THINK INDIA JOURNAL

ISSN:0971-1260

Vol-22-Issue-10-November-2019

Water Hyacinth [*Eichhornia Crassipes* (Mart.) Solms]-Threats And Potentials

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THINK INDIA JOURNAL

ISSN:0971-1260

Vol-22-Issue-10-November-2019

***Abstract—Eichhornia crassipes*, Water Hyacinth is a fast growing aquatic perennial native to South America. They are known for their potential to grow in highly polluted water, exhibits foliar plasticity making it adaptable to all climatic and environmental conditions . They are rich in oxidative enzyme and non enzymatic antioxidants. Having low lignin, cellulose and hemicellulose are more easily converted to fermentable sugar thus resulting in enormous amount of utilisable biomass for biofuel industry besides its other applications which ranges from the field of biofuels, pharmaceuticals, cosmeceuticals, material and phyto remediation. Besides the drastic losses offered to the biodiversity, it possess a great future in fuelling our future economy. Being a great source of biomass they are widely accepted as a source of green fuel. In this study it discusses about the growth factors of water hyacinth, chemical composition of the plant, problems faced in the current scenario, various control measures, phytochemicals present in the plant, pharmacological applications, it's edibility, possibilities to be used in waste water treatment, fuel production and materialistic applications.**

***Keywords*-Water hyacinth, Control measures, Phytochemicals, Pharmacology, Edibility, Phytoremediation, Future fuels, Materials**

I. INTRODUCTION

Water Hyacinth (*Eichhornia crassipes*) is a perennial fast growing aquatic macrophyte, a member of the pickerelweed family (*pontederiaceae*). They are indigenous to South America especially to the Amazon basin. It is being described as a serious invasive weed in literature, and ranked eighth among the list of worlds ten most serious weeds.

They are widely known as “beautiful blue devils” and known by different names in different accents, “Jalkhumbhi” in Hindi, “ Pisachitha Tamarai” in Tamil and “Kolavazha” in Malayalam. They are known for its ability to grow in severe polluted waters. It was widely planted as a water ornamental around the world for its striking flowers but its rapid growth adversely affected human activities and biodiversity. The species was first described and named *Pontederia crassipes* by C.F.P.von Martius in 1824 and finally in 1883, H.solms-Laubach established the combination *Eichhornia crassipes* (Mart.) Solms by which the species is now universally known.[26][9]

Water Hyacinth belongs to the kingdom *plantae*, Division *magnoliophyta*, Class *liliopsida*, Subclass *commelinidae*, Super order *commelinanae*, Order *pontederiaceae*, Subfamily *Trollioideae*, Genus *Eichhornia*, Species *Crassipes*.[1]

They are vascular plants with shiny green leaves with flowers that resembles orchids. They have bulbous and spongy petioles with large air spores which help them to float on the water surface. Inflorescence consists of 10-30 violet blue or violet pink flowers. Roots are unbranched with a conspicuous root cap. It has the property to exhibit variations in morphology and function depending on the climate and environmental factors to which they are being exposed or treated.[18]

II. GROWTH AND ITS FACTORS

They have a very high growth and reproduction potentials depends on the atmospheric conditions and environment to which they are being exposed because it impose genetic variations in the plant.

They have very low genetic diversity since the plant mainly reproduce by generating clones. This uniformity in the genes of water hyacinth enables them to spread faster. They are able to resist unfavourable conditions by regulating their genes making it more difficult to control its spread.

They grow faster in the temperature range 20-30℃and growth ceases completely at 8-15℃. They can withstand pH about 4-10. It grows best in warm water which is essential with macronutrients.[18][1][11][29]

Fig.1.Water hyacinth

III.CHEMICAL COMPOSITION

The plant extract is rich in phytochemicals like Flavonoids, Alkaloids, Phenols, Tannins and other which exhibit a future in many medical and cosmeceutical applications. They are rich in amino acids which includes Methionine, Phenylalanine, Threonine, Glycine, Isoleucine, Valine, Leucine and Essential vitamins. They are highly fibrous primarily cellulose.

The seeds of water hyacinth has the capability to remain viable without germination for over 20 years. The mineral contents in the plant is also very high. Fresh plants has 95.5% Moisture, 0.04% Nitrogen, 1.0% Ash, 0.06% P_2O_5, 0.20% K_2O and 3.5% Organic matter and other minerals which includes Phosphorous, Potassium, Sodium, Calcium, Magnesium, Manganese, Zinc and Iron.[24][9]

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IV. PROBLEMS IN THE CURRENT SCENARIO

The most treacherous problem caused by water hyacinth is the loss of water by evaporation which is about ten times higher than that from open water surfaces. This hilarious growth of water hyacinth prevents sunlight from entering into the water, reduces dissolved oxygen and nutrients which greatly affects the life of aquatic species.

It provides good breeding conditions for mosquitoes and other vectors which spreads deadly diseases like malaria, encephalitis, skin rashes, intestinal disorders,etc .

It also interrupts irrigation channels, marine transportation and intakes for hydropower. Interruption to the irrigation seriously affects the life of farmers which result in economic losses, since in the presence of dense mats of the weeds, farmers cannot cross the invaded water bodies to access to their farms, it can also result in destruction of the farm produce. Income of the farmers are indirectly affected by the negative effects of water hyacinth on farming activities .[18][28][14]

V. CONTROL MEASURES

Commonly used control methods are physical, biological and chemical. Each of the methods have advantages and drawbacks. The optimum control depends on specific conditions of each affected location such as extend of water hyacinth infestation, regional climate and proximity to human and wildlife.

A. Physical control

It is the most commonly used method of control by cleaning or removing using machines or manually but it is time consuming and a not a complete remedy for preventing the growth of water hyacinth. It is suitable for only extremely small areas.[26]

B. Chemical control

It is done by using chemical herbicides like 4-dichlorophenoxy acetic acid, glyphosate. In a study conducted using herbicides for treatment of water hyacinth in a lagoon channel at Ere, Nigeria, Glyphosate (N-phospho-no methyl glycine) of composition 360g/litre glyphosphate in the form of 480g/litre isopropyl amine salt was used at the rate of 2.16kg assisted using AG-CAT Schweizer plane followed by mop up operations done with knapsack sprayer with special protusiblelance, Glyphosphate achieved a total mortality of water hyacinth within 14 days of application. It is suitable only for limited areas. Repeated usage of chemicals can cause pollution and eutrophication.[26][39]

C. Biological control

This method is economical and sustainable. It uses natural parasites like moths, fungi and insects that is capable of destroying the water hyacinth completely. Agents like *Neochetina eichhorniae Warner, N.bruchi Hustache,* fungus *Alteraria eichhorniae* were used. But the major disadvantage of using biological agents is that it will take a long time to initiate such projects because it can take several years for the insect population to reach a population density sufficient to tackle the pest problem.[26]

D. Biodiversity conservation

Macrophyte succession caused by water hyacinth has the capacity to alter the aquatic biodiversity. The contemporary control measures are expensive and provide no returns on investment since most of them are self propagating and return nutrient back into the system. Control measures for water hyacinth must also include measures to reduce the nutrient content in the water bodies. Loss of biodiversity is a major concern caused due to the over exploitation of water hyacinth over the water surface.[5]

VI. PHYTOCHEMICAL ASPECTS

Phytochemicals, chemicals that are being produced by plants through secondary metabolism. These chemicals exhibit biological activities which are not been completely established. They are the main source of active incredients for the pharmaceutical industries. They exhibit Anti microbial, Anti fungal and Anti cancerous properties. Water hyacinth possess a large no of phytochemicals.[2][31][32]

A. Phenolic compounds

They are considered as an important factor in human diet due to its anti oxidant properties. Phenolic compounds are isolated from the plant extracts of water hyacinth and experiments showed that it inhibits the growth of the fungus *Candida albicans* and some fresh water alga .[2][33]

B. Flavonoids

These are groups of polyphenolic compounds, a source of anti oxidants. Flavonoids promotes health and prevents diseases. They possess anti bacterial, anti microbial, anti viral and other effects . Study of the plant extract from shoot and rhizome confirms the presence of flavonoids like, Tricin, Chrysoeiol, Orientin, Kaya flavone and others.[2]

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C. Tannins

These are complex polyphenolic bio molecules. Tannins are detected in methanol and aqueous extracts of water hyacinth. They possess many herbicidal applications.[2]

D. Alkaloids

These are cyclic derivatives of Quinolizidine. They are known for their anti microbial activities. The investigations done on water hyacinth proved the presence of alkaloids which includes Cystine, Codeine, Thebaine, Quinine and Nicotine[2].

E. Sterols

These are lipids which is found to play a major role in the membranes of eukaryotes. Sterols like Campesterol, Stigma sterol and β -sitosterols are isolated from extracts of water hyacinth.[2]

F. Glycosides

These are substances which consists of sugar molecules bonded to alcohol or phenol. Cardiac glycosides, Monogalactosyl diglycerides, Digalactosyl diglycerides and

Phospholipids were detected in the plant extracts of water hyacinth .[34][2]

G. Other metabolites

Resins, Saponins, Anthroquinone, Quinone, Ascorbic acid, Iso ascorbic acid, Dehydro ascorbic acid and Anthocyanins were obtained from various extracts.Olefins were obtained from the surface waxes of water hyacinth leaves. Oils like Phenoethyl alcohol and Benzyl alcohol were found in the

extracts which are the components mainly found in essential oils [2]
.

VII. PHARMACOLOGICAL ASPECTS

A. Anti microbial

Aqueous methanol, Ethanol and Acetone extracts of water hyacinth showed high anti microbial activity against both gram positive and gram negative bacterias. Experiments proved that it showed great activity against multi drug resistant (MDR) bacteria and other bacterial strains like *Bacillus subtilis, Escherichia coli,* Staphylococcus, Aureus and many others

.[19][4]

B. Anti oxidant

Photochemical study of water hyacinths proves the antioxidant activities of the plant extract. The plant extract showed significant activity while comparing with standard ascorbic acid which is a naturally occurring organic compound a form of vitamin C which possess antioxidant properties present in citrus fruits [illegible] vegetables [illegible] water. They possess high reducing power, converting oxygen to and DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging capability.[18][35]

C. Wound healing

A methanolic extract of water hyacinth leaves in the form of an ointment (10%-15% w/w of leaf extract in a simple ointment base) showed wound healing potential in an excision experimental wound model in rats, showing better wound contraction ability than control.[38]

D. Anti cancer

Experiments conducted showed that the aqueous extract shows cytotoxic property against NCl-H322 (lung) cell line, T47D (breast) cell line, B16F10 invivo melanoma tumour, liver cancer cells and HeLa cells.[6]

E. Juvenile mortality

Water hyacinth extracts showed nematicidal property (nematicidal compounds are highly toxic and kill exposed nematodes,whereas nemastatic compounds do not kill nematodes but impede nematode movement toward host plant roots or delay nematode egg hatching) and experiments proved 100% mortality of *Meloidogyne incognita*. It's activity increased with increase in concentration and exposure time . Alkaloids and flavonoids are considered as the reason for this juvenile mortality.[3]

F. Other applications

Water hyacinths have been used to treat goitre in India for long with equal amount of table salt and *Piper congum*. Anti aging, DNA damage inhibition assay and DPPH radical scavenging assay were detected which shows it a future in the cosmeceutical industry. [18]

VIII. EDIBILITY

Data collected from experiments by analysing edible forms of water hyacinth leaf protein concentrate (WHLPC) revealed that WHLPC is a potential raw material for food and beverage industry. It contain Unsaturated fats, Carotenes, Xanthophylls, Starch, Iron, Calcium and Phosphorus. They are also rich source of Amino acids and Poly phenols . Due to its high protein and mineral content it is used as an animal feed . It can also be exploited for increasing the fish yield since the decay of water hyacinth releases nutrients which promotes the growth of phyto plankton.[18][20][15][28][25]

IX. WASTE WATER TREATMENT

Water hyacinths are highly efficient in the removal of a wide range of pollutants. The roots of water hyacinth provides a medium for micro organisms to oxidase biodegradable substances present in the water. They possess supernatural affinity towards the removal of nitrogen. Waste water treatment systems are suitable in tropical wet and dry climate and in

ISSN:0971-1260

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places suffering water scarcity also requires less space for implementation. They possess the ability to remove heavy metals like Lead, Cadmium, Mercury, Nickel, Copper, Silver, Chrome, Strontium-90 and some organic compounds which tends to cause cancer.[21][22][1][10][30][16][36][37][17]

X. FUTURE FUELS

A. *Biogas*

Biogas is produced by the break down of organic matter in the absence of oxygen from raw materials like agricultural waste, plant materials, green waste. C/N ratio of water hyacinth is 20:1. It has large quantity of fermentable substances and thus possess great potential to produce gas. Biogas production yield is determined by factors like pH, temperature and retention time. Anaerobic fermentation of water hyacinth process to provide a continuous supply of biomass for producing methane. Biogas produced can be upgraded using solid adsorbents and wet scrubbers which increases the methane up to 70-76%. This upgraded gas can be used to power internal combustion engines coupled to an electricity generator and direct heat applications. Water hyacinth biomass is a valuable resource for the generation of biogas to meet our future fuel requirements.[18][9][12]

B. *Biofuel*

Biofuels are produced by the contemporary methods from biomass rather than the very slow geological process involved in the formation of fossil fuels. Biofuels such as bioethanol can be considered as a renewable source of fuel which reduces the dependence on depleting fossil fuels. Bio hydrogen is eco friendly and can be directly produced from water hyacinth. The low lignin content of water hyacinth makes it sensible source of biofuel. It is easy to convert into fermentable sugars because of its rich cellulose and hemicellulose content. Biofuel or bioethanol is produced through a series of steps which includes pre treatment, hydrolysis and fermentation.[18][27][9][12]

C. *Bio fertilisers*

Bio fertiliser is a substance that contain living micro organisms which add nutrients through natural processes like nitrogen fixation, solubilising phosphorus. Decayed water hyacinth can provide nutrients to the soil since they are great adsorbent of Nitrogen, Phosphorus and potassium. Being water absorbing in nature they exhibit moisture retention property and can be used in the soil with low water retention properties .[18][15][9][12]

XI. MATERIALS

A. *Nano fibres*

Water hyacinths are great source of natural fibres due to the presence of cellulose and hemicellulose. They are low cost, non toxic, abundant and has high thermal and mechanical properties.[23][7]

B. *Bio plastics*

Water hyacinth fibres reduces the dependence on synthetic plastics. The promising carbohydrate content of water hyacinth makes it a potential substrate for producing commercially important products. They are potential source for producing PHA with the assistance of *Pseudomonas aeruginosa* can be used for the manufacture of commercially viable products.[8]

C. *Carbon dots*

Carbon dots are upcoming nanocarbon members for the production of PL sensors. Water hyacinth is used as a source of activated carbon using Phosphorus acid (Carbon dots). The sensor developed is used for detecting herbicides .[13]

D. *Paper and fibre board*

Water hyacinth biomass is used for the production of paper and fibre boards due to their physical properties. Fibre boards manufactured possess sufficient good quality and is used for indoor partition walls. For the production of paper from water hyacinth, the pulp from leaves and stem is treated with bleaching powder, calcium carbonate and sodium carbonate, mixed with small amounts of used news paper and appropriate binders. Coir industry waste fibres known as “baby fibres”, is blended along with the plant pulp to manufacture unique canvas for paintings. For fibre boards, stalks are boiled, washed and beaten, mixed with waste paper pulp and filter agents such as China clay to balance pH.[26]

E. *Yarn ,rope and basket work*

Fibre obtained from the stems are used to make yarns and rope and dried stalks are being used to make baskets for domestic purposes using traditional weaving techniques. Water hyacinth fibre is an excellent raw material for clothing and fabrics. The stalks are passed through a series of chemical treatment to obtain the property of wool yarn. For ropes the stalks are shredded length ways and exposed to sunlight for several days, rope making is similar to jute rope making process. The finished ropes are treated with sodium meta bisulphate to prevent it from rotting.[26]

Fig.2.Products

ISSN:0971-1260

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F. *Charcoal briquettes*

Briquetting of charcoal by the pyrolysis of water hyacinth helps to reduce over exploitation and dependence on other sources of fuel such as fuel wood. Various steps involved in this process includes, harvesting and collection of the plant, drying, collection and transport to the kiln, pyrolysis, mixing of the resultant dust with a binder, pressing into briquettes, marketing of briquettes.[26]

XII. CONCLUSION

Water hyacinth (*Eichhornia crassipes*) the fast growing perennial species which exhibits foliar plasticity making it adaptable to all climatic and environmental conditions. A great source of raw material for the production of biofuels, biomaterials and have wide applications in the fields of pharmaceuticals, cosmeceutical and phyto remediation. Having low lignin, that is cellulose and hemicellulose are more easily converted to fermentable sugar thus resulting in enormous amount of utilisable biomass for the biofuel industry. Beside the drastic loss offered to the biodiversity it possess great future in fuelling our future economy.

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