FSN-EN 0006

MANAGEMENT AND UTILIZATION OF WATER HYACINTH (*Eichhornia crassipes*) FOR IMPROVED AQUATIC RESOURCES

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ABSTRACT

Natural aquatic plants population can be healthy for any aquatic ecosystems as they serve as fish feed, play an important role in nutrient cycling, purify the water, control unwanted algal growth and support fauna including birds. Water hyacinths (Eichhornia crassipes) have proven to be a persistent and expensive aquatic weed problem. The review was carried out in the face of current global challenge (climate change) which threatens biodiversity conservation and sustainable use of natural resources so that water hyacinth could be viewed as an asset of multifarious benefits considering the revealed highlights rather than been labeled expensive nuisance. The simplest method of management of aquatic weeds is to harvest it and utilize it for cost effectiveness in production such preparation of fish and livestock feeds, bio-gas production, making of charcoal briquetting and waste water treatment for domestic and industrial use. The main problem of utilization and management of water hyacinth is its high cost of transportation to sites for utilization but, once this can be overcome as revealed in the review appropriate utilization techniques is recommended.

***Keywords**:* Water hyacinth, Ecosystems, Aquatic weed, Utilization, Biodiversity

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an aquatic plant which can live and reproduce floating freely on the surface of fresh waters or can be anchored in mud making it the most successful colonizer in the plant world (Wolverton and McDonald, 1979). The extremely rapid rate of proliferation (Hill *et al.*, 1997) of the water usually result in reduction in height penetration and dissolved oxygen in water bodies, change water chemistry, affect flora and fauna, increase rate of water loss due to evapotranspiration and it is now presently being considered as a serious threat to biodiversity (Mathur, 2007). During an International Water Hyacinth Consortium at World Bank, Washington, Hill *et al.*, (1997) reported that more action should be geared towards the control of the weed as its utilization is not an effective means of control. In recent times, considerable attention seems to be given to its harvesting for practical uses, namely, for partially defraying the cost of removing plants from water ways and for use as alternative plant protein source in livestock feed including fish (Daddy, 2000; Sotolu, 2008; Aderolu and Akinremi, 2009) due to persistent problem of high cost of feeding in aquaculture. The reports of Boyd (1968 and 1969) on the chemical analyses of water hyacinth indicated that it contains very high fibrous or cell wall materials, mainly cellulose which was corroborated by Igbinosun *et* *al*., (1988) but very rich in amino acid profile (Wolverton and McDonald, 1978) and essential vitamins Liang and Lovell (1970). The high fibre content of the whole water hyacinth plant meal has put great limitations into its effective utilization by fish as feed ingredient (Akinyama, 1988; Igbinosun *et al*., 1988: Nwanna *et al.*, 2008) despite its high nutritive value but its potential in waste water purification has been enumerated by several researchers (Timmer and Weldon, 1967; Oki *et al*., 1988; Une and Oki, 1988; Sotolu, 2010). The main factor affecting the utilization level of water hyacinth meal (WHM) has been its high crude fibre content. Tables 1 and 2 show proximate composition and mineral composition of water hyacinth respectively while Table 3 presents amino acid profile of water hyacinth in comparison with two other plant protein sources. This review therefore presents results of several researches on water hyacinth in waste water treatment and a relevant free existing plant for use in sustainable environmental management instead of being considered a weed.

Adaptation of Water Hyacinth and its Emergence in Nigerian Waters

Eichhornia crassipes originated in the Amazon Basin and was introduced into many parts of the world as an ornamental garden pond plant due to its beauty (Hill *et al*., 1997). It has proliferated in many areas and can now be found on all continents apart from Europe. It is particularly suited to tropical and subtropical climates and has become a problem plant in areas of the southern USA, South America, East, West and Southern Africa, South and South East Asia and Australia. Its spread throughout the world has taken place over the last 100 years or so, although the actual course of its spread is poorly documented. In the last 20 years the rapid spread of the plant in many parts of Africa has led to great concern. An early record of its presence in River Nile was in the later part of the 18^{th} Century (Hill *et al.*, 1997; (Ekelemu 1998),). The biological dynamics of water hyacinths in terms of genetic uniformity has been investigated by Zhang *et al*. (2010) who reported that existing clonal diversity in the plant enhances its ubiquity as sexual recruitment occur in invasive sites where environmental conditions favour seedling establishment. The plant now circum-globed in tropical and subtropical regions, was first noticed in Nigerian waters, on the shore of Lagos lagoon in October 1984 through port-novo creek in Benin Republic in September 1984 according to Konyeme *et al.* (1988), but has since spread to other parts of the country, particularly in the Coastal states. This aquatic plant is problematic in Nigeria coastal waters. It is known to block navigation ways, greatly reduces fishing activities as well as recreational activities within the environment (Konyeme *et al*., 2006). The plant is a perennial aquatic herb (*Eichhornia crassipes*) which belongs to the family Pontedericeae, closely related to the Liliaceae (lily family). The mature plant consists of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plants are up to 1 metre high although 40cm is the more usual height. The inflorescence bears 6 - 10 lily-like flowers, each 4 - 7cm in diameter. The stems and leaves contain air-filled tissue which give the plant its considerable buoyancy and it has been observed travelling upstream against the current (Vietmeyer, 1975). The vegetation reproduction is asexual and takes place at a rapid rate under preferential conditions. Tyagarajan (1983) reported that one hectare pond of water hyacinth will produce 0.9 to 1.8t of dry matter per day. It grows rapidly in water with temperatures of between 28 and 30°C and with a pH of 4.0 - 8.0, and ceases to grow when the water temperature is above 30°C or below 10°C. The weed dies when the tip rhizome is frozen. The weights and proportions of water hyacinth differ considerably in different samples collected in various seasons. However, the typical green plant consists of 24.80% root, 41.90% stalk and 33.305 leaf (Thyagarajan, 1983). The physical structure of the plant made its transporting very cumbersome and expensive after harvesting towards its utilization. The efforts of Mathur (2007) have provided ways of overcoming it through design of a machine. The machine consisted of pair of rollers, set of blades, a shear plate, a hopper and conveyors. Performance of the machine was evaluated on the basis of biomass reduction of water hyacinth. The developed system reduced the specific volume of water hyacinth by 73 per cent and thus reduced the cost of transportation up to 65.7 per cent (Mathur, 2007). The chopped and crushed biomass can be used for alternative applications like preparation of paper, fiber board, furniture, biogas production, making of charcoal briquetting, as animal feed, fish feed etc. and completed his recommendations that crushing and effective utilization of water hyacinth will help in to solve the problem of management of water hyacinth. Barrett (1990) has pointed out that there are number factors to be considered when deciding on the best management strategy. For example, there is a choice between total control or some form of selective control. This depends on the particular management objective. The management techniques chosen must be appropriate both to the type of weed problem, and to the uses and functions of the body of water. The risk of adverse side-effects for users of the water must always be given priority. In general, the more effective the weed clearance, the greater will be the risk of an adverse environmental impact (Barrett, 1990). Accordingly, aquatic weed management systems must be developed which are socially and environmentally acceptable. In addition, freshwater systems are now being viewed as a public amenity and recreational area which should be in agreement with the environment. It should be noted that no single method will guarantee the success of aquatic weed management. The combined use of several appropriate methods, including utilization of water hyacinth as a resource, is often the best way of protecting the quality of the environment.

Water Hyacinth for Sustainable Aquaculture Production

The farming demands of a controlled aquatic plant system have repressed application in the aquaculture industry. Mathur (2007) provides considerable detail about various methods of water treatment that can be applied to aquaculture, including a number of filtration systems, and bacterial-based technologies, such as rotating biological contactors (RBC). However, the discussion of aquatic plants is limited, with only two species mentioned: water chestnuts (*Eleocharis dulcis*) and water hyacinths (*Eichhornia crassipes*-Mart Solms). Water hyacinths are stated as having some potential as a livestock feed, but it is suggested that drying of the plants makes the economics unattractive. It is implied that the perceived difficulties in the dynamic farming of aquatic plants tend to overpower the water quality benefits they provide, and it is noted that most Aquaculturists are more concerned about eliminating aquatic plants than they are interested in producing them. However, in spite of this observation, Mathur (2007) is not reluctant to suggest that integration of plant and fish systems has merit as a means of improving water quality and increasing fish production, which was in line with earlier reports of Balasooriya (1984). Boyd (1990) also stated that using water hyacinths or other aquatic macrophytes to remove nutrients and reduce the potential for phytoplankton growth in fed ponds might have practical application in tropical and subtropical areas.

Water Hyacinth in Eutrophicated Waters

Using aquatic plants to improve water quality within an integrated fish culture system has also been reviewed seriously by researchers. In a recent study, Tan *et al*., (2008) provided some support for the use of created wetland systems for treating effluents from aquaculture operations, specifically, static catfish ponds. They do not, however, address the possibility of true integration of the wetland system into facility operations as a source of additional aquaculture products, or as a means of improving fish production, but rather offer the use of wetlands solely as a means of treating effluents from drained ponds. Water hyacinth-based systems and the algal turf scrubber (ATS) system are well suited for coordination with fish cultivation in a tropical and subtropical environment, as they are compatible with crop management routines and operational manipulation (Mathur, 2007). Further, they offer high productivity levels at the associated temperature and influx levels. Due to the oxygen-generating and phosphorus-reduction capabilities, and its ability to sustain rather high levels of production under a wide range of nutrient concentrations, the ATS system is a logical selection as a plant cultivation system for the integrated system of the present invention. The use of water hyacinths provides additional support in facilitating nitrification, reduction of BOD and suspended solids, and as a pretreatment and hydraulic equalization system.

Water Hyacinth Technology for Integrated Aquaculture System

The use of water hyacinths for control of nutrients within wastewaters has been developed and commercially applied in subtropical areas such as Florida. The role of a water hyacinth system within the integrated aquaculture system is to provide initial control of nitrogen and oxidation of ammonia; oxidation of CBOD; storage of residual solids and removal of total suspended solids (TSS); insulation to retain heat in winter and shade in the summer; hydraulic equalization during periods of flow diversions or fluctuations; production of high-fiber, high-protein material for livestock feed; reduction of residual toxins; attenuation of pathogens; and pretreatment of makeup waters prior to dispensing into the ATS or fish cultivation systems. Although water hyacinths are referred to herein, the plant subsystem may include monocultures or polycultures, and may include plants of the genera Eichhornia, Spirodella, Salvinia, Azolla, Lemna, and Pistia, although these are not intended to be limiting. Work on the effectiveness of water hyacinths in treating agricultural wastes (dairy) provided an indication that in addition to direct plant uptake, extensive nitrification and consequential denitrification occur within the water hyacinth root zone (Klumpp *et al.* 2002). A number of commercial applications in Florida (Stewart *et al*., 1987) established the ability of managed water hyacinth systems to significantly reduce nutrient loadings from wastewaters. Considerable investigation has also been directed towards the removal of both suspended solids (TSS) and CBOD by water hyacinths. Early work by Wolverton and McDonald (1979) provided evidence that at high CBOD and TSS loadings water hyacinths could facilitate extensive reductions, approaching 400 kg/ha/day. Similar results were documented by Klumpp *et al*. (2002) at the Disney facility near Orlando, Florida. In a commercial application at the Iron Bridge Treatment Facility in Orlando, Gangstad (1978) achieved reductions in CBOD and TSS to below 2.5 mg/l. Similarly, the rate of nitrification has been shown to be high within a functioning hyacinth system (Gangstad, 1978; Amasek, 1989). The potential of water hyacinth has been utilized by the national space Technology Laboratories NSTL of the United State in the treatment of eutrophicated lagoon due to high cost of waste water treatment in order to meet Environmetal Protection Agency (EPA) regulation (Rogers and Davis, 1972) and this result was corroborated by observations of Addison (1997) in a recent study. The reports of the treatment indicated that mean influent BOD was reduced by 95% from 110 mg/L to 5 mg/L in the effluent while the mean influent TSS was reduced by 90% from 97 mg/l to 10 mg/l in the effluent. The average monthly total kjeldahl nitrogen (ammonia and organic bond nitrogen) was reduced from 12.0 to 3.4 mg/l and the total phosphorus was reduced from 3.7 mg/L to 1.6 mg/L. The water hyacinth was able to control nuisance algal blooms and no repulsive came from the lagoon due to the improved water quality that was achieved, which was corroborated by the recent reports of Willoughby *et al*. (1993). An analysis of the fish cultivation effluent, applied to the HYADEM model, allows projections of cultivation area, effluent quality, and plant management needs for a water hyacinth system that would serve as a pre-ATS process. This system receives flows from the fish cultivation ponds and tanks; makeup water sources; any diverted ATS water; and various waste streams that might come from plant and fish processing, or from external sources.

Summary

Water hyacinth has been perceived as a nuisance to fisheries threatening biodiversity and as such greater attention has been given to it towards its total eradication via International and Regional workshops and conferences. However, in the face of current global challenge (climate change) which threatens biodiversity conservation and sustainable use of natural resources, it is high time water hyacinth is viewed as an asset of multipurpose character rather than been considered an environmental threat already labeled expensive nuisance. Table 4 presents different researches involving water hyacinth and the various forms of successes recorded.

CONCLUSIONS

Most of our riverine communities on the African continent of which Nigeria is one are poor. They are highly dependent on local natural resources for their livelihood and are disproportionately vulnerable to the effects of climate change. On another note aquaculture has remained the saving grace for the declining captured fisheries over decades and therefore requires all round support for the sustainability of the production systems. New approaches for its effective utilization and management techniques should be embarked upon vigorously beyond keeping research findings on the shelves.

Ways purification of water for healthy use within the poor communities devoid of pipe borne water supply should be focused.

- Intensification of aquaculture as well as its expansion being a necessary strategy for ensuring adequate supply of fish globally cannot be achieved without provision of sufficient quality water.
- It serves as source of feed to fish and protection of breeding ground and its utilization in aquaculture and waste water treatment for fish production (Integrated multitrophic aquaculture, aquaponics and recirculating aquaculture) cannot be over-emphasized.

Water hyacinth should be considered a blessing as it confers more benefits to man and natural resources conservation than its perceived nuisance.

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Table 1: Proximate composition of water hyacinth (*Eichhornia crassipes*) %

Parts	Dry matter	Ash	Crude protein	Crude fibre	lipid
Leaves	14.70	12.40	22.75	15.00	4.82
Petioles	7.00	19.85	9.60	22.00	1.29

Source: Igbinosun *et al.*, (1988)

Table 2: Mineral composition of Water hyacinth

Parts	%				ppm			
	P	**K**	**Na**	**Ca**	**Mg**	**Mn**	**Zn**	**Fe**
Leaves	0.44	4.28	0.02	2.63	190.50	77.30	77.30	161.10
Petioles	0.37	9.70	1.56	0.64	199.50	69.00	69.00	151.00

Source: Igbinosun *et al.*, (1988)

Table 3: Amino acid composition of cottonseed meal and soybean meal as compared to dried water hyacinth leaves

Amino Acid Analysis	Concentration, g/100g crude protein		
	Cottonseed meal	**Soybean meal**	**Water hyacinth leaves**
Lysine	5.40	6.49	5.68
Histidine	2.16	2.63	2.20
Arginine	5.17	6.98	5.23
Aspartic	19.22	12.18	12.03
Threonine*	4.86	4.26	4.34
Serine	4.94	5.51	4.08
Glutamic	13.66	19.36	11.01
Proline	5.02	5.29	6.00
Glycine	5.56	4.48	5.14
Alanine	6.33	4.58	6.19
Valine	5.48	4.80	5.55
Methionine*	1.31	1.37	1.40
Isoleucine*	4.40	4.90	4.66
Leucine*	7.80	7.98	8.26
Tyrosine	3.55	3.94	3.38
Phenylalanine*	5.10	5.37	5.42
Tryptophan	--	--	0.99
Crude Protein (%)	**39.10**	**44.50**	**31.30**

*Essential amino acids

Source: Wolverton and McDonald (1978)

Table 4: Some Studies Involving Use of Water Hyacinth

Studies/Observations	Researcher(s)	Summary report
Nutritional value in feeds.	Liang and lovell (1970).	It is a source of essential vitamins in Channel catfish diet.
Utilization (raw material for paper making, source of biogas, organic manure, potash and fish feed formulation).	Little (1979)	Fibre content was advantageous for industrial purpose.
Probable use in fish feed formulation.	Igbinosun *et al.* (1988)	Water hyacinth meal can successfully replace wheat offal in Tilapia diet at a level of 23%.
Domestic waste water treatment.	Barsom (1973)	It is an inexpensive method of treating domestic waste water treatment. BOD and TSS were effectively reduced.
Chemical waste water treatment.	Wolverton *et al*., (1976); Wolverton and McDonald (1978)	Water hyacinths readily absorbed and concentrate heavy metals such as Pb, Cd, Hg, Ni, Cu and Ag.
Nutrient potential of water hyacinth meal.	Nwanna *et al*. (2008)	Water hyacinth can replace soybean meal in catfish diet at a level of 25%.
Serve as ornamental plants.	Soerjani (1986)	Add to the beauty and serenity of an aquatic landscape.
Source of feed for fish.	Barrett *et al*. (1990)	Grass carp grow rapidly, so that their food demand steadily increases.
Investigate sporulation and cost benefit of raw materials for the production of *Curvularia pallescens.*	Oluwanisola and Adebayo (2009)	The formulated water hyacinth agar medium appeared most economically feasible for the mycelial production of *C. pallescens* Boedijn.