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Elemental Composition of Bean (*Phaseolus vulgaris*) and Soy Bean (*Glycine max* L.) Grown on Wood Ash Amended Soil

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Among the three primary agricultural inputs namely seeds, water, and fertilizers, in a rain fed farming system, fertilizer is the largest investment that can be made by both the individual farmer and the large scale enterprises (Safo et al., 1997). Fertilizers are usually used as farm inputs since they are valuable sources of macro and micro-nutrients required for normal plant growth. However, commercial fertilizers are imported and are very expensive. In situation of limited resources, attention should be focused on locally available substitute material with some potential of being used as fertilizer. Most of the domestic energy production in Uganda depends on wood fuel. It has been estimated that over 90% of the total population uses wood fuel, and the production of wood ash in this country is posing an increasing ash disposal problem. There have been several reports on the use of fly ash as a soil amendment (Fail & Wochok, 1997, Adriano et al., 1980; Mollner & Street, 1982). Investigations on the movement of nutrient and toxic elements from soil amended with fly ash into a range of vegetable, forage and grain crops have also been carried out (Plank et al. 1975; Cary et al., 1983). Addition of ash to the soil has been reported to increase the availability of sodium, potassium, calcium, magnesium, sulphate, and other nutrients (Wong and Wong, 1988). The foliar application of ash has been observed to enhance growth and metabolic rates as well as increasing the photosynthetic pigments of maize and soybean (Mishra & Shukla, 1986). A number of studies have been investigated, the potential for agronomic utilization of ash (Elseewi et al., 1978) and its use to improve the water holding capacity of soils. The response of ecosystems to plant macro and micro-nutrients in ash may vary from beneficial effects when these have been growth-limiting in the natural environment (Chang et al., 1977) to toxic effects of high concentrations of many elements. Heavy metal contamination and the problems that it poses to the plant life have been well documented (Raskin and Ensley 2000). Furthermore, saw-dust ash has been found to increase growth and yield of lettuce (Siregar, 1991). Application of ash similarly increased growth and yield of other vegetable crops, for example Amaranthus tricolr (Zake & Tenywa, 1987). Soybean plants treated with rice straw ash were found to perform better than plants treated with calcium carbonate (Riviera, 1984). In the work reported here, *Phaseolus vulgaris* and *Glycine max L.*, two economically important crops, were grown on soil amended with wood ash so as to determine the effect that the wood ash has on the plant height and biomass and the accumulation levels of selected elements in different parts of the two plants investigated in order to trace any heavy metal along various parts of the plant.

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MATERIALS AND METHODS

Wood ash used in this experiment was collected from different cooking centers in Kampala area. The wood ash was from the sources which use common forest tree species, *Celtis spp, Albizia spp, Lovoa ssp* and *Senna spp.* (Katende et al 1995). The study was carried out at Kawanda Agricultural Research Institute during 1997-1998. Kawanda is in the lake Victoria catchment area, north of Kampala (0181N., 32°30'E) located at 1167 m above sea level. The soils are quite deep and highly drained. The experimental site had been kept under fallow for approximately 3 years and we worked on the assumption that the soil possessed the background physico-chemical status. The study area has a moist tropical type of climate with highest temperatures in February and September. The mean annual rainfall is about 1470 mm with two peaks in January and November and two periods of low rainfall in December and June. The soil used in these experiments is classified as errauti soil. Detailed physical and chemical characterstics of soil and wood ash are presented in Table 1. The following doses of wood ash were applied and mixed with 0-20 cm of soil (ton/ha): 0,1,2,3, and 4. Each treatment was replicated three times in a completely randomized design. The ash was hand-broadcast evenly in assigned treatment to plots and then incorporated into the soil using a hoe. The study area consisted of three blocks with a total of thirty plots. Each plot was 3m x 4m with paths of 1m between plots and 2m between blocks. Planting of soy bean, *glycine max* was done using surface sterilized seeds at a recommended spacing of 50 x 10cm (Uganda seed Project 1997). Each plot consisted of seven rows and were initially irrigated on alternate days with tap water (5000 ml $plot^{-1}$). 56 Days after planting, sampling started following the method outlined by Safo et al (1997). The sampling was continued till the end of experiment.

Table 1 Physical and chemical characteristics of Wood ash and soil used in the study.

Characteristics	Units	Soil	Wood ash
Sand[a]	%	49 ± 1.2	15 ± 3.0
Silt[a]	%	13 ± 1.8	32 ± 2.0
Clay[a]	%	38 ± 3.2	18 ± 2.0
Organic matter[a]	%	2.38 ± 0.2	-
pH[b]		4.9 ± 0.1	10.5 ± 0.2
Phosphorus[c]	$mg\ g^{-1}$	1.9 ± 0.2	1,760 ± 82
Potassium[c]	$mg\ g^{-1}$	0.13 ± 0.4	269 ± 18
Calcium[c]	$mg\ g^{-1}$	0.13 ± 0.4	129 ± 6.1
Magnesium[c]	$mg\ g^{-1}$	0.35 ± 0.2	22 ± 4.0
Copper[d]	$\mu g\ g^{-1}$	0.09 ± 0.1	57 ± 3.0
Zinc[d]	$\mu g\ g^{-1}$	28 ± 0.4	134 ± 6.0
Cadmium[d]	$\mu g\ g^{-1}$	68 ± 4.0	4.30 ± 0.2
Lead[d]	$\mu g\ g^{-1}$	0.99 ± 0.2	79 ± 2.0

[a]Determined by pipette method (Okalebo et al 1993)
[b]Misra (1968)
[c]Jackson (1973)
[d]Determined by atomic absorption spectrophotometer

Five bean and soybean plants per plot were randomly selected for height measurements. Measurements of the shoot heights were carried out using a metre rule, from the ground level to the shoot apex. The mean height was recorded to represent the height of plants per treatment. The harvested plants were separated into shoots, roots and seeds. All crop portions (roots, shoots and seeds) were oven-dried at 80°C to constant weight to give total dry matter accumulation. Equal weights of these samples for each of the two crops were combined from the replicates of each of the treatment groups for chemical analysis. Dried samples were ground to pass a 1-mm screen, taking, care to avoid contamination during the process. The powdered plant samples (1.5g) were separately transferred to the teflon-lined uniseal bomb. This was followed by fuming nitric acid (10ml), 48% hydrofluoric acid (5ml) and 72% perchloric acid (1ml). The vessel was closed by hand tightening the screw cap containing the Teflon sealing disk. The uniseal bomb, with its contents was placed in a drying oven at 140°C for 3 hours, and then let cool to ambient temperature. The decomposed sample solution, with the precipitated metal fluoride, was transferred to polystyrene beaker. Boric acid (2.8g) was then added, stirred to dissolve metal fluorides with the help of water addition. The soil and ash samples were treated following the same digestion procedure except that 0.50g of soil and ash portions were taken.

The solutions were each transferred to a 50ml volumetric flasks, volume adjusted to the mark and stored in polyethylene containers. The concentration of potassium (K) and calcium (Ca) were determined by flame photometer (Jackson, 1973). Magnesium, lead, copper, zinc and cadmium concentrations were determined by direct aspiration of the sample solution into atomic absorption spectrometer, instrumental laboratory Perkin Elmer model 3280, with detection limits and recoveries checked for all elements and found to fall within 0.01- 0.1 $\mu g\ ml^{-1}$ and 93-102% respectively.

RESULTS AND DISCUSSION

The organic matter content of the normal field soil of Kawanda research station was 2.38% while it was below detection limit in the wood ash. Wood ash had greater amounts of all other parameters tested (Table 1). Application of wood ash to the soil at a rate of up to 4ton/ha had favorable effects on the growth of bean and soybean, as evidenced by their heights and biomass taken at the end of the experimental period (Table 2).

Increase in plant height and plant biomass of both crops (Table 2) grown at higher rates of wood ash application (1.0 ton/ha and above) is attributed mainly to the presence of utilizable plant nutrients, phosphorus, potassium, calcium and magnesium. Definitely nutrient deficiencies were supplemented by the addition of wood ash to the soil. Tables 3 and 4 show the elemental content in the root, shoot and seeds of both bean and soybean, at various application rates of wood ash. With the control, the concentration of the 8 elements and in the two crops was highest in the seeds followed by the shoots and was lowest in the roots, whereas the two crops grown on wood ash treated soil showed the presence of relatively higher concentration of trace elements (Cu Zn, Cd and Pb) in the root than in the shoots. The concentrations of these trace elements appeared to be higher in the

Table 2. Plant height and biomass (root, shoot, seed) of bean and soybean grown on soil treated with wood ash (± SD), after 8 weeks.

Wood ash in soil (ton/ha)	Height (cm)	Biomass (g plant^{-1})
Bean		3.18 ± 0.2
0	31.94 ± 3	3.98 ± 0.5
1.0	38.82 ± 2	4.50 ± 0.4
2.0	37.98 ± 4	5.15 ± 0.7
3.0	40.33 ± 2	5.56 ± 0.4
4.0	48.30 ± 4	
Soybean	43.32 ± 2	3.19 ± 0.2
0	43.35 ± 1	4.22 ± 0.4
1.0	44.16 ± 1	4.44 ± 0.4
2.0	48.30 ± 2	4.92 ± 0.5
3.0	53.92 ± 2	6.02 ± 0.4
4.0		

shoots than in the seeds. The experimental results from the study show that the concentration of trace metals of the two crops was affected by wood ash addition. Copper, zinc, cadmium and lead concentrations were higher in each of the three components (root, shoot, and seeds) of the crops tested on ash-treated soil than their respective levels in the control crops. In contrast to the trace elements, the concentration of phosphorus, magnesium, potassium, and calcium in the two crops were significantly affected by the wood ash application. This observation does not agree partly with the results obtained by other investigators (Hodgson & Holiday, 1966; Martens et al., 1970; Adriano et al. 1980) in which fly ash samples were generally found to be ineffective sources of available phosphorus, magnesium, potassium and calcium. In conclusion, the addition of wood ash to soil at the rate up to 4ton/ha may benefit the crop productivity by correcting soil deficiencies of trace elements such as copper and zinc. Deficiencies in these trace elements are normally encountered in ferrallitic soils of Uganda. Application of wood ash as a soil amendment might therefore help to rectify such deficiency problem. Treatment rates, however, would have to be closely controlled to obviate the possible accumulation of toxic levels in edible part of the plant. Additionally the two crops grown on soil in which 1.0 ton/ha or greater of wood ash had been incorporated, accumulated significantly ($P < 0.01$) higher levels of potentially toxic metals in root, shoot and seed thereby resulting in their introduction in the food chain. The levels of the metals were greatest in the roots when compared with shoot and seed. A similar order has been observed by Chakrabarti and Chakrabarti, (1988). The higher concentration of metals in roots has been explained before (Smith et al., 1979) by the large surface area in contact with the wood ash, resulting in greater metal absorption as compared to other parts. In Uganda people eat a lot of beans (*Phaseolus vulgaris)*. Assuming that an average intake of 500g of beans per person per day, the Cu, Zn, Cd, and Pb available in beans harvested from control plots will be 1.43mg, 1.46mg, 0.06mg and 0.12mg respectively. The intake of Cu, Zn, Cd and Pb will increase to 1.92mg, 2.13mg. and 0.11mg and 0.18mg, respectively, if the seeds harvested from 4ton/ha ash

Table 3. Elemental composition of three components (root, shoot and seed) of bean grown or Wood ash treated soil

Wood ash in soil (ion/ha)	Components	Concentration, µg g-1							
		P	K	Ca	Mg	Cu	Zn	Cd	Pb
0	Root	0.18	1.54	0.20	0.10	2.12	2.27	0.05	0.14
	Shoot	0.22	1.70	0.22	0.12	2.32	2.80	0.09	0.19
	Seed	0.24	1.88	0.28	0.16	2.86	2.92	0.12	0.23
1.0	Root	0.24	1.86	0.22	0.13	2.80	4.20	0.11	0.29
	Shoot	0.20	1.78	0.18	0.11	2.61	3.25	0.10	0.24
	Seed	0.18	1.6	0.25	0.13	2.50	3.04	0.09	0.24
2.0	Root	0.26	1.90	0.25	0.15	2.72	4.52	0.13	0.29
	Shoot	0.24	1.87	0.19	0.13	2.77	3.92	0.11	0.27
	Seed	0.21	1.62	0.22	0.11	2.56	3.41	0.09	0.25
3.0	Root	0.20	1.24	0.21	0.14	2.90	5.04	0.14	0.30
	Shoot	0.19	2.02	0.19	0.14	2.88	4.26	0.12	0.28
	Seed	0.21	1.76	0.21	0.12	2.80	4.23	0.11	0.27
4.0	Root	0.25	1.76	0.24	0.16	2.96	5.72	0.16	0.42
	Shoot	0.18	1.80	0.19	0.14	2.91	4.69	0.14	0.38
	Seed	0.25	1.84	0.21	0.15	2.84	4.26	0.12	0.35

Table 4. Elemental composition of three components (root, shoot and seed) of soybean grown on wood ash treated soil after 8 weeks.

Wood ash in soil (ton/ha)	Component	Concentration, µg g-1							
		P	K	Ca	Mg	Cu	Zn	Cd	Pb
0	Root	0.30	2.28	0.30	0.14	3.33	2.21	0.22	2.85
	Shoot	0.31	2.40	0.32	0.17	3.64	3.04	0.31	2.21
	Seed	0.39	2.88	0.37	0.19	3.79	3.79	0.39	2.99
1.0	Root	0.76	5.75	0.76	0.38	8.39	5.57	0.55	7.18
	Shoot	0.72	5.50	0.73	0.39	7.90	5.02	0.45	7.01
	Seed	0.70	5.14	0.70	0.32	7.66	4.88	0.40	6.80
2.0	Root	0.68	5.84	0.79	0.42	8.88	5.70	0.64	7.64
	Shoot	0.62	5.52	0.74	0.38	8.60	5.40	0.61	7.30
	Seed	0.65	5.30	0.72	0.36	7.80	5.04	0.60	6.90
3.0	Root	0.67	6.07	0.85	0.50	9.02	6.10	0.71	8.04
	Shoot	0.54	5.80	0.77	0.47	8.70	5.90	0.70	7.84
	Seed	0.49	5.40	0.75	0.42	8.65	5.12	0.68	7.35
4.0	Root	0.82	6.28	0.91	0.55	9.42	6.50	0.82	8.54
	Shoot	0.74	6.01	0.88	0.51	9.00	6.30	0.79	8.20
	Seed	0.66	5.70	0.86	0.48	8.80	6.02	0.73	8.05

treated plots are consumed. The daily requirements, for instance Cu and Zn for adults are estimated to be about 2mg/day and 15mg/day (Prasad, 1978) respectively. As a consequence, the application of wood ash enhances the levels of copper and zinc in the human body. The elements Pb and Cd are elements with no known physiological function, and there is as yet no substantial evidence to suggest that these elements are essential trace elements. Instead they have been shown to be harmful to humans. In conclusion wood ash has been found to be beneficial for the cultivation of bean (*Phaseolus Vulgaris*) and soybean (*Glycine Max L.*). Its application at 4.0 ton/ha increased the plant height by a factor of 1.5 in bean and 1.2 in soybean while the factor increase in biomass for the bean and soybean was 1.7 and 1.9 respectively. If wood ash is to be considered for this purpose, various aspects of its utilization are to be evaluated. Large scale details are necessary to determine the exact response of crop plants under the same conditions. It is also important to investigate the accumulation of toxic substances present in wood ash treated soil and especially in the edible parts of plants. Lead in the two crops was highest in the seeds followed by the shoots and was lowest in the roots, whereas the two crops grown on wood ash treated soil showed the presence of relatively higher concentration of trace elements (Cu Zn, Cd and Pb) in the root than in the shoots.

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