ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Utility Potential of *Eichhornia crassipes* for its Strategic Management- A Review

Rekha [1], Dr. B.R. Bamaniya [2]

Research Scholar, Department of Environmental Sciences, Mohanlal Sukhadia University, Udaipur, Rajasthan, India[1]

Professor, Department of Environmental Sciences, Mohanlal Sukhadia University, Udaipur, Rajasthan, India[2]

ABSTRACT: *Eichhornia crassipes* is one of the world's most invasive aquatic weed. It is a free floating plant, growing abundantly in the tropical water bodies. It is known to cause significant ecological and socioeconomic effects. Various weed control strategies are being used globally to reduce its population to manageable levels. But owing to many limitations associated with the conventional methods, management of *Eichhornia crassipes* still remains a challenge. Recently large scale utilization has been taken up as a holistic approach for the control of weed. It can be managed by exploiting this weed in diverse fields. In agriculture it can be used as green manure after composting. Industrially, it can be used for producing various value added products. The weed also exhibits many environmental applications. This review briefly discusses the problem of water hyacinth and enlists its possible utilities which can open new avenues for effective management of this weed.

KEYWORDS: aquatic weed, water hyacinth, management, utilities.

I. INTRODUCTION

Eichhornia crassipes (Mart.) Solms-Laubach commonly known as water hyacinth belonging to the family Pontederiaceae is listed as one of the most productive plants on the earth and is considered the world's worst aquatic weed (Holm et al., 1977, Westerdahl and Getsinger 1988, and Grodowitz, 1998). Biological control against water hyacinth has been ongoing in South Africa since the release of the first biological control agent on water hyacinth in 1974.Its habitat ranges from tropical desert to subtropical or warm temperate desert to rainforest zones. It tolerates annual temperatures ranging from 21.1°C to 27.2°C and its pH tolerance is estimated at 5.0 to 7.5. The 'beautiful blue devil' water hyacinth, recognized by its lavender flowers and shinning bright leaves is a prolific aquatic plant, which spreads at an alarming rate. The plant is euryhaline, tolerating both fresh and marine water; hence its spread knows no boundaries. This macrophyte is one of the most invasive aquatic weeds in the world (U.S.EPA.1988 and Maine et al 1999) causing a serious hindrance to nations development activities. The plant is now considered as a serious threat to biodiversity. The possible ways of combating its proliferation and the various methods of eradicating this "weed" not proved much. All the efforts were in vein. Hence the present investigation aims towards the exploration of "best out of waste". Thus its utilization may become a way of its management. Day (1918) described the manorial value of water hyacinth especially in regard to its potash content, which is particularly high in the stalks. Singh and Yadav (1986) also proved that different composts prepared from water hyacinth, mixed weeds and dry leaves increased yields of wheat, green beans and rice.

The weed has adapted itself exceedingly well to almost every area in which it has been introduced. It has an extremely high growth rate, propagates itself vegetatively and sexually. Its rapid proliferation often results in the clogging of drains and can interfere with shipping, recreational activities and the movement of water. Thyagarajan (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

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

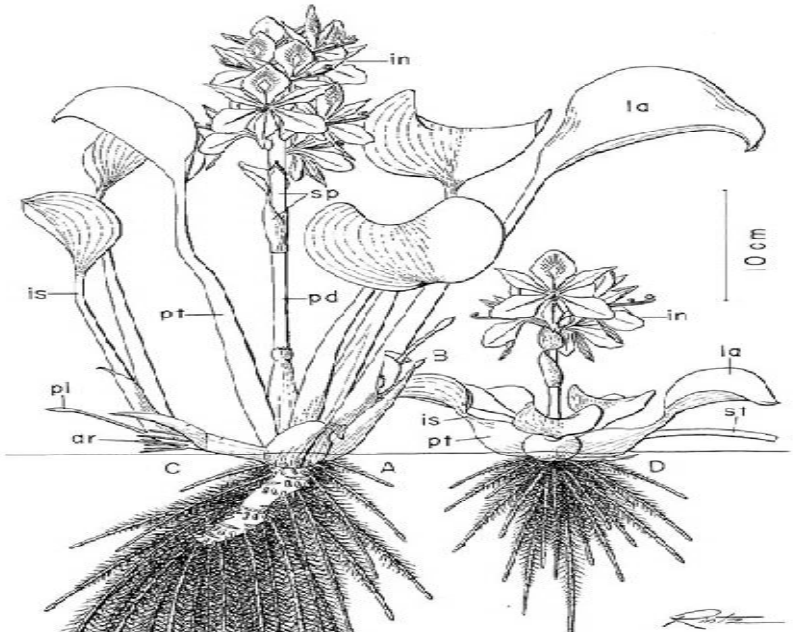
Vol. 6, Issue 7, July 2017

of 24.8 percent root, 41.9 percent stalk, and 33.3 percent leaf (Thyagarajan, 1983). Only the stalk portion of the plant is used for the manufacture of paper-board.

II. RELATED WORK

Taxonomy

Division: *Magnoliophyta*
Class: *Liliopsida*
Subclass: *Commeinidae*
Superorder:*Commelinanae*
Order: *Pontederiales*
Family: *Pontederiaceae*
Genus: *Eichhornia*
Specific epithet: *crassipes* (Martius) Solms-Laubach.
Cronquist (1988), Thorne (1992) and Takhtajan (1997) suggest following water hyacinth taxonomic placement (Center *et al.*, 2002):



Morphology of water hyacinth:

A the "attenuated-petiole" rosette form produced in crowded conditions; B. An expanding axillary bud; C. A developing ramet; and D. The "bulbous-petiole" rosette form produced in open conditions. Abbreviations: ar - adventitious root; bb - bud bract; in - inflorescence; is - leaf isthmus; la - leaf blade; pl - primary leaf; pd - peduncle of flower spike; pt - leaf petiole; rh - rhizome; sp - spathe; st - stolon.

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Growth, development and reproduction

As mentioned above *E. crassipes* is fast growing perennial plant with great reproduction potential. Growth of water hyacinth is primarily dependant on: ability of plant to use solar energy, nutrient composition of water, cultural methods and environmental factors (U.S. EPA, 1988). Plant growth is described in two ways: first is by reporting the percentage of water surface covered for a period of time; second and more useful method is by reporting the plant density in units of wet plant mass per unit of surface area (U.S. EPA, 1988). So under normal conditions loosely packed water hyacinth can cover the water surface at relatively low plant density (10 kg/m^2 wet weight) and it can reach maximum density of 50 kg/m^2 wet weight before growth ceases (Reddy and Sutton, 1984). According to other authors this aquatic macrophyte can totally clog aquatic ecosystems by reaching density of 60 kg/m^2 wet weight outside of its native range (Julien and Orapa, 1999). Just like all other biological processes growth of *E. crassipes* depends on various ecological factors. Water hyacinth is growing fastest at temperatures from 20º to 30ºC, but growth fully stops at temperatures from 80 to 150ºC (Stephenson *et al*., 1980). This aquatic plant can reproduce in both generative and vegetative ways. That means new plants can be produced from seeds or they represent clones derived from stolon elongation due to division of auxiliary meristems of mother plant (Center *et al*., 2005). At first these new rosettes are attached to mother plant but stolons are very fragile so they easily break enabling young individuals to float away and colonise new areas (Wilson *et al*., 2005; Center *et al*., 2005).Only ten plants in just eight months can produce population of 655,330 individuals (Babu *et al*., 2003). So theoretically, by vegetative reproduction one plant can colonise water surface during one month by creating 8,191 new individuals. Numerous authors (Gopal, 1987; Wilson *et al*., 2005) who have been studying water hyacinth in its flowering period had obtained very similar results about its fenology and generative reproduction. The flowering period lasts for about fifteen days. When flowering cycle ends flower stalk bends and the spike is now under the water surface and seeds are released directly into the water (Center *et al*., 2002). Each inflorescence contains normally 1 to 20 seed capsules and capsule carries 3 to 250 seeds. The authors mentioned above also agree that in spite of the production of this large number of seeds there are only 3 to 3.4 seeds per plant each year that are eventually able to germinate (Wilson *et al*., 2005). Seeds usually germinate within 6 months but in wet sediments at the bottom they can contain germination for 15 to 20 years (Center *et al*., 2002).So when maintaining and monitoring aquatic ecosystems or aquatic systems one must keep in mind that *E. crassipes* can colonise areas at a very fast pace even after control measures have been applied.

Habitat and Characteristics of *E. crassipes*

The mature plant of water hyacinth consists of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plants are up to 1 metre high although 40cm is the 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. The vegetation reproduction is asexual and takes place at a rapid rate under preferential conditions. (Herfjord, Osthagen and Saelthum, 1994). Water hyacinths grow over a wide variety of wetland types from lakes, streams, ponds, waterways, ditches, and backwater areas. The treatment of textile wastewater with water hyacinth has some effects on the growth of the plant, the small size of which may be due to nutrient imbalance mainly of nitrogen in water (Thomas, 1983). The plant height may vary from a few inches to 3 ft (0.9 m). The leaves, growing in rosettes, are glossy green and may be up to 8 inches (20 cm) long and 6 inches (15 cm wide). The showy, attractive flowers may be blue, violet, or white and grow in spikes. The leaf blades are inflated with air sacs, which enable the plants to float in water.

Root system of water hyacinth is dark blue in colour (Aquatics, 2005; APIRIS, 2005) with numerous stolons. New plants are formed at the end of these stolons. Measured from flower top to root top *E. crassipes* usually reach height of 1.5 m and more (Center *et al*., 2005). When grown in wastewaters water hyacinth is smaller and it often reaches heights no more than 0.5 to 1.2 m (Reddy and Sutton, 1984).

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Ecological Factors

Water hyacinth is heliophyte plant growing best in warm waters rich in macronutrients (Center *et al.*, 2002). Optimal water pH for growth of this aquatic plant is neutral but it can tolerate pH values from 4 to 10 (Center *et al.*, 2002). Temperatures above 33º C inhibit further growth (Center *et al.*, 2002). Optimal air temperature is 21-30º C (U.S. EPA, 1988). If lasting for 12 hours temperature of -3º C will destroy all leaves and temperature of -5º C during the period of 48 hours will destroy whole plant (U.S. EPA, 1988).

APPLICATION IN AQUACULTURE

A common observation in recent times in Nigeria and other countries is the practice whereby fish farmers allow controlled growth of water hyacinth in their fish ponds. Evidently, such plant is employed to provide shade against the scorching effects of sunlight during the day, as well as offering protection for the young fish against predators. Similarly, water hyacinth is used as a substrate for the deposition of eggs by spawning brood-stocks especially for the production of ornamental fish. Scores of water hyacinth are introduced into the spawning ponds especially for the production of ornamental fish. Thereafter, the brood fish are put into the pond. After spawning, the water hyacinth is removed with the eggs adhering to the roots. The whole plants with the eggs are incubated in the hatchery. After hatching, the hatchlings detach from the root system of the weed and swim freely. At this stage, the weed is removed from the ponds.

Water hyacinths consist of more than 95 % water but despite this they have high nutrient (N and P) and crude-protein content and very fibrous tissue (Gunnarsson and Mattsson, 1997). They also have an ability of absorbing both trace element ions (Cu^{2+}, Pb^{2+}, Cd^{2+} and Zn^{2+}) as well as minor element ions (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) from water bodies. These properties can make them potentially useful in many different application areas. In Table 1 the general levels of some nutrient and minor elements in water hyacinths are summarised (Gunnarsson and Mattsson, 1997).

Table 1. Nutrient and minor element levels in water hyacinths, summarised by Gunnarson and Mattsson (1997). DW in the second column stands for the plants dry weight-

Parameters	mg/g plant (DW)
Phosphorous, tot-P	5,3
Nitrogen, tot-N	27,6
Magnesium, mg^{2+}	1,7
Calcium, Ca^{2+}	5,8-22,9
Potassium, K^{+}	24,4

APPLICATION IN BIOLOGICAL WASTE WATER TREATMENT

The application of water hyacinth for waste water treatment in Nigeria, is gradually gaining ground. Ogunlade (1992) reported its potentials as a mopping agent and scavenger of heavy and toxic elements in industrial and domestic effluents. Akobundu (1987) reported the use of water hyacinth for waste water treatment by some agencies. The capacity of this plant to purify water rests on its ability to vigorously extract nutrients from its medium. Laboratory analysis has shown that water hyacinth is of a high absorptive capacity (Soerjani, 1984). Although it is relatively poorer in extraction of nutrient compounds when compared to water lettuce and guinea grass (Table 2), it functions as an effective mopping agent and scavenger of heavy metals like cadmium, mercury, and nickel. And also its extraction of other chemical substances such as nitrates, phosphates, ammonia, silicate, chlorine and sulphur deposited in the aquatic habitat from industrial and domestic effluent is remarkable (Ogunlade, 1992). Its vigorous growth and repeated cultivation coupled with its capacity to extract nutrients efficiently from its medium makes it a good candidate for the purification of turbid and polluted waters. However, it should be curtailed to prevent dispersal beyond the area of application.

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 2. Analysis Of Water Hyacinth, Water Lettuce And Guinea Grass For Eight Different Minerals

Mineral concentration (ppm)	Water hyacinth	Water lettuce	Guinea grass
Calcium (Ca)	1,808	6,594	4,545
Phosphorus (P)	791	1,108	3,030
Potassium (K)	46,060	72,524	2,257
Magnesium (Mg)	3,114	3,305	2,952
Sodium (Na)	3,784	2,043	174
Manganese (Mn)	222	156	212
Iron (Fe)	2,557	6,717	213
Copper (Cu)	20	31	26

Source: Aderibighe and Brown (1993)

A RAW MATERIAL FOR BIO-GAS

Bio-gas technology requires large and continuous supply of vegetative materials for the production of methane which can be used directly in homes for cooking and heating and even in agriculture for drying or converted to other sources of energy, such as electricity. The process will go a long way in ameliorating the threat posed by the incursion of water hyacinth into our water bodies. Biogas production is most appropriately termed Biomethanogenesis (National Academy of Sciences 1987). This term was given to it due to the high amount of methane (40 - 65%) produced during the digestion process. For the production of this gas on a small scale, Soerjani (1984) has suggested that a digester of 6 m^3 in dimension be loaded with a mixture of shredded water hyacinth (stems) and 10% by weight of cattle dung. The temperature of 30 - 35°C at pH of 7.0 - 7.5 is maintained for maximum production. This set-up is left for one week before the production of gas commences and continues for the next four weeks. Approximately, 2.0 m^3/day of the gas produced was used on a burner for 3 hours or in a gas lamp for 6 hours. Pig dung produced 7.0 m^3 while poultry dung yielded 29.4 m^3. It has been recommended that ferro-cement gives a better yield of this gas and should be used. However, other types of digesters include French, Chinese, Indian and Trans-mulched.

AS RAW MATERIAL FOR BIOFERTILIZER AND COMPOST

Bio-fertilizer is acclaimed to be a sustainable source of plant nutrient due to its improvement of soil structure as well as the slow release of the nutrients. The biomass of water hyacinth can be used directly as green manure as compost. Also, the digested vegetative waste from biogas generation as indicated above can also be collected for use directly on the farm. Alternatively, these materials could be mixed with other organic materials before use. The practice is popular among farmers around the aquatic habitats where water hyacinth abounds. The waste products (slurry) coming from biogas production is collected regularly and used for growing maize, peanuts, soybean and cassava. The coarse powder obtained from the root of water hyacinth has effectively been used to aid crop production in economic crops such as vegetables (Oso, 1988). Because of the high moisture content of this plant, it was reported to increase the moisture holding capacity of the soil while promoting good adhesion to seeds. In whatever condition, water hyacinth is used, it may be necessary to do mineral analysis to guard against the pollution by potential uptake of heavy metals.

Composting water hyacinths is a good and feasible way of using harvested plants, especially indeveloping countries. Composting is a well-known low budget option for improving crop yields and can be carried out by mixing dried water hyacinths with soil, ash and organic municipal waste (PACE, 2013). Most important nutrients (N, P and K) are retained during the process and tolerable compost can be reached during the relatively short time period of 30 days (Polpraset et al., 1998). A study in India showed that decomposition of water hyacinths resulted in an increased mineralisation of

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

nutrients in the soil and as a result enhanced grain yield. This was when partly decomposed water hyacinths were applied to a sandy clay loam in a pot experiment with rice (Gunnarsson & Mattsson, 1997).

AS RAW MATERIAL FOR LOCAL INDUSTRIES

Akobundu (1987) reported that aquatic weed, can serve as raw material for pulp and paper, fibre for making chairs, mats and baskets. It can also be used as thatch. However, their application has not received the required attention. Healey (1994) observed that the enormous biomass of water hyacinth has stimulated many attempts at its utilization. He further reported that it has limited application in the manufacture of poor quality paper, biogas generation, effluent treatment and certain handicraft. Research could improve on the existing information at converting the raw material of water hyacinth into industrial products. Thyagaraja (1983) demonstrated how the stalks of water hyacinth could be pulped and converted into medium quality papers/boards such as cardboard and coloured cards/cover papers. Such pulps should however be blended with long fibrous pulps such as cotton rags and waste paper pulps to minimize the shrinkage of paper during drying. Thyagaraja (1983) advised that the manufacturing unit should be attempted and this will go a long way in stimulating community participation by reducing the nuisance created by water hyacinth, when continuous harvest is made and manufacturing units located in all places where water hyacinth is available in abundance and free of cost.

POTENTIALS AS A FEEDSTUFF

The dearth of animal protein with increasing cost of food production coupled with rapid population growth necessitate the search for non-conventional sources of protein such as leaf protein concentrate (LPC) from water hyacinth (Ogunlade et al 1988). The plant in combination with concentrate of other feeds has proved to be a good quality protein source for animal feed (Igbinosun and Talabi, 1982). When compared with conventional NIOMR feeds, dried water hyacinth was found to be a suitable artificial feed.

Some other documented research findings have indicated that water hyacinth has great potentials as animal feed source. It has a reasonable amount of crude protein content. Pig can consume 1-2 kg of fresh weight water hyacinth daily. The dried crushed ones are used in mixtures of various percentages 2.5- 10% with the ordinary feed for pig, chicken, ducks, cow and rabbits (Soerjani, 1984). This has limited scope in the present practice and the quantity potentially utilized is not substantial enough to meet the control target. Adenbigbe and Brown (1993) have demonstrated that the nutritive value as nutrient digestibility of water hyacinth is enhanced when dried and supplemented with high energy feed ingredient and a suitable protein source. Thus water hyacinth though now a foe, is a potential saviour of the animal feed industry that is currently groaning under high cost of feedstuff.

III. CONCLUSION

The threat of water hyacinth to aquatic ecosystems is real. The infestation of our water bodies by this aquatic weed is a scourge that must be tackled with all amount of seriousness. However, the current drive towards the total eradication of the weed may not be the most viable option, for the reason of high cost and the fact that some of the eradication methods may do further harm to the environment. In the face of today's economic stress militating against mankind, the costs of basic input resources have gone beyond the reach of ordinary people. Water hyacinth, which is seen as a nuisance and combated at huge economic costs to resource-poor economies, may well become the cornerstone of raw-material production to the growing industries. The potentials outlined have good promises particularly for a growing economy. The international efforts to rid the water bodies of water hyacinth deserves commendation but the need to turn its menace into a blessing for the populace, in our opinion, will certainly receive a wider support. Thus, the exploitation of means by which this plant could be harnessed and put into profitable use may sound a viable option. Some of these probable benefits have been articulated and advocated. However, the realization of these objectives may truly be possible if there is institutional support from the government and non-governmental organisations NGO's) in the form of establishment of pilot programmes or cottage industries to translate some of these potential benefits into

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

income generating ventures. Additional institutional support could also be in the form of research grants, public enlightenment of local communities, extension services, on existing technology on the utilization of water hyacinth, and capacity building for potential operators of the industry. This could create employment, and alleviate poverty.

Future Prospects

In light of designing new control strategies for *Eichhornia crassipes* management, limited work done so far for exploring beneficial uses of *E. crassipes* should be expanded further to broaden the utilization scope of the weed. Also the research work dedicated to one particular application is very restricted and needs elaborative studies. The weed has many utilities, each of which can be used separately to control this weed. Such methods can also be designed in future, which integrate two or more applications, aiming at maximum utilization of weed for acquiring economic benefits. Zero waste technology, being followed these days, can also be taken into account while shaping these integrated approaches. Thus new and improved methods of managing *Eichhornia crassipes* weed, encouraging well-being of human society, are anticipated in near future.

REFERENCES

1. "APIRIS - Invasive Nonindigenous Plants in Florida." http://plants.ifas.ufl.edu/hyacin2.html (11/18/05)"Aquatics"http://pss.uvm.edu/pss123/aquatics.html (11/18/05).
2. Aderibigbe, A.O., and Brown, A. A., "Nutritive characteristics of two tropical aquatic weeds for ruminants", Ife Journal of Agriculture, Vol.16 & 17, pp. 42-54, 1993.
3. Akobundu, L.O., and Agyakwa, C.W., "A handbook of West African Weeds", International Institute of Tropical Agriculture", Ibadan, Nigeria, 1987.
4. Babu, R.M., Sajeena, A., Seetharaman, K.., "Bioassay of the potentiality of Alternaria alternate (Fr.) keissler as a bioherbicide to control water hyacinth and other aquatic weeds", Crop Protection , Vol.22, pp.1005- 1013, 2003.
5. Center, T.D., Van, T.K., Dray Jr, F.A., Franks, S.J., Rebelo, M.T., Pratt, P.D., Rayamajhi, M.B., "Herbivory alters competitive interactions between two invasive aquatic plants", Biological Control , Vol.33,2, pp. 173-185, 2005.
6. Center, TD., Hill, MP., Cordo, H., Julien, MH., "Water hyacinth. In: Van Driesche, R., et al: Biological Control of Invasive Plants in the Eastern United States", USDA Forest Service Publication FHTET-2002-04, pp.41-64, 2002.
7. Cronquist, A., "The Evolution and Classification of Flowering Plants, 2nd edition", New York Botanical Garden, New York, 1988.
8. Day F.W.F., "Water hyacinth as a source of potash", Agric. Bull. Fed. Malay States, Vol.6, 7-8, pp. 309-14, 1918.
9. Ekelemu J.K., "Malacostracan species inhabitin' water hyacinth (*Eichhornia crassipes*) in Benin River, Southern Nigeria", Nigerian Field, Vol. 63, pp.149-157, 1998.
10. Garry, H. J., Waage., and C. Phiri., "The water hyacinth problem in Tropical Africa", Meeting of International Water Hyacinth Consortium held at World Bank, Washington, 18-19 March, 1997.
11. Gopal, B., "Aquatic Plant Studies on Water Hyacinth", Elsevier Publishing, New York, USA, 1987.
12. Grodowitz M.J., "An active approach to the use of insect biological control for the management of non-native aquatic plants", Journal of Aquatic Plant Management, Vol. 36, pp. 57-61, 1998.
13. Gunnarson, C., and Mattsson, C., "Water hyacinth-trying to turn an environmental problem into an agricultural resource", MFS-report no. 25, Swedish University of Agriculture, 1997.
14. Herfjord, T., Osthagen, H., Saelthun, N. R., "The Water Hyacinth, Norwegian Agency for Development Cooperation", Water Resources and Energy Administration, Oslo, 1994. ISBN 82-410- 0207-6, 1994.
15. Holm, L.G., Plucknett, D.L., Pancho, J.V., Herberger, J.P., "The world's worst weeds: Distribution and biology", University Press of Hawaii, Honolulu, 1977.
16. Julien, M.H., Orapa, W., "Successful biological control of water hyacinth (*Eichhornia crassipes*) in Papua New Guinea by the weevils Neochetina bruchi101 and Neochetina eichhorniae (Coleoptera: Curculionidae)", In: N.R., Spencer (ed.), Proceedings of the X International Symposium on Biological Control of Weeds, Montana State University, Bozeman, Montana, USA, pp. 1027,1999.
17. lgbinosuii, J.E., and Talabi, S.0., "Studies on the nutrition of brackish water catfish: *Chrysichthys nigrodigitaius*", Paper presented at the 2nd Conference of Fisheries Society of Nigeria, Calabar, 24-27 Jan, 1982.
18. Maine, M.A., Sune, N.L., Panigatti, M.C., Pizarro, M.J., "Relationships between water chemistry and macrophyte chemistry in lotic and lentic environment", Arch. Hydrobiol, Vol.145, 2, pp. 129-145, 1999.
National Academy of Science. "In: Making Aquatic weeds useful: Some perspectives for developing countries", Washington D.C., USA, 1987.
19. Ogunlade, V., "Chemical and nutritional evaluation of water hyacinth in Nigerian waterways", Ph.D Thesis, Obafemi Awolowo University, Ile-Ife, 1992.
20. Ogunlade, Y., Afolabi, 0.A., Osuntogun, O.A., and Oke, 0.L., "Extraction of protein from water hyacinth", The Proceedings of International Workshop/Seminar on water hyacinth, Lagos, 7th-12th August, pp.1,1988.

ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

21. Oso, B.A., "Invasion of Nigeria waterways by water hyacinth: Ecological and Biological Observation", The Proceedings of the International Workshop/Seminar on water hyacinth, Lagos, 7th-12th August, pp. 116-123, 1988.
22. PACE, Pan African Conservation Education project, [online], Action sheet 29, Available at http://www.paceproject.net/Userfiles/File/Water/Water%20hyacinth.pdf (accessed: 2013-08-05), 2013.
23. Polprasert, C., Wangsuphachart, S., Muttamara, S., "Composting nightsoil and water hyacinth in the tropics", Compost Science/Land Utilization, Vol. 21, pp. 25-27, 1980.
24. Reddy, K.R., Sutton, D.L., "Water hyacinths for Water Quality Improvement and Biomass Production", J. Environ. Quality, Vol.13, pp. 1-8, 1984.
25. Singh, R.D., Yadav, D.V., "Evaluation of low grade rock phosphate composted with some agricultural wastes for use in a crop rotation", Agri. Wastes, Vol. 18, 1, pp. 73-79, 1986.
26. Soerjani, M., "Indonesia experience in water hyacinth Utilization", Proceedings of International Conference on water hyacinth, Hydrabad, India, Feb. 7-11, 1984.
27. Stephenson, M. G., Turner, P., Pope, J., Colt, A. Knight., Tchobanoglous, G., "The Use and Potential of Aquatic Species for Wastewater Treatment", Publication No. 65, California State Water Resources Control Board, 1980.
28. Takhtajan, A., "Diversity and Classification of Flowering Plants", Columbia University Press, New York, 1997.
29. Thomas, K.T., "Studies on the ecology of aquatic weeds in Kerala, India", Int. Conference on Water Hyacinth, Kerala, India, 1983.
30. Thorne, R. F., "Classification and geography of flowering plants", Botanical Review Vol. 58, pp.225-348, 1992.
31. Thyagarajan, "Water hyacinth - material for handmade papers and Industry & Environment", Vol.60, pp. 18-21, 1983.
32. U.S. EPA., "Design Manual Constructed Wetlands and Aquatic Systems for Municipal Wastewater Treatment", U.S. Environmental Protection Agency, Report no. EPA/625/1- 88/022, Office of Research and Development, Cincinnati, OH, pp. 83, 1988.
33. Westerdahl, H.E., Getsinger, K.D., "Aquatic Plant identification and herbicide use guide, Volume II: Aquatic plants and susceptibility to herbicides", Technical report A-88-9. Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, 1988.
34. Wilson, J.R., Holst, N., Rees, M., "Determinants and patterns of population growth in water hyacinth", Aquatic Botany, Vol. 81, pp. 51-67, 2005.