



Review Article

**Distribution, threats and management options for water hyacinth
(*Eichhornia crassipes*) in Ethiopia: A review**

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ABSTRACT

Water hyacinth is free-floating, stoloniferous and perennial herb. It is an aquatic invasive species; native to South America and most aggressive invasive species worldwide. It profoundly invaded the tropical and subtropical region of the world, as a result of ornamental properties and reproductive capability of the weed. In addition, it is recognized as one of the worst weeds due to its rapid proliferation rate, ecological adaptability and detrimental effects on environment, human health and economic development. It poses serious socio-economic and environmental problems includes destruction of biodiversity, hindrance to water transport and recreation, oxygen depletion and reduction of water quality, breeding ground for pests, vectors and their effect on human health, hampering agriculture and fisheries, affect hydropower and water supply systems and increased evapo-transpiration. Therefore deferent management strategies such as physical, chemical and biological methods had been used to control the weed. Accordingly manual removal was used in South Africa; Zimbabwe Lake Mutirikwi; Ethiopia Wonji-Shewa Sugar Factory and Owen fall hydropower in Jinja at Lake Victoria. Chemical control was practiced in Zimbabwe Lake Chivero using 2-4-D; South-west Nigeria Ere fishing channel by glyphosate; South Africa larger dams and river systems by using glyphosate; Zimbabwe acetic acid and glyphosate control the weed at experimental site. Biological control was practiced in Zimbabwe Lake Chivero through combination of weevil and fungi; Kenya Lake Victoria and China by two types of weevils (*Neochetina bruchi* and *Neochetina eichhornia*) and Ethiopia *Neochetina bruchi* and fungi at Rift Valley and in green house at experimental level respectively.

Introduction

Water hyacinth (*Eichhornia crassipes* Mart. Solms), is one of the world's worst perennial aquatic herb which belongs to the family (*Pontederiaceae*) and native of South America (Hill et al. 2011). Due to its rapid growth rate and high adaptability to extreme conditions contributes to its high

degree of invasion (Hill et al. 2011). It is particularly dominant in the tropics and subtropics due to improper waste water management in these areas (Villamagna and Murphy, 2010). Its usage as ornamental plants has tremendously increased its distribution, originally from the Amazon Basin nowadays to more than fifty tropical and sub-tropical countries over five continents (Toft et al. 2003). The success of this invasive alien species is largely due to its reproductive output. The weed originated from the Amazon Basin and has disseminated very quickly to many tropical and subtropical countries of Latin America and the Caribbean, Africa, Southeast Asia and the Pacific (Julien, 2000). The first introduction to African continent was made in Egypt in the late 1880s (Navarro and Phiri, 2000). The first recorded in Zimbabwe was in 1937 and some important rivers in Ethiopia was in 1956 (Mujingni, 2012). In Ethiopia, water hyacinth was announced in 1956 in *Koka* Lake and *Awash* River (Tegene and Ayele, 2014). At present, it is one of the five-invasive alien plants in the country (Fessehaie, 2005). It causes to a significant ecological and socio-economic effects (Villamagna and Murphy, 2010). The weed forms thick mats over the infested water bodies which causing hindrance to water transport, disrupting hydro-electric operations, blockage of canals and rivers, causing flooding and human health problem, increased evapotranspiration, reducing water quality, interference with fishing, irrigation, navigation, livestock watering and reduction of biodiversity (Senayit et al. 2004). The economic impacts of the weed in seven African countries have been estimated at between US\$20-50 million every year. Across Africa, costs may be as much as US\$100 million annually (UNEP, 2011). In Ethiopian comprehensive local estimates of economic impacts of water hyacinth in the affected areas of the Ethiopian water bodies have not been done yet, except for the Wonji-Shoa Sugar estate which incurred about US\$ 100,000 in total from 2000 to 2013 for the control of this weed (Firehun et al. 2014). Thus controlling of these aggressive weeds by different method was crucial to alleviate its negative impact from both biodiversity distraction and interference in economic activities. Worldwide, several control methods have been adopted to manage water hyacinth. Mechanical, chemical and biological control methods are commonly used to control the weed (Julien et al. 2001). Mechanical control includes harvesting by hand or machine (Villamagna and Murphy, 2010). The use of machinery to remove water hyacinth from water bodies is the most effective non-polluting control method (Mara, 1976). The main advantage to the use of mechanical harvesting is the simultaneous removal of nutrients and pollutants from the water body (Wittenberg and Cock, 2001). Despite the environmental pollution and human health risks caused by the application of chemical pesticides (Mehdizadeh and Gholami Abadan, 2018) chemical herbicides are the principal means of control, when an immediate solution to water hyacinth problem is needed (Charudattan, 1986). Glyphosate and 2,4-D [(2,4-dichlorophenoxy) acetic acid] have been the most widely used herbicides and considered as

effective and safe herbicides to control water hyacinth (Chen et al. 1989). The practice of biological control using a natural predator (the weevil species *Neochetina eichhorniae*, *N. bruchi* or the moth species *Sameodes abligullatis*) or pathogen (the fungus *Alternaria eichhornia*) (Coetzee et al. 2009). The principal drawback with biological control of water hyacinth is the time required to achieve control. In tropical environments, this is usually 2 to 4 years (Wittenberg and Cock, 2001). Therefore the objective of this paper was to review the distribution, threats and management options practiced to control water hyacinth.

General Overview of Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) is a monocotyledon belonging to the family of Pontederiaceae (Solms). The name water hyacinth refers to its aquatic habitat and the similarity of the flower colour to that of the garden hyacinth (Parsons and Cuthbertson, 2001). It is an erect, free-floating macrophyte, stoloniferous, perennial herb and lives at the air-water interface which forms two distinct canopies: leaf canopies comprising above water structures and root canopies comprising below water structures (Downing-Kunz and Stacey, 2012). The mature water hyacinth consists of roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. It has thick rounded green leaves, lavender blue flowers with a central yellow dot organized in spike inflorescence and dark purple to black roots with rhizomes and stolons (Gettys, 2014).

The reproductions of water hyacinth are both sexual and vegetative. Flowers produce large numbers of long-lived seeds that can remain viable for up to 20 years in sediments (Gopal, 1987). Sexual reproduction is limited by a scarcity of suitable pollinators (mostly, long tongued bees) and a lack of appropriate sites for germination and seedling establishment (Barrett, 1980). The major propagation is by means of stolons which form daughter plants at axillary buds (EPPO, 2008). The spreading of the daughter plants is also thought to be enhanced by wind and wave action (EPPO, 2009). Under suitable conditions, plant numbers can double between 1 to 3 weeks (Parsons and Cuthbertson, 2001).

Origin and Distribution of Water hyacinth

In 1823, the German naturalist Von Martius discovered the species, while carrying out floral surveys in Brazil. He named it *Pontederia crassipes*. Solms included it in the *Eichhornia* genus, 60 years later, as had previously been described by Kuntz in 1829. The native range of *E. crassipes* Gopal, (1987) was South America includes Argentina, Brazil, Paraguay, Uruguay, Bolivia, Ecuador, Colombia, Chile, Guyana, Surinam and Venezuela. It was first reached North America in the late 1800s and Europe in the 1930s (Brundu et al. 2013), In Europe, it is established in the Azores

(France) and in Corsica (Italy), and casual records are known from Belgium, the Czech Republic, Hungary, Netherlands and Romania (EEA, 2013). In Asia, it was widespread on freshwater wetlands of the Mekong Delta, especially in standing water (MWBP/RSCP, 2006). Biswas et al. (2007) reported that water hyacinth has been detected in the Sundarbans mangrove forest of Bangladesh and has caused heavy siltation in the wetlands of the Kaziranga National Park, India. As in many other countries, water hyacinth has caused many economic, social and environmental problems in southern China (Choo et al. 2006). It was first noticed in Australia in Brisbane, Sydney and Grafton in the 1890's and has since spread to all mainland States and Territories (Harley et al. 1996). It introduced to Africa in the early 1900s (Brundu et al. 2013), The first recorded for introduction of water hyacinth in to the continent was in Egypt in the period 1889 – 1892, during the reign of Khevede Tawfiq (Gopal, 1987). It occurs throughout the Nile Delta and is believed to spreading southwards, due to the construction of the Aswan Dam (Gopal, 1987). The second record for the continent was for South Africa in 1908. Thirdly, Zimbabwe recorded water hyacinth infestations in 1937 (Chikwenhere et al. 1999). In the period 1941 to 1960, further ten African countries recorded water hyacinth infestations, namely: Angola (1942), Benin (1942), Burundi (1957), Congo (1950-1951), the Democratic Republic of Congo (1952), Ethiopia (1956), Mozambique (1942), Rwanda (1957), Sudan (1954) and Tanzania (1955). It occurs in almost all of the wetlands of Africa and poses serious social, economic and environmental problems for millions of people in riparian communities and therefore, added constraints on development of the nation (Howard and Matindi, 2003). The reason for the worldwide distribution of this weed varies, but generally it has coincided with the plant's ornamental properties and serving as feed (Ding et al. 2001). Extensive use of chemical fertilization for agricultural production around wetlands leading to an increase of nutrient concentrations of water bodies (eutrophication) and combined with high solar energy (Ndimele et al. 2011) represent favorable conditions for the spread of the weed (Charudattan et al. 1996). As a result, *Eichhornia crassipes* was distributed throughout the world, flourishing in tropical and subtropical regions, extending into Mediterranean climatic areas.

Threats of Water hyacinth

Impacts of water hyacinth on other species

However, the total amount of invertebrates decreases because of the overall reduced availability of phytoplankton (Midgley et al. 2006). According to Mujere (2016) diversity of fish stocks is often affected with some benefiting and others suffering from the proliferation of water hyacinth. The thick mats of water hyacinth lead to a decrease of phytoplankton (due to light deprivation), an increase in water turbidity (due to the constant rotting of the mat base) and a decrease of dissolved

oxygen (due to the high oxygen consumption of rotting plant biomass) (Villamagna and Murphy, 2010). Collectively these effects may negatively impact animal and plant species at Lake Alaotra. The impacts of the water hyacinth on water birds are ambivalent: The dense mats of water hyacinth or the low dissolved oxygen under the mats could physically hinder water birds access to prey or impact negatively the abundance of the prey species (Villamagna and Murphy, 2010). At Lake Alaotra, several bird species such as the white backed duck suffer from the spread of water hyacinth (Rakotoarisoa, 2017).

Impacts of water hyacinth on water transport and recreation

Access to harbors and docking areas can be seriously hindered by mats of water hyacinth. Canals and freshwater rivers can become impassable as they clog up with densely intertwined carpets of the weed. In the Wouri River Basin in Cameroon the livelihood of close to 900,000 inhabitants has been distorted; the entire Abo and Moundja Moussadi creeks have been rendered impassable by the weed leading to a complete halt in all the socioeconomic activities with consequent rural exodus (Mujingni, 2012). According to Cho and Tifuh (2012) riparian communities in Cameroon, as part of their social activities they derive recreational benefits from the river where activities like boat racing, swimming and site seeing but this can no longer be possible in water hyacinth infested areas. Based on study of Mujere (2016) water hyacinth was becoming a serious hazard to lake transport on Lake Victoria as large floating islands of water hyacinth form, while many of the inland waterways of south-east Asia have been all but abandoned. They include difficulty in navigation, which is a result of the mesh formed by the roots. This has grave implications such as failure to transport essential commodities from one landing site to another. In Uganda, residents of some islands such as Kasanje and Busi depend on water transport to take the sick to hospitals located in the mainland, for example, in Entebbe. When the weed blocks the way, deaths are common (Mujere, 2016).

Impacts of water hyacinth on water quality

The most apparent environmental impact of water hyacinth infestations that affect the riparian community directly is the degradation of water quality by its foul smell and debris (Cho and Tifuh, 2012). The thick mats of water hyacinth lead to an increase in water turbidity (due to the constant rotting of the mat base) (Villamagna and Murphy, 2010). According to Mironga et al. (2012) water hyacinth infested area showed low pH values ranging between 6.7 and 7.1, while shoreline without water hyacinth had higher values ranging from 7.4-7.95. Free carbon dioxide was also higher in the water hyacinth infested areas with values ranging from 23.97-34.97 mg L⁻¹ when compared to

shoreline without water hyacinth values which ranged between 3-20 mg L⁻¹ (Mironga et al. 2012). The infested areas also showed low values of dissolved oxygen in the range of 1.02 to 3.60 mg L⁻¹. The shoreline without water hyacinth had high concentrations of dissolved oxygen (1.96±0.71) while shoreline with water hyacinth had a mean of 5.89±0.85 (Mironga et al. 2012).

Impacts of water hyacinth for Breeding of pests, vectors and their effect on human health

According to Firehun et al. (2007) based on the information obtained from Wonji Hospital malaria is still one of the major fatal disease in the area that is supported by the stagnant water resulted from the impeding effect of water hyacinth. The weed also blocks access to water points and has been linked to an increase in cholera and typhoid.

Impacts of water hyacinth to agriculture and fisheries

When weed infestation is present, access to fishing sites become difficult for riparian communities which rely solely on fishing as their main economic activity. Similarly, in Lake Naivasha, the water hyacinth infestation has been observed to have a negative impact on the economic status of the fisher community (Waithaka, 2013). According to Rakotoarisoa (2017) at Lake Alaotra, also invade rice fields; suppressing rice crop, inhibiting rice germination and interfering with rice harvest was observed frequently due to inefficient water control. The risk of production loss due to the water hyacinth can become more prevalent in the near future; the water scarcity at the lake, combined with badly maintained irrigation systems are pushing the rice fields closer into the marshlands.

Impacts of water hyacinth on hydropower plants

The hydropower dams on the Shire River in Malawi also frequently forced to stop production due to clogging the intakes for the water cooling system by this weed (Wise et al. 2007).. In addition Ethiopian Electric Power Corporation (EEPC) has reported this plant as a problem disrupting their operation at the three hydropower stations located along the Awash River (Tegene and Ayele, 2014).

Impacts of water hyacinth on water loss

Water hyacinth caused wastage of water through excessive evapotranspiration. Studies have shown that a dense cover of water hyacinth enhances evapotranspiration (Mailu, 2001). The rate of water loss due to evapotranspiration can be as much as 1.8 times than that of evaporation from the same surface but free of plants (Haider, 1989). This has great implication where water is already

scarce. The estimated water loss due to this weed from the highly infested water reservoirs that are used directly for irrigating the fields were ranged between 393,660 to 2,945,160 m³. Such impacts of the weed were also reported in different countries (Howard and Matindi, 2003). Increased water loss by water hyacinth leads especially in shallow lakes such as Lake Alaotra to a drop in water level. It is estimated that the flow of water in the Nile could be reduced by up to one tenth due to increased losses from evapotranspiration by water hyacinth in Lake Victoria (Ndimele et al. 2011). Allen et al. (1997) also indicated that this effect can result in loss up to 13 times from that of a free water surface with a minimum rate of 2.5 times. In Ethiopia, water hyacinth caused wastage of water through excessive evapotranspiration that would otherwise be used for sugarcane production (Firehun et al. 2007).

Management Options of Water Hyacinth

Manual/mechanical control

Mechanical control refers to the use of machinery such as mechanical mowers, crusher boats, destruction boats, dredgers and weed harvesters which are designed to physically cut, shear, shred, crush, press, lift or remove and transport aquatic plants and associated organic material from water bodies (Cho and Tifuh, 2012). Mechanical cutting and harvesting are practical for large-scale (several acres) vegetation removal because they remove plants from large areas in a relatively short time. Mechanical cutting and harvesting are non-selective and could eliminate valuable fish, plants and wildlife habitat within the target area. However, recently some 75km of the Guadiana River in Spain was controlled mechanically (Têllez et al. 2008).

Manual control involves the removal of water hyacinth by uprooting with hands or cutting with cutlasses. However, the method is very risky because of the existence of some animals such as snakes, alligators and crocodiles which live under water hyacinth mats. Furthermore, it is time consuming and labour intensive (May et al. 2003) but if implemented systematically, it may be of great value to reduce a moderate stand of the weed (Labradar, 1995). Manual removal was used in South Africa (Hill and Coetzee, 2008). According to Mujere (2016) study, manual removal of the weeds or pulling through nets using hands and/or rakes, was done in Lake Mutirikwi (90 km²) in Zimbabwe. Based on Firehun et al. (2007) interview about management of the weed at Wonji-Shewa Sugar Factory indicated that the factory has been practicing manual and mechanical removal of the weed from the canals periodically and left to dry at the border of the canals. The fisher-folk communities around Lake Naivasha also, identified key infested sites and control the weed manually (Mironga et al. 2012). The Owen falls hydropower scheme at Jinja on Lake Victoria is a

victim of water hyacinth's rapid proliferation and physical removal was practiced to control the weed (Mailu, 2001).

Chemical control

Chemical method is an effective management options for weed control. However there are many risks associated with these chemical compounds such as human safety, environmental pollution (Mehdizadeh, 2014), as well as the negative impacts on non-target species (Mehdizadeh, 2016; Mehdizadeh, 2019; Mehdizadeh et al. 2019). According to the Agriculture and Consumer Protection Department of FAO, aquatic herbicides are a swift and effective technique for managing water hyacinth, in the case of severe infestation. The three most commonly used aquatic herbicides are: 2,4-D, Diquat (6,7-dihydrodipyridol) and Glyphosate. All these herbicides are absorbed through the leaves and are quickly transported throughout the whole plant, killing all parts of it (Lindsay and Hirt, 1999). Herbicide applications are usually less expensive than mechanical control but may have to be repeated on an annual basis (GISD, 2006); owing to the fact that once plants are removed, light penetration increases, favoring the germination of water hyacinth seeds and therefore new water hyacinth re-infestation. The limitation of this method remains its negative impact on the environment and health related effects, especially where people collect water for drinking and washing. The herbicide 2-4-D was used in Lake Chivero from 1971 to 1985, after which time, it was banned. Lake Chivero was observed to be reinfested with hyacinth 6 months after spraying with 2-4-D, due to poor transport of the chemical in the stems from the parent shoots to the offshoots (Chikwenhere, 2001). According to Uka et al. (2007) a few trials were undertaken at Ere fishing channel South-west Nigeria. The application of Glyphosate gave rise to total mortality of water hyacinth within 14 days. Herbicidal control, using formulations containing the active ingredient glyphosate, is still used to control water hyacinth in some of the larger dams and river systems in South Africa. Based on the experiment of Agidie et al. (2018) the chemicals particularly, acetic acid and glyphosate showed better efficacy in suppressing water hyacinth tissue growth when applied at experimental site.

Biological control

The biological control of water hyacinth began in the 1960s and involves control of water hyacinth through the use of host-specific insects, moths or pathogens which are natural enemies of the weed and imported from the point of origin of the weed (Deloach and Cordo, 1976). Biological control remains the most cost-effective and environmentally friendly technique for the sustainable control of water hyacinth (van Wyk and van Wilgen, 2002). Adult beetles feed on leaves which

increase transpiration and places the plant under stress. The weevils *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache (Center et al. 1982) are two species that have provided the best results for biological control. Other biological agents include the fungi *Alternaria eichhorniae* and *Cercospora piaropi* (Martínez and Charudattan, 1998) and the moths *Niphograpta albiguttalis* and *Xubida infusellus* were used to control the weed (Julien et al. 2001). Marked successes with biological control agents have been reported from many parts of Africa and the world, notably at Lake Chivero (Zimbabwe), Lake Victoria (Kenya), Louisiana (USA), Mexico, Papua New Guinea and Benin (Gichuki et al. 2012). A combination of weevil and fungal attack on water hyacinth has been applied in Lake Chivero. The weevils *Neochetina bruchi* and *Neochetina eichhornia* have been identified as absolutely specific to control the hyacinth in Lake Victoria and Chivero (Mujere, 2016). The weevils were used for the control of water hyacinth in China. A release of 1000 insects per (1000 m²) in two sites exerted an efficacy around 90% of the water hyacinth infestation (Ding et al. 2001). According to the experiment of Admas et al. (2017) in green house level, *Tricothecium roseum*, *Aspergillus flaves*, *Trichoderma spp1*, *Fusarium spp*, *Rhizocotonia spp*, *Aspergillus niger* and *Trichdoerma spp* fungi were promising to eradicate water hyacinth at above 26°C and at less than 25% humidity. The plant hopper, *Megamelus scutellaris* Berg (*Hemiptera: Delphacidae*), was the most recent agent have been released in 2013 and impacting the plant in the cooler areas of South Africa (Hill and Coetzee, 2017). According to Firehun (2017) *Neochetina bruchi* was considered as a promising candidate for control of water hyacinth under Ethiopian conditions.

Conclusion

Aquatic weeds have become an increasing concern in all water use types. Water hyacinth is one of the top ten most invasive aquatic plant species in the world. It is arguably the most noxious aquatic weed in the world, due to its ability to rapidly cover whole waterways and efficient survival strategies in extreme conditions. It imposed enormous negative effects that include: destruction of biodiversity by out-competing all other species growing in the vicinity; oxygen depletion and reduction of water quality due to the large mats prevent the transfer of oxygen from the air to the water surface or decrease oxygen production by other plants and death and decay of the weed; impacts on hydropower and water supply systems because of clogging the point of water intakes; increased evapotranspiration that has reduced the water table; physical obstruction of water transport as a result of the large mats of the weed; increased operational costs attached to fishing activities resulting from loss of nets and boat engine breakdowns; reduced fish reproduction and being a breeding ground for many disease-causing organisms. Therefore deferent management strategies such as manual/mechanical, chemical and biological methods had been used to control

the weed. Accordingly manual removal was used in South Africa; Zimbabwe Lake Mutirikwi; Ethiopia Wonji-Shewa Sugar Factory and Owen fall hydropower in Jinja at Lake Victoria. Chemical control was practiced in Zimbabwe Lake Chivero using 2-4-D; South-west Nigeria Ere fishing channel by glyphosate; South Africa larger dams and river systems by using glyphosate; Zimbabwe acetic acid and glyphosate control the weed at experimental site. Biological control was practiced in Zimbabwe Lake Chivero through combination of weevil and fungi; Kenya Lake Victoria and China by two types of weevils (*Neochetina bruchi* and *Neochetina eichhornia*) and Ethiopia *Neochetina bruchi* and fungi at Rift Valley and in green house at experimental level respectively. The management and control of water hyacinth was beyond the capabilities of local governments alone. Therefore involvement of multi-disciplinary approach like creation of awareness to the public in all aspects of the weed; use different controlling methods simultaneously and should be designed in a way that the highest political and administrative levels recognize the potential seriousness of the weed.

Conflicts of Interest

No conflicts of interest have been declared.

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