Article

Eichhornia crassipes as a potential phytoremediation agent and an important bioresource for Asia Pacific region

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Abstract
Eichhornia crassipes is a free floating plant found growing in almost all the aquatic environment of Asia Pacific region. The invasive and infesting nature of this plant disturbed the whole environment wherever if present and has become one of the most problematic environmental concern. The current review discussed the cost-effective and eco-friendly way of utilizing this invasive and infesting plant in a way to incur the daily needs and also help in controlling the negative outcome. Development of the technology and used in accumulation and absorption of the heavy metals and other nutrients under phytoremediation from the aquatic bodies, biofuel and biogas production through fermentation and decomposition, fertilizer production through composting / vermicomposting, production of feeds for animal and many more utilities which are beneficial is discussed in this review. The review paper also deals with this multifaceted utility approach of this plant and their application in management.

Keywords bioresource; phytoremediation; wetlands; invasive; Asia Pacific

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1 Introduction

Eichhornia crassipes (Water hyacinth) of a Pontederiaceae family, a native of South America, is one of the free floating macrophytes found in the aquatic environment such a ditches, ponds, and lakes, is mostly studied for the purposes of phytoremediation (Melignani et al., 2015) because of its easily cultivable under heavy metal stress and could produce high biomass in aquatic environment without showing much toxic symptoms (Malar et al., 2015).It is listed as one of the most productive plants on earth and is considered one of the world’s worst aquatic plants (Malik, 2007).The plant can achieve a growth rate of 17.5 metric tons per hectare per day under the favourable conditions (Shoeb and Singh, 2002). Still though, the infestation of the Eichhornia crassipes has been studying by many researchers, taking its productive advantages, many have also developed the technology using this plant such as accumulation and absorption of the heavy metals and other nutrients under phytoremediation from the aquatic bodies, biofuel and biogas production through fermentation and decomposition, fertilizer production though composting/vermicomposting and production of feeds for animal.

2 Distribution

Eichhornia crassipes has distributed all over the world and has invaded Asia, Africa, Australia, Europe and North America (Téllez et al., 2008; Shanab et al., 2010). In South America, its presence was reported in 1902 from Brazil, from Argentina in 1942, from Paraguay, Uruguay, Bolivia, Equador and Columbia in 1959, from Venezuela in 1976, and from Chile in 1979 (Téllez et al., 2008). In India, the plant was first introduced from Brazil as an ornamental plant in the year 1896 (Rao, 1988).

3 Importance

It has been mostly studied for its tendency to bio-accumulate and biomagnify the heavy metal contaminants present in water bodies (Tiwari et al., 2007). The potential application of this plant in the removal of heavy metals from water was discovered in the early 1980s (Govindaswamy et al., 2015). It accumulates metals and as the recycling process is run by photosynthetic activity and biomass growth, sustainable process and cost efficient (Garbisu et al., 2002; Lu et al., 2004; Bertrand and Poirier, 2005). Due to its exotic invasive nature and rapid decomposition in comparison to other plants, it has been reported that the growth of water hyacinth poses problem in functioning in the aquatic ecosystem e.g. constructed wetlands (Khan et al., 2000; Rai, 2011, 2012). However, it is one of the most suitable plant for phytoremediation used by various researchers and scientists. *Eichhornia crassipes* colonized natural wetland systems could serve as “nature’s kidneys” for proper effluent treatment to preserve the earth’s precious water resources from the pollutions (Malik, 2007). The application of *Eichhornia crassipes* as a cleaning agent for phytoremediation is very useful in a way to preserve the aquatic bodies from many variant pollutants specially heavy metals because of its easily availability, low cost, effectiveness and eco-friendly methods.

4 Phytochemicals Composition

Eichhornia crassipes being a fast growing plant, is used for rapid removal of various kinds of pollution in water resulting in positive outcomes. The plant was evaluated for its possible potential of heavy metal accumulations which results in the discovery of high cellulose content and its functional groups including amino (-NH2), carboxyl ($-COO^-$), hydroxyl ($-OH^-$), sulfahydryl (-SH) showing high tolerance and affinity towards heavy metals adsorption (Patel, 2012). *Eichhornia crassipes* contains many phytochemical such as amino acids including glutamic acid theonine, leucine, lysine, methionine, tryptophan, tyrosine, and valine; flavonoids including apigenin, azaeleatin, chrysoeriol, gossypetin, kaempferol, luteolin, oientin and tricin (Nyananyo et al., 2007). The dry mass of the plants is consisted of 5.2% nitrogen, 0.22% of phosphorous, 2.3% of potassium, 0.36% of calcium, 280 ppm of Iron, 45 ppm of Zn, 2 ppm of Cu and 332 of Mn (Koutika and Rainey, 2014).

5 Phytormediation Potential and Utility

Eichhornia crassipes has the ability to remove hazardous heavy metals and nutrient conditions of aquatic bodies by accumulating and translocate in their harvestable part. It is a fast growing plants and can remove the accumulated heavy metals in a rapid progress. Its uses in phytoremediation were reported by various researchers and scientists. Moreover it has various utility including removal of nutrients, biofuel production, composting into manure and feeds for animals.

5.1 Heavy metal phytoremediation

Eichhornia crassipes were used in various polluted sites such as wetlands, rivers basins, ponds, ditches, sewages, industrial effluents, landfills, etc. for remediation purposes. It is adopted by many researchers and scientists for phytoremediation because of its easily availability, its effectiveness, easily applicable to wide range of water contaminant, cost free plant for the method, safe and eco-friendly technology. *Eichhornia crassipes* as a common plant for the removal of Pb, Cu, Zn, Hg, Cd, Cr and Mn (Tiwari et al., 2007; Kumar et al., 2008; Rai 2009; Rai et al., 2010; Chatterjee et al., 2011; Fawzy et al., 2012; Padmapriya and Murugesan, 2012; Sasidharan et al., 2013; Mishra et al., 2013).

A study to assess the growth of Eichhornia crassipes and its ability to accumulate Cu from polluted water with high Cu concentrations and mixture of other contaminants under short-term exposure, in order to use this plants for remediation of highly contaminated sites results in high accumulation and translocate much lesser in leaves than in roots (Melignami et al., 2015). *Eichhornia crassipes* were also exposed to varying concentration of Hg as seedlings under hydroponic system to investigate accumulated mercury level, anti-oxidant defence mechanisms, growth patterns changes, and damaging of DNA from the exposure effect. (Malar et al., 2015). It is also an As hyperaccumulator which can uptake As, have the tolerance, and accumulate in their biomass (Tiwari et al., 2014). Eichhornia crassipes reduce levels of heavy metals in acid-mine water with little sign of toxicity (Falbo and Weaks, 1990).

5.2 Removal of nutrients

Eichhornia crassipes in the removal of nutrients from the aquatic bodies is very effective (Roger and Davis, 1972; Wolverton and McDonald, 1979; Trivedy and Pattanshetty, 2002; Jayaweera and Kasturiarachchi, 2004; Cristina C et al., 2009). Many researchers have studied *Eichhornia crassipes* with waste water containing high nutrients (Gamage and Yapa, 2001; Jayaweera and Kasturiarachchii, 2004; Tripathy and Upadhyay, 2003). Domestic sewage purification potential were studied using this plant many parameters which includes Biochemical Oxygen Demands (BOD), Chemical Oxygen Demand (COD), Faecal coliform count, nitrate and phosphate concentrations, pH value, heavy metals, turbidity, odor and colour (Alade and Ojoawo, 2009). Moreover, *Eichhornia crassipes* has the capacity to remove nutrients and heavy metals from leachate from landfill which minimize pollution to an acceptable level (Akinbile and Yusoff, 2012). Significant results were obtained in the physiological response of *Eichhornia crassipes* to the combined exposure of excess nutrients and Hg (Cristina C et al., 2009). A study also reveals that *Eichhornia crassipes* grown in nutrient-poor conditions are ideal to remove Fe from wastewater with a hydraulic retention time of approximately 6 weeks (Jayaweera et al., 2008). The plant is also effective for purifying wastewater from an intensive duck farm during its growing season and also the harvested plant had an excellent performance as duck feed (Jianbo et al., 2008). Also the plant can survived extremely eutrophic water with anaerobically digested flushed dairy manure wastewater (Sookah and Wilkie, 2004).

5.3 Biofuel production

The biogas produce from the organic matter of plants serves as a cheap mode of replaceable biofuel from the present petroleum fuels. Bhattacharya and Kumar (2010) listed attributes of an ideal biofuel crops. They are:

1. The plant should be naturally grown vegetation, preferably perenials.
2. The plant should content high cellulose with low lignin per unit volume of dry matter.
3. The plant should be easily degradable.
4. The plant should not compete with arable crop plants for space, light and nutrient.
5. The plant should resists pest, insects and disease.

6. The plant should not be prone to genetic pollution by cross breeding with cultivable food crops.

Eichhornia crassipes is abundantly available, perennial, non crop, biodegradable and high cellulose content which fulfils all the criteria for bio-energy production (Patel, 2012). The cellulose and hemicellulose content in the plant are more easily converted to fermentable sugar which results in enormous amount of utilizable biomass for the biomass industry (Bhattacharya and Kumar, 2010). *Eichhornia crassipes* mixed with animal waste yields better biogas (Kumar, 2005) and the obtained sludged mixed feed with nitrogen, phosphorous and potassium content can be utilized as good manure (Malik, 2007). Microbes take a great role in decomposing the organic matter of plants. Patel et al (1992) work in stimulation of microbial activity to increase the biogas production using different biological and chemical additives. Also the plants biomass fermentation with the help of methanogens in a reactors turn out to be positive producing good biofuel (Chanakya et al., 2009).

5.4 Compost and manure

The species is rich in nitrogen content therefore it is beneficial in composting (Gunnarson and Petersen, 2007).It is advantageous after vermicomposting with earthworm as it loses the ability to reproduce (Abbasi and Ramasamy, 1996; Malik, 2007). The sun dried plant can be mixed with ash, soil and some animal manure which mixture can be pile up to compost, the warmer climate of tropical countries accelerating the process and producing rich pathogen free compost and can be applied directly to the soil (Jafari, 2010). The compost made from agitated pile this plant collected from sewage water mixed with cattle manure and sawdust content more nutrient (Singh and Kalamdhad, 2015). The nutrient deficient soils mainly due to conventional farming practices and nutrient runoff can be checked mulching soils with naturally and abundantly growing *Eichhornia crassipes* (Balasubramaniun et al., 2013).The plant is positively affected on its mulching in pearl millet growth in sandy soil (Parra and Hortenstine, 1974). The application of this plant as mulch at 22 metric ton/ha (air dry weight) reduced evaporation by 15% from a 1:2 sand-soil mixture, increased soil water penetrability into clay soils, and enhanced salt leaching (Rahman et al., 1996)

5.5 Feeds for animal

Eichhornia crassipes is used as animals feed for various beneficial reasons. The plant shave nutrient which are available to ruminants and can be used in developing countries could help solve some nutritional problems (Jafari, 2010). The ample biomass of this plant were studied for ruminant nutrition (Aboud et al., 2005) The plant content easily digestible cellulose which is important as a starting substrate for the cellulolytic bacteria and that once the environment is created for them they will provide the ruminant with sufficient nutrients through the process of fermentation even if the bulk of the feed is of low digestibility (Dolberg et al., 1981). It is rich in mineral content and can serve as suitable economic feed (Lata and Veenapani, 2010). The plants is also rich in protein, vitamins and minerals and it is effective for purifying wastewater from an intensive duck farm during the plants growing season, as harvested plants had an excellent quality duck feeds (Jianbo et al., 2008).This plant is also used as indirect feed for fish as the decayed plants after chemical control releases nutrients which promote the growth of phytoplankton with subsequent increases in fish yield (Gopal, 1987).The plants is also commonly used as forage for cattles as basal feed resource or supplement to a diet consist of sugarcane, molasses and cereal straw as it contains adequate mineral that is sufficient for maintainence and production requirement of cattle (Hossain et al., 2015). Studies have shown that sun dried *Eichhornia crassipes* plants is beneficial for raising goats at level up to 40 percent of diet (Dada, 2002). The incorporation of this plant in cattle diets improved in crude protein intake and digestibility (Tham, 2012).

5.6 Other utilities

Eichhornia crassipes is a kind of multi-utility plant that can take into different roles from different perspective utility. It can be used to make traditional basket and weaving purposes (Jafari, 2010). Moreover it can be crafted into coasters, placemeats, mats, shoes, sandals, bags, wallets, vases etc. from its dried petioles (Patel, 2012). Pulp materials extracted from this plant have the potential for producing greaseproof paper (Goswami and Saikia, 1994). The plant can also be used for oil sorption in a wide range of temperatures, and absorbed oils can be recovered (Yang et al., 2014).

6 Conclusion

Eicchornia crassipes being an infesting plant, it's used as beneficial utility plants have been restricted by many. However, taking its positive advantages of this plants, many have also developed the technology and used in accumulation and absorption of the heavy metals and other nutrients under phytoremediation from the aquatic bodies, biofuel and biogas production through fermentation and decomposition, fertilizer production through composting/vermicomposting, production of feeds for animal and many more utilities which are more beneficial. As the plant is infested throughout the world in every corner and every sides, utilization of the plant should be done from every angle seeing the positive attributes. It will also help in controlling the infestation of the plant. The current review paper will help in acquiring the positive attributes of the *Eichhornia crassipes* in order to aware and make used the most of it in eco-friendly and sustainable ways.

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