produced ; essentially the same amount of increase in topsoil pH, indicating that PBA is as effective as limestone in ameliorating soil acidity.

The decrease in soil total N content with ash application could be attributed to a more efficient utilization of indigenous soil N by the plants for increased growth. It is probable that the amount of N fixed by the plant could not meet the increasing N need caused by the increase in growth. This observation agrees with the assertion that most legumes can deplete soil N unless their nodules fix a lot of N_2 [15], and with the general view that liming acid soils improves N use by crops primarily by maintaining or restoring a soil pH environment favourable for plant growth and microbial activity [2].

The decrease in soil exchangeable Mg with increase in PBA application could be attributed to an enhanced uptake of soil Mg in order to offset the increasing inbalance in the K/Mg ratio in the plant. This means that Mg Fertilization would be required if a second crop of cowpea were to be grown on the same amended soil after the first crop. This is because at and above the PBA application rate of 0.83g kg $^{-1}$ soil (considered optimum rate in this study), residual soil exchangeable Mg was 0.40 cmol kg^{-1} soil and lower, which was below the adequacy range of 0.42-0.83 cmol kg $^{-1}$ soil [9]; according to Doll and Lucas [9], absolute deficiency of Mg is not likely in field crops if soil exchangeable Mg is 0.42-0.83 cmol kg soil (that is, 51-100 mg Mg kg^{-1} soil). The K/Mg ratio in soil is very important. Very wide ratios cause decreased uptake of Mg by plants [18]. In fact, Doll and Lucas [9] recommended that for field crops the

K/M ratio should not be greater than 1.5 on an equivalent basis (that is, not greater than 5 on a weight basis). Thus, at PBA application rates greater than 0.83g kg^{-1} soil (Table 3) the residual K/Mg ratios were so high that they would adversely affect the Mg nutrition of a second crop of cowpea. In view of the potentially great imbalances in K/Mg ratios resulting from PBA application, it is suggested that PBA application be done in combination with $MgSO_4$ to ensure proper Mg nutrition of cowpea on acid soils inherently low in Mg.

CONCLUSION

The study has shown that oil palm bunch ash has a great potential for ameliorating soil acidity and as a source of plant nutrients especially K. The very high K content of PBA results in wide soil K/Mg ratios that adversely affect the Mg nutrition of plants; it is suggested that PBA be applied in combination with $MgSO_4$ to ensure proper Mg nutrition of plants on acid soils that are low in Mg. On the Ofin soil, a PBA application rate of 0.83g kg^{-1} was found to be optimum for the growth of cowpea.

More research is needed on the on the use of oil palm bunch ash as a nutrient source for increasing yields of crops (especially the high-K demanding ones such as the root crops) on acid soils.

REFERENCES

1. *Acquaye, S. K., Response of Maize to Applications to Cocoa Pod Ash on a Sandy Loam Soil . BSc.(Hons) Agriculture Dissertation, University of Science and Technology, Kumasi, Ghana, (1987) .*
2. *Adams, F. and Martin, J . B ., Liming Effects on nitrogen use and efficiency. In Hauck, R.D. (ed), Nitrogen in Crop Production. American Society of Agronomy, Madison, Wisconsin, U.S.A., 417-426, (1984) .*
3. *Ahenkorah, Y. and Halm, B.J., Potting media for growing cocoa seedlings. Ghana J. Agric. Sci., 9, 207-210, (1976) .*
4. *Ankomah, A.B. and Osei-Kofi, V., External and internal critical phosphorus requirements of soybean [Glycine max (L.) Merrill] in three Ghanaian soil]. Trop. Agric. (Trinidad), 69 (4), 315-318 (1992) .*
5. *Arokiasamy, M., Investigation on the best method of using the oil palm bunch waste as a fertilizer. Commun. (Agron.) Chemara Res. 7, 1-7, (1969).*
6. *Bray, R.H.. and Kurtz, L.T., Determination of total, organic and available forms of phosphate in soils. Soil Sci., 59, 39-45, (1945).*
7. *Chesney, H.A.D., Performance of cowpea cv "Black-eye" in Guyana as affected by potassium and phosphorus . Turrialba, 24 (2), 193-199, (1976) .*
8. *Dickman, S. R. and Bray, R. H .. Colorimetric determination of phosphate . Ind. Eng. Chem. Anal. Ed., 12, 665-668, (1940) .*
9. *Doll, E.C. and Lucas, R.E., Testing soils for potassium, calcium, and magnesium. In Walsh, L.M. and Beaton, J.D. (eds), Soil Testing and Plant Analysis. Soil Science Society of America, Madison, Wisconsin, U.S.A., 133-151, (1973).*
10. *Eaglesham, A.R.J., Minchin, F.R., Summerfield, R. J., Dart, P. J., Huxley, P.A. and Day, J.M., Nitrogen nutrition of cowpea (Vigna unguiculata). III. Distribution of nitrogen within effectively nodulated plants. Expl. Agric., 13, 369-380, (1977) .*
11. *Effa-Baafi, Y., Nodulation and Dry Matter Yield of Cowpea in Response to N and P Applications on a Sandy Soil. BSc (Hons) Agriculture Dissertation. University of Science and Technology, Kumasi, Ghana, (1985) .*
12. *Kumar, B.B. and Pillai, P.B., Effect of N, P and K on the yield of cowpea variety. Agric. Res. J. Kerala, 17(2), 194-199, (1979).*
13. *Loue, A., The interaction of potassium with other nutrients. Potassium Workshop. Int. Potassium Inst. Ibadan, Nigeria, (1980) .*
14. *Mengel, K. and Kirkby, E.A., Potassium in crop production. Adv. Agron., 33, 59-110, (1980).*
15. *Mulongoy, K., Nitrogen-fixing symbiosis and tropical ecosystems. In: Singh, S.R. and Rachie, K.O. (eds), Cowpea Research, Production and Utilization. John Wiley and Sons, Chichester, U.K., (1985).*
16. *Robson, A.D. and Lonragan, J.F., Nodulation and growth of Medicago truncatula on acid soils. Effect of calcium carbonate and inoculation level on the nodulation of Medicago truncatula on a moderately acid soil. Aust. J. Agric. Res., 21, 427-434, (1970) .*
17. *Small Jn., H. G. and Ohlrogge, A. J., Plant analysis as an aid in fertilizing soybeans and peanuts. In Walsh, L.M. and Beaton, J.D.(eds). Soil Testing and Plant Analysis. Soil Science Society of America, Madison, Wisconsin, U.S.A., 315-327, (1978).*
18. *Sugiyono, The Use of Palm Bunch Ash as a Potassium fertilizer. MSc Thesis State University of Ghent, Belgium, (1988) .*
19. *Teoh, C.H., Chang, A.K. and Chong, C.F., Fertilizer and soil amelioration trials on inland and coastal soil in Malasia. In Pushparajah, E. and Chew, P.S. (eds), Cocoa and Coconut: Progress and Outlook. International Conference on Cocoa and Coconuts: Progress and Outlook. Kuala Lumpur, Malasia. Kuala Lumpur (Malasia) Incorporated Society of Planters, 467-487, (1986).*
20. *Toh, P.Y., Poon, Y.C. and Yeow, K.H., Bunch ash as a nutrient source in oil palm. Proceedings of National Workshop on oil palm By-product Utilization. Inst. Penyelidikan Minyak Kelapa Sawit Malasia, Kuala Lumpur, Malasia, 135-139, (1983).*