Communications in PLANT SCIENCES

http://cpsjournal.org
e-ISSN 2237-4027
Volume 9 (2019)

SHORT REVIEW ARTICLE

Control of water hyacinth: a short review

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Submitted on November 15, 2019
Accepted on December 03, 2019
Early View on December 04, 2019
Final Publication on December 06, 2019

Authors declare no conflict of interest

KEYWORDS:
Eichhornia crassipes
Aquatic weed
Macrophyte
Weed control

ABSTRACT

Water hyacinth (*Eichhornia crassipes*) is an aquatic weed native from South America that invades waterbodies of tropical and sub-tropical sites worldwide. Mechanical, chemical and biological efforts are been used to control water hyacinth. Each method of control shows advantages and disadvantages. There are no water-use restrictions associated with mechanical control and it does not require much technical expertise, especially when plants are removed from the waterbody. However, changes in dissolved oxygen and trophic structure can accelerates eutrophication when plants are cut, leading to a subsequent increase in water hyacinth blooms. Chemical control is less labor intensive and expensive than mechanical control, especially at large scales. However, herbicides can kill non-target algae and non-target macrophytes, resulting in far reaching ecological impacts. Biological control is an alternative to mechanical and chemical control. It is not labor or equipment intensive, and has the potential to be self-sustaining. However, host specificity is critical to the success of biological control and the and long-term results can discourage one to use this method. Probably, biological control is the most efficient and safety method for water hyacinth management, especially for long-term results. Mechanical and chemical control are effective for short-term results, but they can seriously impact on ecological conditions of waterbodies.

Highlighted Conclusions

1. Mechanical, chemical and biological methods are efficient to control water hyacinth.
2. Biological control is very efficient and safety for long-term control of water hyacinth.

INTRODUCTION

Eichhornia crassipes Mart. (Solms) is an aquatic weed commonly known as water hyacinth. This species is a free-floating vascular plant (Center 1994) originated from South America (Jiménez and Balandra 2007; Villamagna and Murphy 2010) that is found abundantly throughout the year in very large and drainage channel systems in and around the fields of irrigation (Mohanty et al. 2006). Water hyacinth commonly forms dense, interlocking mats due to its rapid reproductive rate and complex root structure (Mitchell 1985) and reproduces both sexually and asexually (Villamagna and Murphy 2010).

Water hyacinth has invaded freshwater systems in over 50 countries on five continents (Hellmann et al. 2008; Rahel and Olden 2008). This species is prevalent in tropical and sub-tropical waterbodies where water nutrient concentrations are often high due to agricultural runoff, deforestation and insufficient wastewater treatment (Villamagna and Murphy 2010). The success of water hyacinth as an invader is attributed to its ability to outcompete native vegetation and phytoplankton and the absence of consumers found within its native range (Wilson et al. 2005). Changes to water hyacinth density have the potential to affect other ecological and human communities in areas where it is established (Gibbons et al. 1994).

Difficulties to control water hyacinth are related to the weed's rapid growth rate and its ability to reinfest via the seed bank or by flood-borne plants (Jiménez and Balandra 2007). The objective of this review is to show and summarize the most efficient methods for controlling water hyacinth.

METHODS OF CONTROL OF WATER HYACINTH

Water hyacinth is extremely difficult to eradicate once established; therefore, the goal of most management efforts is to minimize economic costs and ecological damage (Villamagna and Murphy 2010). Chemical and mechanical methods have been used to manage water hyacinth, but these methods have resulted expensive and unsatisfactory because many repeated applications have been needed (Gutiérrez et al. 1994). Biological control is the only long-term and sustainable solution that can play a key role in the management of water hyacinth (Jiménez and Balandra 2007). Actually, mechanical, chemical and biological control methods are used to control water hyacinth, but no one method is suitable for all situations (Villamagna and Murphy 2010).

Mechanical control

Mechanical control options include harvesting plants and *in situ* cutting (Villamagna and Murphy 2010). There are several advantages and disadvantages to implementing a mechanical control strategy. Manual and mechanical removal which have physical limitations and are labor intensive which could involve health risks (Smith et al. 1984) or might be expensive and energy intensive (Harley et al. 1997). In general, there are no water-use restrictions associated with mechanical control and it does not require much technical expertise (Villamagna and Murphy 2010). Mechanical control immediately opens physical space for fish, boat traffic, fishing and recreation (Villamagna and Murphy 2010). *In situ* cutting, where plants are left to die and decompose in the water, can decrease dissolved oxygen and alter trophic structure as result of changes in nutrient and carbon balances (Greenfield et al. 2007). Moreover, low dissolved oxygen conditions catalyze the releases of phosphorus from the sediment (Villamagna and Murphy 2010). This process accelerates eutrophication and can lead to a subsequent increase in water hyacinth or algae blooms (Perna and Burrows 2005; Bicudo et al. 2007).

While this is an obvious downfall of in-situ cutting, harvesting the plant can be costly and logistically difficult (Villamagna and Murphy 2010). Water hyacinth is comprised of approximately 90% water, making it very heavy to transport (Gopal 1987). Disposal of water hyacinth from polluted water bodies also becomes an important health and ecological consideration due to its capacity to absorb contaminants and, in some cases, the cost of an offsite disposal area can be more expensive than the removal process itself (Thayer and Ramey 1986). Many countries have used mechanical control of water hyacinth either by hand or machine, although it is considered expensive and not very effective (Cilliers 1991). Mechanical control may not be cost effective for large areas when expensive cutting or dredging equipment is required (Villamagna and Murphy 2010).

Chemical control

Chemical control is less labor intensive and expensive than mechanical control, especially at large scales (Guitierrez-Lopez 1993). The use of chemical control might be effective but it had negative side effects on the environment (Julien et al. 1999). Cadmium (Cd) was an effective chemical control of water hyacinth (Toppi et al. 2007), however it is a widespread nonessential toxic heavy metal (Koutika and Rainey 2015). In addition, herbicides can become expensive if management requires repeated applications (Villamagna and Murphy 2010). The cost of chemical control will depend heavily on the equipment used to apply the herbicide (Villamagna and Murphy 2010). Herbicides are less selective than mechanical or manual approaches (Villamagna and Murphy 2010). Herbicides can kill non-target algae, a critical foundation of aquatic food webs (Wetzel 1983), in addition to non-target macrophytes (Seagrave 1988), resulting in far reaching ecological impacts (Arora and Mehra 2003; Rocha-Ramirez et al. 2007) and dangerous deoxygenation of water (Lugo et al. 1998).

Herbicides, such as glyphosate, diquat and 2,4-D amine have been used worldwide to reduce water hyacinth populations (Seagrave 1988; Gutierrez et al.,1994; Lugo et al. 1998). In addition, sulfentrazone, imazapyr, imazapic, metsulfuron-methyl and sulfosate are very efficient to control water hyacinth (Neves et al. 2002). Imazamox is also an effective herbicide to control water hyacinth (Emerine et al. 2010; Gettys et al. 2014; Garlich et al. 2019). New herbicides are required to be used. However, the water use restrictions that may be required by law following herbicide spraying due to chemical control can have significant socio-economic impacts if beneficial or designated uses of the waterbody are affected (Villamagna and Murphy 2010).

Biological control

Biological control is an alternative to mechanical and chemical control (Villamagna and Murphy 2010; Koutika and Rainey 2015). It avoids the introduction of toxic chemicals into the environment, is not labor or equipment intensive and has the potential to be self-sustaining (Seagrave 1988). Much of the cost of biological control is related to research and development (Villamagna and Murphy 2010). According to these authors, the host specificity is critical to any successful biological control program, and the introduced agent will have a narrow range of requirements to keep its effects focused on the target plant, but broad enough to maintain a viable population when the host plant is in low densities.

Biological control is commonly preceded by mechanical removal or chemical treatment in order to quickly reduce the plant population, making initial conditions suitable for effective biological control (Adekoya et al. 1993).

Common biological control options for water hyacinth include various insect species, introduced plant pathogens (Coetzee et al. 2007b) and allelopathic plants (Malik 2007). *Neochetina eichhorniae* and *Neochetina bruchi* are two commonly used weevil species from the plant's native range (Sosa et al. 2007). In cases where *Neochetina* spp. was introduced, effective control of water hyacinth was not realized for many years (Hill and Olckers 2001; Coetzee et al. 2007a; Coetzee et al. 2007b; Wilson et al. 2007). The fungal *Alternaria eichhorniae* was found controlling water hyacinth (Babu et al. 2004). Aqueous leachate of *Lantana camara* was found killing water hyacinth (Saxena 2000).

Biological control of water hyacinth has been conducted in many parts of the world (Koutika and Rainey 2015). Center et al. (1999) showed that sustained herbivory of water hyacinth reduced biomass and floral structures. Center et al. (2005) argued that herbivory directly and indirectly affected plant performance by altering competition between water hyacinth and other aquatic plants and that the competitive response depended upon the herbivore species and availability of nutrients. In addition, Center and Dray (2010) argued that improved nutritional quality of the host plant could lead to more effective biological. Finally, it is very likely that almost all alien invasive plant species will have natural enemies or predators in their original ecosystem (Lee 1979), so that biological control can be very effective for a long-term water hyacinth management.

CONCLUSION

Mechanical, chemical and biological control might be used for water hyacinth management. Biological control is probably the most efficient and environmental safety method for water hyacinth management, especially for long-term results. Mechanical and chemical control are effective for short-term results, but they can seriously impact on ecological conditions of waterbodies.

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DOI: 10.26814/cps2019021 | 4 pages