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Potassium Ion Uptake by Water Hycinth (*Eichhornia crassipes*) on The Lower Reaches of the Niger River, Nigeria

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ABSTRACT

The concentration of potassium ion in water hyacinth (*Eichhornia crassipes*), a free-floating aquatic weed, was studied. Field trips were made to sample stations and harvested water hyacinth digestate were analyzed using Atomic Absorption Spectrophotometry. Investigations showed that the concentration of potassium ion in January to June 2003 ranged from 0.52 mg/l to 0.59 mg/l and that the cumulative mean average of the ion concentration for the six months was 0.55 mg/l. From January to June in 2004, the ion concentration ranged from 0.55 mg/l to 0.62 mg/l. The cumulative ion mean average within this period was 0.59 mg/l indicating an increasing trend in potassium ion uptake from January to June in 2003 and 2004 in the Lower Reaches of the Niger River, Nigeria. This was likely as a result of increased agricultural, industrial and human waste activities around the sample areas. Run-off from these activities is washed into the river by rainfall, which coincided with an increase in average rainfall level during the sampling periods, thus creating an upsurge in nutrient levels.

INTRODUCTION

Historical background

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant, which forms dense free-floating mats on the surface of fresh water or is often anchored in mud. It obtains its nutrients from the water environment.

The plant ranges in size from a few centimeters to a meter in height. Floating mats develop just as growth in root production occurs making up to about 50% of the total plant biomass (Holm *et al*. 1969). Its flourishing rate depends on certain circumstances (Harley 1988) and thus a reduction in light and oxygen levels of the water or a change in water chemistry affect flora and fauna (Sharma *et al*. 1988) and cause significant increase in water loss due to evapotranspiration (Sharma *et al*. 1988). The mean rate of water loss by water hyacinth shows that transpiration is usually low at night and rises at noon, then falling in the evening. However, the rate of transpiration depends predominantly on the prevailing temperature and relative humidity.

Reproduction is accomplished both sexually and vegetatively. Vegetative reproduction is most prolific. The plants rarely produce seedlings. Vegetative reproduction starts with the production of daughter plants and growth continues until maximum biomass is achieved. Vegetative reproduction is effective and can occur through one of two ways: (i) by the process of fragmentation or (ii) by forming plantlets at the end of a shoot that grows from the base of the stems. This process of reproduction produces many new plantlets in a short time. Fragmentation or breaking into smaller pieces is caused by the churning of propellers of outdoor motor boats, the thrashing of swimming animals, animals grazing on hyacinth fields or by wave action in storms, tossing about the plant.

Water hyacinths are Native to the Amazon Basin but ware introduced into many parts of the world as an ornamental garden pond plant because of their beauty (Khan *et al*. 1988). Its proliferation has seen it introduced in many areas and they can now be found in every continent besides Europe. The plant is a perennial aquatic herb, belonging to the family *Pontederiaceae* which is often confused with the aquatic free floating weed, *Limnobium spongia* (http://en.wikipedia.org/wiki/Water_hyacinth) but closely related to the *Liliaceae* (lily family). Water hyacinth's dominance in its habitats can be linked to many factors, a few of which include: a) effective form of vegetative reproduction as described above; b) the stems are spongy and easily filled with air spaces; hence the plant can float around easily for long periods; c) the plant's leaves are slightly cupped and fanlike. This gives the hyacinth effective sail and allows the plants to flourish easily as wind blows over water bodies; d) the root is a feathery network of fibres, this allows the plant to amass nutrients very easily from the water.

With these characteristics the water hyacinth has tremendous advantage over other native floating aquatic plants. Few plants cover a relatively large surface of their new aquatic habitat in a short period of time (Holm *et al*. 1969). Water hyacinths are found in 13 states within the US and in 53 other countries around the world (Khan *et al*. 1988).

The effects of water hyacinth on a natural ecosystem can be very devastating. As the weed covers the water's surface, life-sustaining factors such as sunlight is restricted. As a result, submerged plants native to the environment eventually die and decay (Sharma *et al*. 1988). The decaying plants deplete the amount of dissolving oxygen in the water and thus reduce the oxygen level (Sharma *et al*. 1988). Life forms such as fish now seek new habitat areas thereby altering the ecology balance (Kusemiju 1984). Humans are also affected by the infestation of water hyacinth in that dense mats of the plants interfere with water transport, clog drainage systems, and prevent fishing, swimming and other recreational activities.

Water hyacinths have a water content of over 90% (Edewor 1988). The dry matter contains between 10 and 26% of crude protein, but the leaves contain higher levels, about 38%. The mineral content depends directly on the water where the hyacinth grows, but the mean value ranges from 17 to 26%. In the removal of zinc from simulated wastewater samples, the growth rate of the plant decreases with an increase in metal ion concentration (Hasan *et al*. 2003). In India the plant has also been used successfully for the removal of Zn (II) and Cd (II) from samples of aqueous solution. After 16 days of exposure to the metal ions there was an increase trend of up to 2.5 ppm of Cd (II) and 6.0 ppm of Zn (II) concentrations (Hasan *et al*. 2007). The sur-

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vival and behaviour of water hyacinth under varying conditions of heavy metal concentrations indicated that the heavy metal (Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn) concentrations, pH and conductivity of the media were measured and analysed for heavy metals carried out on the plant samples after termination of the experiment showed that water hyacinth can survive in a mixture of heavy metal concentrations up to 3 mg/l and in 100 mg/l Pb solutions, whereas higher concentrations of metals as mixtures and 100 mg/l Cd led to rapid fading of the plants (Soltan 2003). These authors also showed that the process of metal uptake by the plant is monophasic in nature with the increase of metal ion concentration, that the amount of metal ion concentrated in the root is larger than that at the top of the plants, that the percentage removal of the metal from the aqueous solution decreases with increasing initial concentration of the metal and that inorganic nitrogen and phosphorus are concentrated to a large extent in the roots. This makes the weed very desirable as a compost or organic fertilizer. Water hyacinth provides nutrients such as potassium in an appreciable amount adequate for good growth of bacteria. Studies have shown that potassium and calcium formed the larger proportion of the macro-elements in the leaves, while magnesium and iron the majority in other parts (Igbinosun *et al*. 1988). The stem and leaf of the plant were subjected to various treatment of acid solution including HCl and tartaric acid. The highest rate of K removal was achieved following HCl treatment, at 69.7% k. Maximum K removal was obtained only at treatment at pH 13. This process demonstrated the potential for use of water hyacinth as a resource of potassium to produce potassium salt (Wenbing *et al*. 2007). The effectiveness of four aquatic plants including water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), zebra rush (*Scirous tabernaemontani*) and taro (*Colocasia esculenta*) were evaluated for their capabilities in removing mercury from water. After exposing the plants to concentrations of 0 mg/l, 0.5 mg/l and 2 mg/l of Hg for 30 days, results indicated that the mercury induced acute toxicity had been removed from the water. All species of plants appeared to reduce mercury concentrations in the water via root uptake and accumulation. Water hyacinth and water lettuce appeared to be the most effective, followed by taro and zebra rush, respectively (Kathleen *et al*. 2007). These studies indicate the potential utility of water hyacinth for nutrient removal and biomass production, based on the continuous harvest at the maximum sustainable yield. Two types of surplus production-harvest models of water hyacinth are constructed to manage the water quality of rivers in both raining and dry seasons. The models are expected to be a simple but adequate tool of pollution control for diffuse sources in the long term (Jukkrit *et al*. 2001).

Utilization of water hyacinth

Utilization as a control measure for water hyacinth sees the weed being used for waste water treatment and water quality management. However the cost/benefit ratio of these proposals and the practicality of them into commercial operation has not yet been addressed. World-wide experience indicates that these proposals are usually neither commercially nor economically viable (Harley 1988). The concern of the Commonwealth Science Council on the potential use of water hyacinth as a means for water pollution abatement was highlighted in Malaysia. Investigations included waste waters from electroplating, pig farming, sugar refining, rubber processing and palm oil industries. The result indicated that the weed is particularly useful as an economical and effective method in the advanced treatment of palm oil mill effluent and rubber factory effluent which are the two major environmental polluters in Malaysia. Cyanide (CN) phytoremediation by water hyacinths in the effluents from Industrial mining waste treatment indicates that CN could possibly be removed by the weed because of its high biomass production, wide distribution, and tolerance to CN and metals. Sodium cyanide phytotoxicity and removal capacity of *E. crassipes* was determined. Toxicity to 5-50 mg CN/l was quantified by measuring the mean relative transpiration over 96 h. Spectrophotometric analysis indicated that cyanide at 5.8 and 10 mg/l was completely eliminated after 23-32 h. Hence, *E. crassipes* could be useful in treating cyanide effluents from small-scale gold mines (Mathias *et al*. 2007). Biogas production from water hyacinth (*E. crassipes*) and channel grass (*Vallisneria spirales*) employed separately for phytoremediation of lignin and metal-rich pulp and paper mill and highly acidic distillery effluents indicated that these plants eventually grow well in diluted effluent up to 40% and often take up metals and toxic materials from wastewater for their metabolic use (Singhal *et al*. 2003). In Egypt, it was discovered that the total eradication of aquatic weeds is not desirable as the presence of some limited plants certainly has advantages. Bank vegetation supports the banks with their roots, and their removal would expose the banks to increased erosion. Crops associated with nutrient-rich waters from domestic sewage effluents indicates the presence of aquatic weeds which are apparently indigenous to Ghana and posed fairly serious threat to water resources, including the submerged weeds *Ceratophyllum demersum* (Coontail of Hornwart), *Potamogeton* sp. (pond weed), *Pistia stratiotes* (water lettuce), among others. Hydrobiological investigations (Egborge *et al*. 1986) of the Benin River, Nigeria, revealed that a comparison of the mean values of eight selected physico-chemical parameters in three stations each of the Lagos, Badagry Creek system and Benin River revealed stunted developments of water hyacinth in the Benin River. felt that the differences in the water quality particularly with the low nutrient levels were not responsible for stunted growth of the plant.

Control methods of water hyacinth

Well-tried physical control methods such as barriers, floating booms, and nets on an extensive scale have been practiced in Nigeria to dent the growth in affected areas, provided there is continuous patrolling and weeding of areas and passages thus cleared. Local resources are not enough to clear and keep clear the entire fresh-water surface in the Lagos/Edo State areas. Indeed, a carefully prepared plan permitting (or living with) infestation of uncritical areas and the effective application of physical barrier controls in critical areas, along with continuous survey and removal of leakages of weed into cleared areas, actually alleviated the worst of the manifestations of infestation. A biological control program of water hyacinth was undertaken in Southern Benin between 1991 and 1993. It consisted of the release of three natural enemies, two weevil species and one moth that feed exclusively on water hyacinth. Using participatory and quantitative methods, it was revealed that water hyacinth, although not eliminated, was perceived by the villagers as having been reduced from a serious pest to one of minor or moderate importance. The reduction of water hyacinth cover through biological control was credited with an increase in income of US$ 30.5 million per year (de Groote *et al*. 2003). Where more than one of the most serious floating aquatic weeds i.e., *Eichhornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* and *Altemanthera philoxeriodes* is present, application of a biological control strategy appropriate to each will ensure that reducing one weed does not simply lead to increase by another. A weevil, *Neohydronomus pulchellus* (Hustached), from southern Brazil has been used successfully for the control of *P. stratiotes* in Australia (Harley *et al*. 1984), South Africa and Papua New Guinea, Zimbabwe and Botswana (Forno *et al*. 1983). The aquatic weed situation in the Kafue River in Zambia continues to be a major challenge to the sustainable utilization of the water resources of the river. The general methods for managing the weeds, especially the water hyacinth, include use of bioagents, chemicals, mechanical and physical approaches. These have had very little impact. Weed management strategies involving use of cleaner production approach and the utilization of the weed for economic purposes e.g., the production of mushroom gave very impressive results in Zambia (Thomson *et al* 2002). This insect gives very effective control in tropical regions and a useful level of control in the sub-tropics. Other insects that have been used successfully for the biological control of water hyacinth include the weevil, *Neochetina eichhornia* and *Neochetina bruchi*; the moth, *Sameodis albiguttalis*, mite, *Orthogaluma terebrantis* and grass carp, *Ctenopharygodon idella* (Charudattan 1986). Chemical control using herbicides is widely recommended in many countries of the world. Herbicides used include, Ametryn (2-ethylamine) 4-isopropylamine-6 methythio-5-triazine, Reglon (Diquat) (1,1 ethylene-2,2 bipyridylium ion), Paraquat ($1,1^{1}$-dimethyl-$4,4^{1}$-bipyridilium ion (Charudattan 1986).

In the present study, we have chosen to study water hyacinth among other aquatic weeds due to its prevalence in the water ways of Nigeria and most importantly due to its phenomenal growth and dominance over other aquatic weeds and also the problems it has caused inhabitants living along the water ways.

MATERIALS AND METHODS

Extensive field trips (**Fig. 1**) were undertaken to harvest water hyacinth samples. Each sample station was visited monthly from January to June in 2003 and 2004. Four specimens of water hyacinth plant were harvested at a distance of 20 meters each between harvest at each sample station. Harvested plant samples were dried using an Akson Scientific Oven for 24 hrs at 110°C until constant weight to remove moisture. The product was very stable without browning or mould growth when stored at room temperature for 7 days. The dried material was milled in a porcelain mortar to a fine powder. Exactly 5 g of the powder of each of the four samples from each station was digested using *aqua regia* (1:3 nitric acid: hydrochloric acid) for 2 hrs. About 5 ml of deionized water was added intermittently at intervals of 10 mins during heating to avoid drying up of the mixture. After cooling at room temperature, the mixture was filtered. Five ml of the filtrate (digestate) was made up to 100 ml with deionised water in a volumetric flask for each of four samples from each sample station. About 5 ml of the digestate of each of the four samples of each sample station was used to evaluate the potassium ion elemental composition of the samples using Atomic Absorption Spectrophotometry (AAS). The concentration (mg/l) of the metal ion in the weed in each sample was determined by the following method: The concentration of 0.1 to 1 ppm of standards of potassium ion were prepared using an appropriate amount of potassium sulphate and deionised water. The absorbance of these concentrations were determined with the spectrophotometer (AAS) at 766.5 nm wavelengths, 4-1.5 abs optimum working range with an Air Acetylene Oxidizing (AAO) flame type. Plots of absorbance of standards of potassium ion against its concentration were made. The concentration within each sample was obtained by interpolating the absorbance from the spectrophotometer (AAS) to the appropriate concentrations on the graph. The mean of four determinations equaling one sample station for all the sample stations was plotted against sampling month.

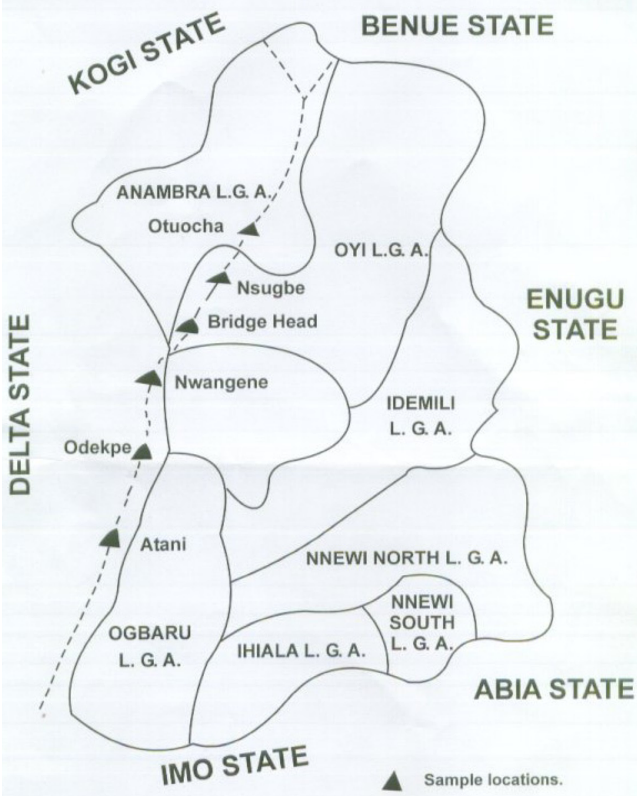

Fig. 1 Sample locations in Anambra State.

RESULTS AND DISCUSSION

For many centuries, weeds growing on waste bodies have been known to mankind and these flamboyant flora constitute major setbacks. These problems, although quite alarming, also allow us to reflect on what advantage these weeds could be to humans. It has been reported that most of these weeds contain dissolved nutrient that aids in the

Table 1 Concentration [mean (mg/l)] of water hyacinth digestate for 2003.

Sample location	Otuocha		Nsugbe		Bridge Head (Onitsha)		Nwangene (Onitsha)		Odekpe		Atani	
Months	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**
January	0.58	1.3	0.47	2.6	0.46	0.9	0.45	0.7	0.54	0.5	0.65	2.5
February	0.56	0.2	0.47	1.1	0.47	1.3	0.45	0.5	0.57	0.6	0.65	2.5
March	0.57	0.5	0.52	0.9	0.48	1.0	0.46	0.6	0.57	0.1	0.66	1.0
April	0.58	1.7	0.55	0.8	0.48	0.3	0.46	0.2	0.57	0.1	0.64	0.2
May	0.65	2.2	0.54	1.8	0.48	0.1	0.46	0.6	0.57	0.4	0.67	0.5
June	0.69	0.6	0.58	0.5	0.51	0.6	0.48	0.2	0.58	0.5	0.67	0.1

Table 2 Concentration [mean (mg/l)] of water hyacinth digestate for 2004.

Sample location	Otuocha		Nsugbe		Bridge Head (Onitsha)		Nwangene (Onitsha)		Odekpe		Atani	
Months	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**	**Mean (mg/l)**	**S.Dx10^{-2}**
January	0.55	0.6	0.45	0.7	0.51	0.6	0.48	0.2	0.63	0.3	0.68	0.3
February	0.54	0.7	0.46	0.6	0.52	0.7	0.50	0.4	0.65	2.5	0.72	0.7
March	0.55	0.9	0.46	0.2	0.53	1.0	0.52	0.5	0.67	0.5	0.74	1.1
April	0.56	0.6	0.47	1.1	0.54	0.5	0.54	0.5	0.68	0.3	0.76	0.3
May	0.57	0.3	0.48	0.2	0.56	0.2	0.56	0.2	0.72	0.7	0.78	0.4
June	0.58	0.5	0.49	0.5	0.57	0.5	0.58	1.7	0.74	1.1	0.78	0.4

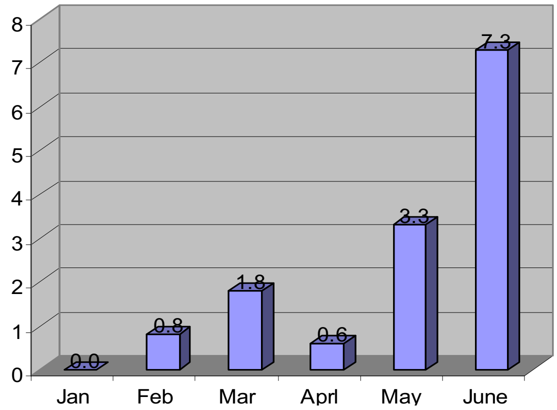

Fig. 2 Average rainfall in Anambra State, Nigeria, during 2003 and 2004. **Source:** National Inland Water Ways, Onitsha, Anambra State, Nigeria.

growth of bacteria, algae and most aquatic macrophytes. The nutrient load may result due to pollution of the water environment from municipal and agricultural sources. Water hyacinth has been known to remove nutrients in polluted water.

Tables 1 and **2** show the potassium ion concentration from January to June in 2003 and 2004. There is increase in the concentration of potassium ion from January to June 2003 and 2004. From the tables, it can be observed that the potassium ion concentration show a marked increase as the table is descended from January to June in 2003 and 2004. In 2003 the Atani sample station show a high increase in potassium ion concentration from January to June although in Otuocha there was an increase in May and June. The highest concentration was observed in 2004 at the Atani sample station in May and June. This coincides with an average increase in rainfall during the 2004 sampling period. **Fig. 2** indicates the sample stations beginning from Otuocha to Atani. The elemental composition of potassium ion in the plant in 2003 showed that the mean concentration (mg/l) was: January (0.53), February (0.53), March (0.54), April (0.55), May (0.56), and June (0.59) while in 2004 values were: January (0.55), February (0.57), March (0.58), April (0.59), May (0.61), and June (0.62). The standard errors of the mean for the six sample stations beginning from Otuocha to Atani in 2003 are: 0.0213, 0.0181, 0.00683, 0.00447, 0.00577 and 0.00494, while the standard error of the difference between the means is 0.0301. In 2004, the standard error of the mean for the six sample station from Otuocha to Atani is; 0.006, 0.00608, 0.00945, 0.01527, 0.3804 and 0.0155. The standard error of the difference between the means is 0.3812. The generalized t-test was used to test the significance difference between the means of sets observations in 2003 and 2004. In 2003/2004, t-test from Otuocha to Atani sample stations are: 2.21, 2.78, 5.00, 2.40, 3.12 and 5.37 at df=10. These values indicate significance at 99% confidence levels at the Bridge Head, Nwangene and Atani sample stations. These values are in line with studies reported by (Igbinosun *et al*. 1988) and (Sharma *et al*. 1988), though the latter's study indicated a decrease trend with time (January to June) in potassium ion concentration of water hyacinth from Badagry Lagoon, Lagos, Nigeria. This could be attributed to two factors. Firstly, there is an increase in agricultural activity from January to June in these sample locations. Hence the enrichment of natural waters by fertilizer run-offs from the agricultural activity creates an increase in nutrient level. Secondly, there is also an increase in human population as well as industrial activity. The human population generates human waste while the industries produce manufacturing wastes which also enhance the nutrient level of the water bodies and promote the growth of water hyacinth. As the use of organic fertilizer increases with an upsurge in manufacturing activities mainly in industrial estates situated around Onitsha through Atani sample stations in Anambra State, Nigeria, the effluents discharged from these factories eventually find their way into the aquatic environment, thus destabilizing the ecosystem. It has been found that after applying water hyacinth to the soil for twelve months, there was an increase in the cation exchange capacity of the soil and also an increase in C, K, Ca, Mg and Mn contents (Parra *et al*. 1974). Thus, water hyacinth can be seen as a supplier of nutrients. On the whole, the rather high concentrations of nutrients make the plant, water hyacinth, a desirable green manure to the farmers' advantage. Potassium is an important nutrient and a component of the NPK fertilizers. Its value is reasonably high in the Lower Reaches of the River Niger, Nigeria, thus making potassium adequate for good crop development. The increasing trend in potassium ion uptake by water hyacinth in this study also coincides with a period of increase rainfall in this part (East) of Nigeria, as shown in **Fig. 2**. Hence as the period of rainfall increases so the amount of nutrients washed into the river increases and hence the increase in pollution of the river.

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