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Production of Organic Compost from Water Hyacinth (Eichhornia crassipes [Mart.] Solms) in the Lake Victoria Basin: A Lake Victoria Research Initiative (VicRes)

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Research Article

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ABSTRACT

The Lake Victoria Basin (LVB) supports one of the poorest and most populous rural populations in the East Africa region. The dipping fish population has forced the community around the Lake Victoria to turn to farming for food crops to meet its daily food demands. Chemical fertilizer which is readily available has been the alternative source of improving soil condition which has led to eutrophication of the lake waters causing the temperature to rise in the process affecting most freshwater animals and plants. This process also encourages large volumes of algae and other biomass such as water hyacinth to flourish. The use of the algae bloom and water hyacinth to provide an alternative ecologically friendly and sustainable source of soil nutrients is imperative. This study utilized water hyacinth (H) to develop compost as a potential soil improvement source. Using four different composting treatments of water hyacinth biomass (H only control, H+ cattle manure, H+EM, H+ Molasses) there was no significant difference in the assessed nutrients at $P<0.05$ in the various treatment. There was though a higher increase in P at a non-significant level at $P<0.05$ in H control, H+ cattle manure, H+EM compared with the H+ Molasses treatment. H+ Cattle Manure and H control treatment also generated high K levels and relative to the other treatments. Overall the project exhibited high level of P, N and exchangeable K in the four hyacinth compost treatment with an alkaline p^H of between 7.38-8.13. The project also determined the optimal composting conditions with highest temperature of about 38°C observed at day 5 to 20 from the onset of the decomposition all the treatments. The temperature stabilized at about 24°C till the 58th day. Resulting in increase of essential elements in Water Hyacinth Organic compost makes it an important source for control of acidic soil pH and soil nutrient replenisher.

INTRODUCTION

Lake Victoria is the second largest fresh water lake in the world and occupies about 69000 km^2. The Lake Victoria Basin (LVB) has an area of approximately 251,000 km^2 [1]. 22% of the catchment area is in Kenya, 11% in Rwanda, 16% in Uganda, 7% in Burundi and 44% in Tanzania [2]. According to Albinus [3], the LVB is characterized by high human population growth and currently the population is more than 40 million, with estimated 30% of the total population living in the three riparian countries: Kenya, Tanzania and Uganda. Most of the people in this region are subsistence farmers who rely on natural rainfall for crop production and they mainly cultivate maize (*Zea mays* L.) and common beans (*Phaseolus vulgaris* L.) [4]. Continued increase in population, poor agricultural and livestock production methods, and deforestation are major causes of land degradation and reduction in productivity in the LVB [5]. To boost food production from the dilapidated farms, farmers are encouraged to use manure or inorganic nitrogen fertilizers. Nitrogen requirements in the soil are usually higher as compared to other major soil nutrients for sustainable food production [6].

Studies have shown that despite availability of other nutrient sources to enhance nitrogen in the soil for improved crop yield, chemical fertilizers have been prioritized as a solution to nutrient deficiencies in the soil [5,7]. Too much use of nitrogen fertilizers for agricultural production has been reported to contribute to greenhouse gas emissions, reduction in water quality and biodiversity and it is a potential health hazard [8]. Agricultural runoff is a major source of high nitrogen loads in Lake Victoria and it accounts for 75% of the total nitrogen flow into the lake from the lakes catchments, with most of the nutrients being deposited into the lake during the wet season of the year [9,10]. Increased inflow of agricultural runoff into Lake Victoria has resulted into increase in nutrient concentrations and potential human pathogen leading to turbidity and reduction of dissolved oxygen [11,12]. This in turn has led to algal blooms, infestation of the lake with waterweeds especially the water hyacinth **(Figures 1 and 2)** and most notable on the Kenyan part **(Figure 3)**, death of fish and water borne diseases [11]. The cost of inorganic fertilizers has also been in upward trend making it unaffordable by many smallholder farmers [13]. To enhance food crop production, there is need to adopt cheaper and environmentally friendly means of improving soil fertility [6,13]. Water hyacinth derived manures which is available in abundance in the Lake Victoria are rich in nutrients especially nitrogen and phosphorus [14-16] which influence root colonization by *Rhizobia spp*. and enhance plant resistance to pathogens [17]. The composting process can also inactivate pathogens while creating a soil amendment beneficial for application to arable agricultural land [12].

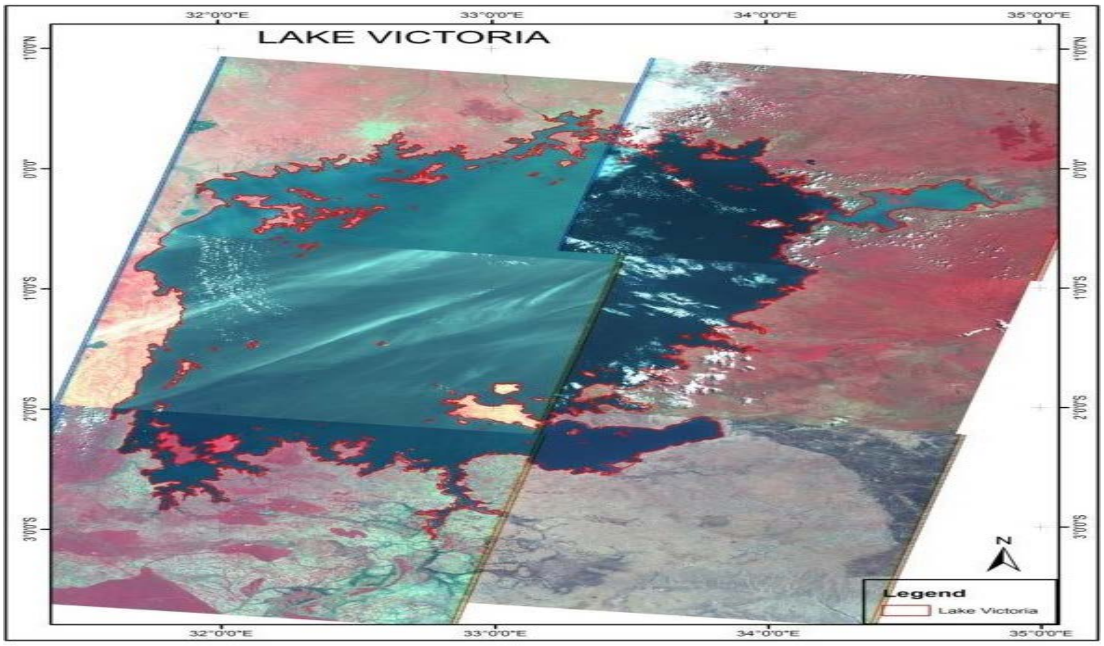

Figure 1. The status (coverage and distribution) of the water hyacinth in Lake Victoria using the GIS.

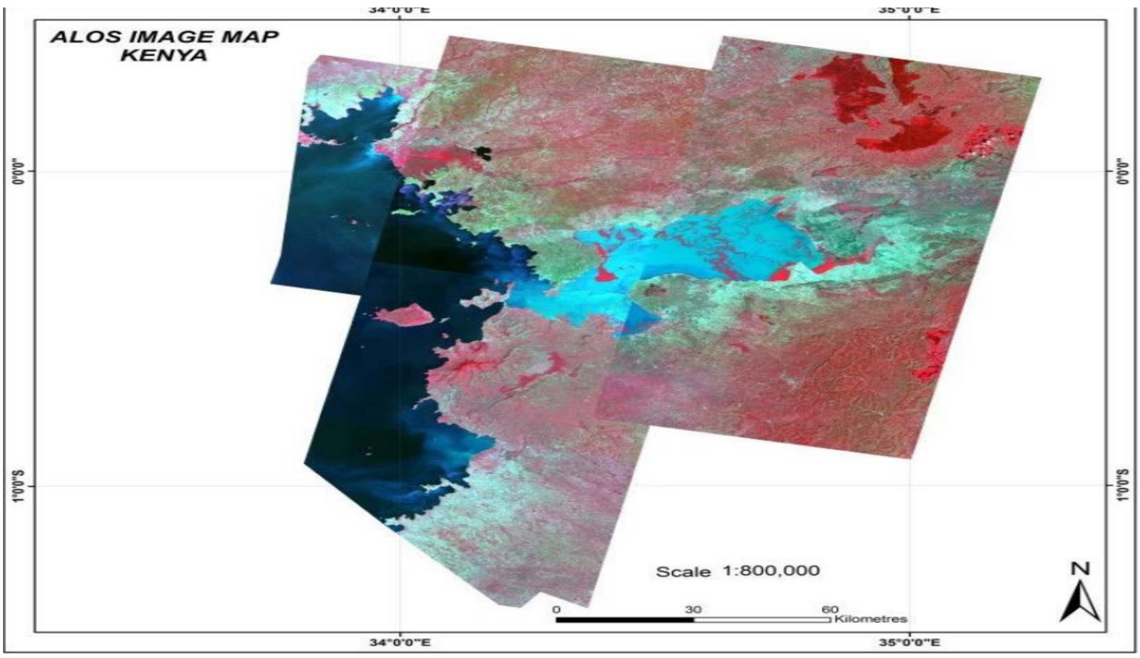

Figure 2. Shows the landsat image of Lake Victoria showing the distribution of water hyacinth.

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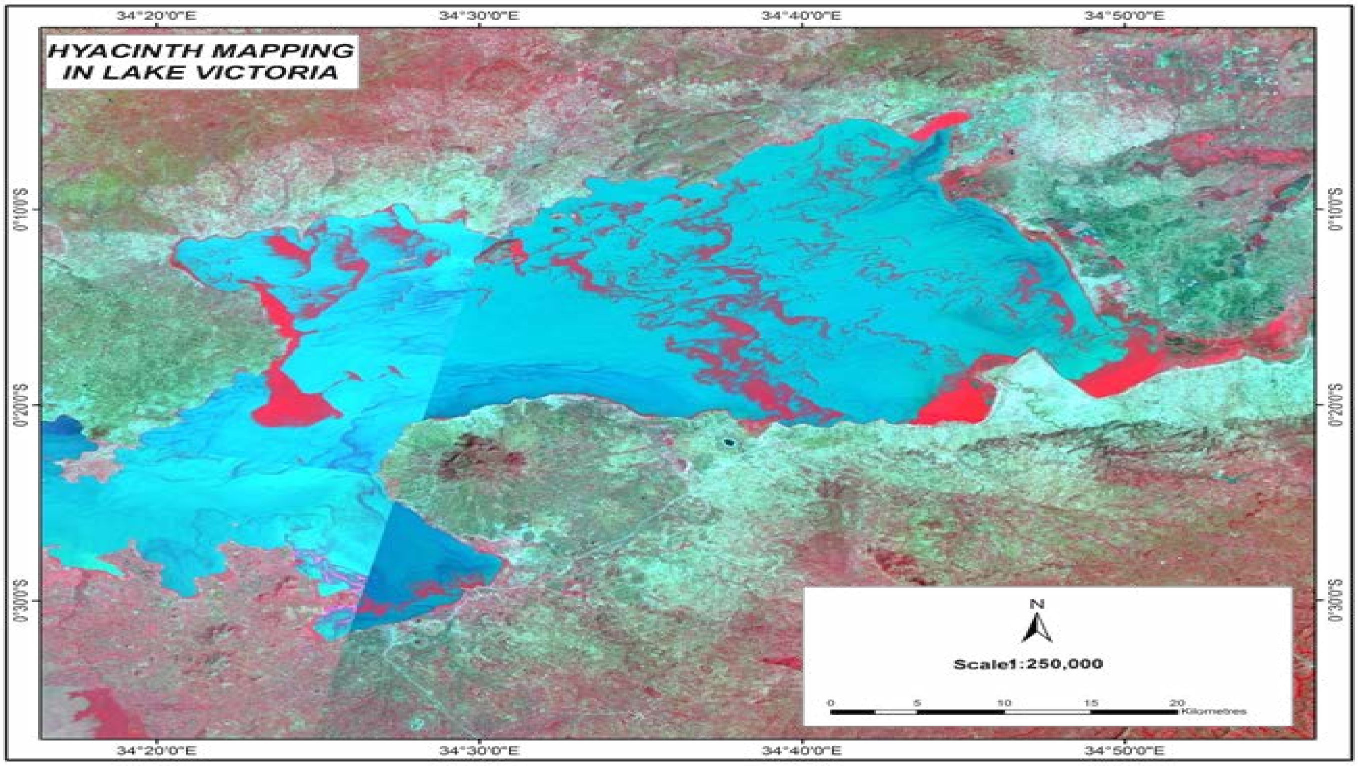

Figure 3. The estimated coverage of water hyacinth in Lake Victoria is 337.5737101 km^2 as per the satellite map.

MATERIALS AND METHODS

Establishment of a Simple Composting Facility

A simple facility for composting of water hyacinth was set up at Makerere University Agricultural Research Institute Kabanyolo (MUARIK) and Korando B in Kisumu. The facilities consisted of twenty composting boxes each having a uniform measurement of 1.35 m x 1.14 m x 1 m for length, width and height respectively **(Figure 4)**. The bottom and the four sides of the box frame were constructed using coffee wire mesh and the upper part left open to allow for turning of the compost. In addition, chicken wire mesh was fitted at the bottom. The boxes were raised to a height of 10 cm above the ground.

Figure 4. Water hyacinth composting boxes.

Harvesting of Water Hyacinth

The water hyacinth was harvested manually from Kawala along the Northern bypass, in a stream about 15 km from MUARIK while in Koran B, Kisumu it was harvested along the shores of the lake **(Figure 5)** and transported to the composting site at MUARIK using lorries **(Figure 6)**. The fresh water hyacinth was then chopped into small pieces of about 5-10 cm in length using a chaff cutter to increase the surface area for microbial action **(Figure 7)**. These were then spread and sun-dried for three days before being filled into the boxes.

Figure 5. Manual harvesting of water hyacinth.

Figure 6. Loading and offloading water hyacinth.

Figure 7. Chopping with a chaff cutter.

Production of Organic compost from water hyacinth

The experiment was set up with five treatments which were; Water hyacinth+Effective Micro-organisms (EM), Water hyacinth+Molasses, Water hyacinth+Cattle manure and Water hyacinth alone (control). These were replicated three times and they were completely randomized in their arrangement. The boxes were placed at a distance of 1-2 m between columns and rows respectively. A well-fitting sack in the shape of the composting box was first fitted in the box before filling each of the boxes with water hyacinth. The chopped water hyacinth pieces were weighed and put into the composting boxes to form a layer of about 10 cm depth at the base for each treatment **(Figure 8)**. 10 L of EM (mixed at a ratio of 1:50 L of water) were sprinkled for each 10 cm layer of fresh water hyacinth up to a height of 1 m high. The same dilution/mixing ratio were used for the molasses treatment and 10 L applied per 10 cm layer of water hyacinth and the box filled to 1 M high as well. For the cattle manure treatments, 5 kg was used per 10 cm layer of water hyacinth in the box for each of the treatment and the box was filled up to 1 M height. The manure was first sprinkled with water before being applied to each layer. In the case of the control, water was used after each layer. After filling the boxes, the tops were covered with a polythene sheet (1000 mm gauge) **(Figure 9)**.

Figure 8. Chopped water hyacinth placed in composting boxes.

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Figure 9. Polythene sheeting covering composting boxes.

Monitoring and Data collection

Turning of the compost was carried out every fifteen days **(Figure 10)** to reduce the compaction and improve aeration of the composting materials which enhances further decomposition. Turning also helped to reduce the moisture of the composting materials. The moisture was measured using a soil moisture meter and maintained at 60%. However, when the moisture was found to be above 60%, the composting boxes were uncovered in the morning to encourage evaporation and later covered in the evening. In some cases, the composting materials were removed and spread for about 3 hours to encourage evaporative water loss and later returned into the boxes.

Figure 10. Turning the water hyacinth compost. Maturity of the compost was determined using temperature and color changes.

Soil Sampling and Analysis

The soils sampled from the identified farms were used for the chemical and physical analyses. Soil samples for chemical analysis were air-dried, passed through a 2 mm sieve and analyzed pH, water soluble carbon (WSC), Ammonium-N, Nitrate-N, total N, total OC, total P, and total K following procedures outlined by Okalebo [15].

Water Hyacinth Compost Analysis

Compost samples for nutrient analysis were collected at weekly intervals to monitor changes in the compost properties with time in order to determine the quality and maturity of the compost. The materials from each treatment were picked from five different points and mixed to make a homogenized composite sample of about 100 g that was kept at 4°C for laboratory analysis. The process was repeated until the heaps turned fully into a dark mass.

The water hyacinth compost from the four treatment were analyzed for the following parameters; p^H, water soluble carbon (WSC), Ammonium-N, Nitrate-N, total N, total OC, total P, and total K following procedures outlined by Okalebo and Tumuhairwe [15,18]. The replicate were subjected to the general Linear Models Procedure of SAS software version 9.1 [19] and means separated using the Least Significance Differences of means (LSD) at $p<0.05$.

RESULTS AND DISCUSSIONS

Temperature Changes during Decomposition

From the temperature readings made for the sixty days, it was observed that the temperature increased steadily for most of the heaps and stabilized at around 35˚C which was the optimum temperature for microbial action especially for the first twenty-four days. Highest temperature was recorded around day 5. After the first turning of the decomposing heaps, the temperature dropped slightly but again increased for most of the heaps. This was observed after every turning of the compost which was done weekly on the twenty fourth day, thirty first days, thirty eighth days and forty fifth days of decomposition **(Figure 11)**. A decline in temperature was also observed as the size of the heaps reduced during decomposition and stabilized at about 24˚C which

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is more of the environmental temperature with minimal microbial action. Hence the experiment was terminated on the sixtieth day. However, higher temperatures were still observed in the control setups after 60 days meaning decomposition, though slow, composting was going on in the heaps without any treatment. Optimal temperatures were observed between day 5 and day 20. Composting temperature ranges depended on treatment.

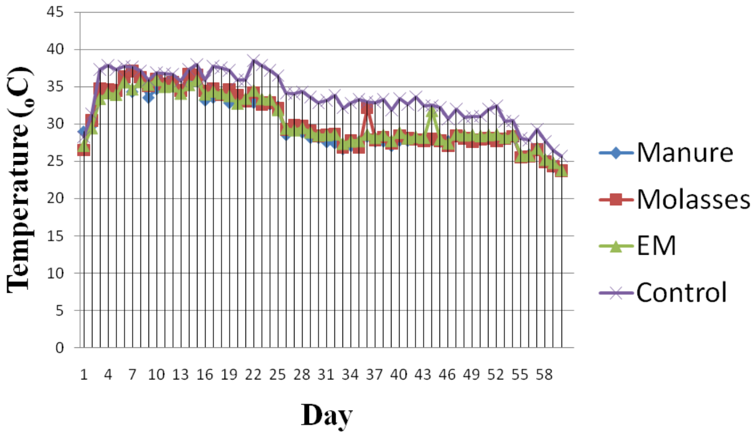

Figure 11. Temperature readings for the sixty days of composting of water hyacinth. The compost turned into dark soil-like fine texture masses for the three treatments apart from the control setups. However, there were a few roots that had not decomposed fully and there- fore had to be sieved after drying the fertilizer but before using it for planting in the farms.

Element Composition

There was no significant difference in the element composition of compost in all composting treatments except P in manure sample 1 compared to the control **(Table 1)**. Composting made all the treatment including the control generate high level of P, N, K and No-3 irrespective of the treatment. The pH of all the treatment including the control was about 8 thus higher than all the soils in the region.

Table 1. Composition of water hyacinth compost.

		Sample			
Element	**Treatment**	**1**	**2**	**3**	**4**
N	CTRL	1.00 ± 0.05[a]	1.12 ± 0.13[a]	1.14 ± 0.09[a]	1.26 ± 0.12[a]
	MANURE	1.14 ± 0.14[a]	1.14 ± 0.09[a]	1.21 ± 0.20[a]	1.07 ± 0.05[a]
	EM	1.00 ± 0.09[a]	1.21 ± 0.13[a]	1.19 ± 0.09[a]	1.19 ± 0.09[a]
	MOLASES	1.00 ± 0.09[a]	0.84 ± 0.56[a]	1.14 ± 0.16[a]	0.93 ± 0.62[a]
P	CTRL	2.71 ± 0.07[a]	2.54 ± 0.28[a]	3.11 ± 0.43[a]	3.16 ± 0.30[a]
	MANURE	3.34 ± 0.14[b]	3.11 ± 0.70[a]	3.51 ± 0.33[a]	3.30 ± 0.31[a]
	EM	2.90 ± 0.44[ab]	3.14 ± 0.26[a]	2.98 ± 0.16[a]	3.09 ± 0.21[a]
	MOLASES	2.89 ± 0.35[ab]	3.25 ± 0.24[a]	3.09 ± 0.34[a]	3.02 ± 0.23[a]
K	CTRL	14.44 ± 2.16[a]	13.13 ± 3.26[a]	12.34 ± 2.33[a]	12.34 ± 1.01[a]
	MANURE	14.78 ± 1.02[a]	11.81 ± 1.79[a]	12.34 ± 3.57[a]	9.98 ± 2.01[b]
	EM	14.70 ± 0.86[ac]	14.63 ± 1.89[a]	11.55 ± 0.86[a]	14.44 ± 2.33[ab]
	MOLASES	11.29 ± 0.53[b]	13.30 ± 3.38[a]	10.76 ± 1.79[a]	10.76 ± 1.79[ab]
NH4-N	CTRL	4.01 ± 3.02[a]	4.28 ± 2.00[a]	8.40 ± 6.62[a]	3.38 ± 1.57[a]
	MANURE	3.68 ± 3.02[a]	2.96 ± 1.63[a]	3.45 ± 1.73[a]	3.68 ± 2.08[a]
	EM	3.71 ± 1.27[a]	3.68 ± 1.35[a]	4.20 ± 2.80[a]	4.20 ± 1.53[a]
	MOLASES	3.08 ± 2.28[a]	2.70 ± 0.52[a]	4.50 ± 2.09[a]	3.25 ± 2.69[a]
NO3-N	CTRL	57.03 ± 43.87[a]	57.95 ± 30.78[a]	43.10 ± 20.26[a]	27.40 ± 21.16[a]
	MANURE	36.28 ± 23.41[a]	33.08 ± 21.31[a]	35.83 ± 22.84[a]	31.50 ± 32.61[a]
	EM	42.90 ± 35.08[a]	32.65 ± 21.84[a]	44.48 ± 40.22[a]	53.60 ± 36.85[a]
	MOLASES	26.25 ± 14.56[a]	38.93 ± 19.51[a]	52.28 ± 45.74[a]	23.73 ± 19.22[a]
WSC	CTRL	0.07 ± 0.03[a]	0.11 ± 0.06[a]	0.10 ± 0.06[a]	0.07 ± 0.03[a]
	MANURE	0.12 ± 0.10[a]	0.10 ± 0.03[a]	0.10 ± 0.01[a]	0.12 ± 0.06[a]
	EM	0.12 ± 0.05[a]	0.09 ± 0.06[a]	0.09 ± 0.05[a]	0.13 ± 0.08[a]
	MOLASES	0.08 ± 0.04[a]	0.09 ± 0.05[a]	0.16 ± 0.09[a]	0.13 ± 0.06[a]

pH	CTRL	8.05 ± 0.13ᵃ	7.65 ± 0.50ᵃ	7.90 ± 0.22ᵃ	8.13 ± 0.36ᵃ
	MANURE	7.98 ± 0.39ᵃ	7.98 ± 0.36ᵃ	7.90 ± 0.45ᵃ	8.10 ± 0.28ᵃ
	EM	7.90 ± 0.19ᵃ	7.70 ± 0.14ᵃ	7.38 ± 0.90ᵃ	7.98 ± 0.35ᵃ
	MOLASES	8.20 ± 0.27ᵃ	7.67 ± 0.25ᵃ	7.88 ± 0.22ᵃ	8.13 ± 0.23ᵃ

Soil Analysis

Soil sample analysis showed that all soils were sandy loam soils, deficient in the soil organic matter and total N while available P was low especially in two farms **(Table 2)**. Soil pH in Kenya was slightly below the critical level in FML and VL while soil pH was above critical level in FLL and Owino's farm however it was within the normal range for crop production. Soil organic matter (SOM) and total N were low in all sites, while available P was low in two sites, and above the critical value in the other two sites. Exchangeable K+ in all sites was above the critical values. In Rwanda, pH, SOM, N, and available P were below the critical level, while exchangeable K was within the normal range. In Uganda, the pH and SOM were within the normal range for crop production, while available P and Total N were below the critical level and evidently inadequate in most sites. Exchangeable K was adequate in some sites, while below the critical value in others.

Table 2. Soil characteristics of experimental sites compared with critical values for East African soils.

SITE	pH	SOM	N	Av. P	K	Textural class
			KENYA			
Okwach's farm	5.4	1.21	0.08	11	0.49	Sandy Loam
Chief's farm	5.1	1.21	0.07	7.8	0.37	Sandy Loam
Nygt's farm	6.4	1.89	0.11	23.7	2.82	Sandy Loam
Owino's farm	6.5	2.28	0.12	42.3	2.12	Sandy Loam
			RWANDA			
Above Road	4.9	2.09	0.09	9.2	0.2	Sandy Loam
Below Road	5.2	1.99	0.09	8.8	0.24	Sandy Loam
UGANDA						
MUARIK	5	3.2	0.08	4.75	0.5	Sandy clay
Farmer 1	5.3	3.12	0.13	10.95	0.16	Sandy Clay Loam
Farmer 2	5.4	2.4	0.13	10.84	0.27	Sandy Clay Loam
Farmer 3	5.5	2.96	0.13	10.5	0.16	Sandy Clay Loam
†Critical value	5.5	3	0.25	15	0.22	-
pH was measured as –log[H+], SOM and N as percentage (%) and P as Cmol kg^{-1}. † SOM=Soil organic matter [15].						

The pH value of 5.5 is more applicable to commercially oriented production systems under tropical conditions where high levels of exchangeable aluminium pose phytotoxicity concern [20]. However, in the small-scale subsistence systems where profitability is largely deemphasized, a pH of 5.2 was recommended as the critical value [21]. Therefore, the pH values for most sites are within the normal range for crop production. The low levels of total N in the soil poses a major concern, this being the nutrient required in large quantities by crops [22]. This N value, by and large signals the urgent need for management attention if viable crop productivity is to be achieved. Like in the case of total N, available P was inadequate in most sites for any level of crop production. This again calls for strategic management attention either through application of mineral P or through use of soil fertility amendments such as organic matter (compost) which are capable of solubilizing the otherwise non- plant available P fractions in the soil. The presence of barely adequate levels of exchangeable K+ in some sites also signals the need for replenishment of nutrients with external nutrient sources.

CONCLUSION

Small scale compost facilities using readily available water hyacinth have great potential around the Lake Victoria Basin. The need for a more environment friendly agricultural practices like the use of compost is a necessity for this practice to be achieved. Compost made from water hyacinth as a source of biomass has potential for providing a source of available P and exchangeable K+ necessary for crop production. The high hyacinth compost pH of about 8 makes it suitable in stabilizing soil pH in the region. Hyacinth compost can act as soil stabilizer hence increase soil productivity in the region.

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