European and Mediterranean Plant Protection Organization
Organisation Europeenne et Mediterraneenne pour la Protection des Plantes

Data sheets on quarantine pests
Fiches informatives sur les organismes de quarantaine

Eichhornia crassipes

Identity

Scientific name: *Eichhornia crassipes* (Martius) Solms-Laubach
Synonyms: Historical synonyms include *Pontederia crassipes* Martius, Nov. Gen.; *Eichhornia speciosa* Kunth; *Heteranthera formosa* Miquel, *Pontederia azurea* Hook, non Sw; *Pontederia azurea* Roem. & Schultes; *Eichhornia cordifolia* Gandoger
Taxonomic position: Pontederiaceae
Common names: aguapé, baronesa (Brazil), jacinto-aquatico (Portugal), bisnidh, zanim, zoqqueym et.tani Baqaqa, habba, halassandi/halassant (Egypt), buchón (Colombia), bora (Venezuela), jacinthe d'eau (France), gulbakauli (Pakistan), jacinto de agua o camalote, lechuguilla, lirio acuatico (Spain), lila de agua (Dominican Republic), tokozelka (former Czechoslovakia), top-chawa (Thailand), violeta de agua (Chile), wampee (former USSR), wasserhyazinthe (Germany), su sümbülü (Turkey), tarulla (Colombia), vanhyacint (Denmark), water hyacinth (United Kingdom), yakinton hamaim (Israel) (Global Invasive Species Database; GIC, 2006)
EPPO code: EICCR.

Notes on taxonomy and nomenclature

Eichhornia crassipes is in the *Pontederiaceae* family, a taxonomically problematic family, traditionally included in Order Liliales and recently moved to the Commelinales by some authors based on phylogenetic proposals (APG II, 2003; Strange *et al*., 2004). Eight other genera occur in this family of predominantly neotropical, freshwater aquatics, and eight species in the genus *Eichhornia* (Cook, 1998), all of which originate in South America, except *E. natans* (P. Beauv.) which is native to tropical Africa (Gopal, 1987). Only *E. crassipes* is regarded as a pan-tropical aquatic weed
Protologue: *Eichhornia cordifolia* Gandoger, Bull. Soc. Bot. Fr. 66: 294, 1920
Phytosanitary categorization: EPPO Alert List.

Geographical distribution

E. crassipes is distributed throughout the world, flourishing in tropical and subtropical regions.
EPPO region: Israel, Italy, Jordan, Portugal, Spain
Asia: Bangladesh, Cambodia, China, Brunei Darussalam, India, Indonesia, Lebanon, Japan, Laos, Malaysia, Maldives, Myanmar, Philippines, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Thailand, Vietnam.
North America: Mexico, USA (Alabama, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, Texas). See the USGS/Florida Caribbean Science Center map from the 'Protect your waters' website.
Central America: Costa Rica, Guatemala, Honduras, Nicaragua, Panama.
South America: Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, French Guiana, Guyana, Uruguay, Paraguay, Peru, Suriname, Venezuela.
Caribbean: Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico.
Oceania: American Samoa, Australia, Cook Islands, Fiji, French Polynesia, Guam, Marshall Islands, Federated States of Micronesia, Nauru, New Caledonia, New Zealand, Northern Mariana Islands, Palau, Papua New Guinea, Samoa, Solomon Islands, United States minor outlying islands, Vanuatu.
Africa: Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Equatorial Guinea, Ethiopia, Gabon, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Niger, Nigeria, Reunion, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

Note: the species is recorded in Moscow (Russia) but does not thrive. In the Paúl do Boquilobo Biosphere Reserve in Central Portugal, it forms dense floating mats over extensive areas of wetlands and is considered the most obvious threat to the ecosystem. It is also invasive in the River Tagus Basin (Portugal). The plant is also recorded as invasive in Spain in Badajoz, Castillon and Alicante, and has been reported from other regions of the country, including Asturias, Cáceres, Mallorca, Tarragon, and Málaga where it disappeared (Téllez *et al*., 2008). The species is also recorded as casual in the South of France. The species has been eradicated from Corsica.

History of introduction and spread

E. crassipes is indigenous to the New World tropics, and originates from Amazonia, Brazil (Barrett & Forno, 1982), with anthropogenic spread to other areas such as Venezuela, parts of central South America, and the larger Caribbean islands (Penfound & Earle, 1948; Edwards & Musil, 1975). The first authentic record of water hyacinth outside South America is from a trade fair in New Orleans in 1884 (Penfound & Earle, 1948). Thereafter, water hyacinth plants spread around the

USA. By the end of the nineteenth century, the plant was recorded in Egypt, India, Australia and Java (Gopal, 1987). Its distribution is now mainly pantropical, but it also occurs in warm temperate regions of the world, as well as in the Mediterranean Basin. Even though the first introduction of water hyacinth to the African continent was made in Egypt between 1879 and 1892 (Edwards & Musil, 1975), many invasions in Africa were first noticed only in the 1980s, and it continues to invade many African waterways, even though regional bans have been placed on its transport, and numerous control efforts have been implemented (Navarro & Phiri, 2000).

E. crassipes is thought to have been introduced into Europe in the 1930s in Portugal, where it has since spread over the central-west of the country through irrigation canals. It was first documented in Spain in 1989, where it forms localised populations between the latitudes 360 and 430 N. In 2005, it was reported to cover 75 km (approximately 200 ha) of the Guadiana River in the South Western Iberian Peninsula (Téllez *et al*., 2008).

Fig. 1 Fruits of *Eichhornia crassipes* (photograph: GIC-University of Extremadura, Spain, 2005).

Fig. 2 Flowering *Eichhornia crassipes*. (photograph: Angel Hurtado Nogales, Confédéracion Hydrographica del Guadiana).

Morphology

Plant types

E. crassipes is a free-floating aquatic macrophyte, reproducing both vegetatively, via ramets formed from axillary buds on stolons, and sexually through seed production.

Description

E. crassipes displays two different morphologies with intermediates, dependent on the conditions in which it grows. In dense stands, the petioles are elongated (up to 1 m in length in nutrient-rich waters devoid of herbivores) with circular leaves; but are short (< 30 cm) and bulbous (Fig. 1), with kidney-shaped leaves where the plants are not in dense mats, or along the edge of infestations (Center & Spencer, 1981). Both forms seem to have a different photosynthetic behaviour (Williamns *et al*., 2005). The 6–10 glabrous leaves are arranged in basal rosettes, each leaf lasting up to 6–8 weeks before senescence. Both the rhizome and the fibrous, feathery roots remain submerged. The root morphology is highly plastic and the plasticity is related to nutrient, particularly phosphorous (P), availability in the water. Lateral roots are generally longer and denser at low P levels than at high P levels (Xie & Yu, 2003). The root–shoot ratio varies inversely with nutrient, particularly nitrogen (N) availability. Roots purple in colour are very characteristic when growing in low nutrient waters (GIC, 2006).

Reproduction is both sexual and vegetative. The showy flowers are pale blue or violet (Fig. 2), displaying a yellow central patch in the standard perianth lobe, and are borne in spikes. The Pontederiaceae is one of only two monocotyledonous families that display the genetic polymorphism of tristyly, in which all flowers of an individual plant possess one of three distinct corresponding style and stamen length phenotypes (Eckenwalder & Barrett, 1986). The intermediate-style form of *E. crassipes* is prevalent in its introduced range, whereas the long-styled form occurs less frequently. The short-style forms predominate in areas of its native range in South America but have not been recorded in its introduced range (Barrett, 1977; Barrett & Forno, 1982). Only the intermediate-style form occurs in the Spanish and Portuguese populations (GIC, 2006). Flowers produce large numbers of long-lived seeds (Fig. 3) that can remain viable for up to 20 years in sediments (Matthews, 1967; 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). In Spain, cross-pollination has been quantified. Honeybees (*Apis mellifera*) act as a pollinator at these latitudes. Seedlings have also been observed on river shores in this country. Seedlings are heteroblastic, so they have two different types of morphology (GIC, 2006) (Fig. 4).

Fig. 3 Seeds of *Eichhornia crassipes* germinating (GIC-University of Extremadura, Spain, 2005).

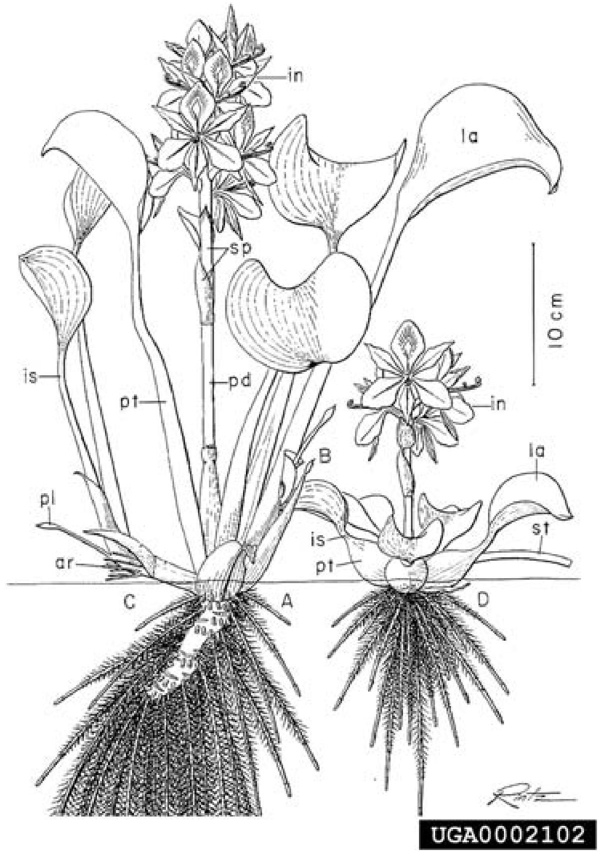

Fig. 4 Morphology of *Eichhornia crassipes* plants. A: the attenuated-petiole rosette form produced in crowded conditions; B: an expanding axillary bud; C: a developing ramet; D: the bulbous-petiole rosette form produced in open conditions. Abbreviations: ar – adventitious root; bb – bud bract; in – inflorescence; is – leaf isthmus; la – leaf blade; pl – primary leaf; pd – peduncle of flower spike; pt – leaf petiole; rh – rhizome; sp – spathe; st – stolon (From Center *et al*., 2002).

Similarities to other species

E. crassipes is very similar to *E. azurea* in appearance, often resulting in their misidentification. General morphology is similar across the eight *Eichhornia* species, particularly flower morphology, but *E. crassipes* is the only free floating species. Both *Monochoria vaginalis* and *M. africana* (Pontederiaceae) are also similar to the *Eichhornia* species. In Florida, USA, *E. crassipes* may be confused with the floating form of a similar appearing native aquatic plant, frog's bit (*Limnobium spongia*). The presence of small, white flowers and petioles that are not bulbous or inflated aid in distinguishing the native plant from water hyacinth (Langeland & Burks, 1998).

Floating seedlings of *E. crassipes* in their first stages (3–4 weeks) closely resemble *Spirodella polyrhyza* (Lemnaceae).

Biology and ecology

General

The main mode of population increase of *E. crassipes* is vegetative, via ramets (daughter plants) formed from axillary buds on stolons produced through elongation of the internodes (Center & Spencer, 1981). Once the ramets have developed roots, the stolons decay or break, separating them from the mother plant. Water hyacinth populations increase rapidly through the spread of these daughter plants, being able to double their numbers under suitable conditions between 1 to 3 weeks (Edwards & Musil, 1975; Gopal, 1987). Rates of growth are enhanced in nutrient enriched water and may be low in pristine waters with no or low flow. Water hyacinth is approximately 95% water (Gopal, 1987), and biomass (total weight of shoots and roots per unit area) varies considerably with age, size, nutrients and crowding. Estimates of dry weight for 14 field studies varied from 0.63 to 3.46 kg/m^2; the average being 2.116 kg/m^2, that is, 6.3 to 35 tonnes/ha, average 21 tonnes/ha (Gopal, 1987), while Center & Spencer (1981) reported 23 to 25 tonnes/ha in a eutrophic lake in Florida. In Europe, populations of the Guadiana River (Spain) have showed growing capacity up to 100 propagules per individual and an ability to extend its initial area up to 20 times in 4 weeks. Doubling times of 1 week were also reported from this area (GIC, 2006).

Habitat

E. crassipes colonises still or slow moving water, resulting in thick extensive mats. It occurs in estuarine habitats, lakes, urban areas, water courses, and wetlands. It can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, and extremes of nutrient availability, pH, temperature and toxic substances (Gopal, 1987), but does not tolerate brackish and saline water (Muramoto *et al*., 1991).

Environmental requirements

Ideal conditions for *E. crassipes* proliferation include neutral pH, although it can tolerate pH4–pH10; high light intensities and certain spectral composition (Methy *et al*., 1990); and nutrient-rich water. Growth is directly correlated with nutrient concentrations (Gopal, 1987), as N and P increase in concentration, so too does water hyacinth biomass accumulation (Gossett & Norris, 1971; Reddy, 1989, 1990). Consequently, eutrophication of water or a steady flow of less enriched waters that provides a continuing supply of nutrients to the roots, leads to very thick stands of water hyacinth. Optimal growth also occurs at temperatures of 28–30°C, while growth ceases when water temperatures drop below 10°C and is retarded above 34°C (Gopal, 1987). During these times of stress, stored carbohydrates from the stem are used as energy reserves (Owens & Madsen, 1995). Sato (1988) suggested that different water temperature conditions affect the growth of *E. crassipes*, depending on the concentration of culture solutions. Prolonged cold temperatures, below 5°C, result in death of the plants, limiting water hyacinth's distribution in high latitudes (Gopal, 1987; Owens & Madsen, 1995). Ueki *et al*. (1976) reported from Japan that the Northern boundary of distribution corresponded to the zone where the average atmospheric temperature is 1°C in January. Plants from Spanish populations (Mérida, Badajoz) were cultivated at a medium temperature below 5°C showing an initial resistance to decay. At the end of the experimental period, only non-aerial parts had survived (GIC, 2006).

Temperature and water nutrient levels determine whether water hyacinth is an important environmental problem at a given site (Wilson *et al*., 2005).

Uses and benefits

Eichhornia crassipes

One hectare of water hyacinth may contain more than two million individual plants with a total wet weight of over three hundred tonnes (Center & Spencer, 1981), and it is this sheer biomass of plant material that has provoked research into its utilization (Julien *et al*., 1999). Indeed, an entire book has been published promoting uses for water hyacinth across the world (Lindsey & Hirt, 1999). Proposed uses for the weed include biogas production (Harley, 1990; Sankar *et al*., 2005 and as observed in Spain by Delgado Arroyo, 1989; Boillot *et al*., 1983), animal fodder, fertilizer as compost or vermicompost (Gajalakshmi *et al*., 2002), the manufacture of paper and furniture, waste water treatment, and water quality management (Julien *et al*., 1999). Water hyacinth is considered by some a relatively cheap and 'environmentally friendly' tool for the decontamination of wastewater because of its rapid growth rate and high rate of heavy metal and nutrient absorption (Muramoto & Oki, 1983; Zhu *et al*., 1999). However, its effective ability to decontaminate water remains to be proven (Hill, pers. com., 2008) and the problem of what to do with the harvested plant contaminated with toxic material remains unsolved.

The main impediment to the utilization of water hyacinth is its very high water content (on average 95%) (Harley, 1990). To gain one tonne of dry material, nine and half tonnes of fresh material have to be collected (Julien *et al*., 1996), making the cost of drying for the paper and furniture industries not commercially viable (Julien *et al*., 1999). *E. crassipes* is reported to be used as a fodder (Gunnarsson & Petersen, 2007; Spain, Ruiz Téllez, pers. com., 2008). Nevertheless; as fodder for horses and cattle it is inferior, again due to its high water content, and it is also unpalatable due to the high potash and chlorine content (Edwards & Musil, 1975), it is however used green or ensiled as an alternative feed for pigs on a local basis, (Febrero *et al*., 2005). Therefore, utilization of water hyacinth is not feasible as a control method due to the low demand for water hyacinth products, the inaccessibility of most water hyacinth infestations and the high cost of processing the raw material (Julien *et al*., 1996). See paragraph on agricultural practice.

For these reasons, water hyacinth utilization does not appear to be commercially viable, and consideration of possible utilization of water hyacinth should therefore not prevent the execution of control programmes against it. In addition, a reliance on water hyacinth should not be created, because this would in turn create a conflict of interest, and lead to an increase in the spread of the weed.

Pathways of movements

Natural dispersal

Propagation is both vegetative via daughter plant production, and by seeds, which are produced in very large numbers, and persist in the seed bank for up to 20 years. The requirements for seed germination are not well understood. Field observations and current experimental trials at the University of Extremadura, Spain (GIC-, unpublished data) suggest that: (a) seeds have an anatomical resistant testa; (b) seeds do not germinate in deep water or under floating mats of the species; (c) germination depends on physicochemical composition of waters as well as on the autogamic or allogamic origin of the seed. Seeds germinate on floating decomposing organic matter, on wet mud or in the substrate under shallow, warm waters. After a short period of growth under water, the seedlings pop to the surface and float (Wright & Purcell, 1995). Seeds are the source of new infestation or re-invasions, as are vegetative propagules, and with a higher capacity to colonize new habitats due to a higher genetic variability. Daughter plants are spread through the river flows, by floods, by wind and wave action, and eventually over large distances via sediments containing seeds stuck to the feet and feathers of water fowl (GIC, 2006).

Accidental transport

Once introduced in a freshwater ecosystem, *E. crassipes* can be accidentally dispersed by human activities during maintenance of swimming areas, attached to fishing gear or to the hulls, anchor lines, engines, or other parts of boats, and through drainage systems Moreover, existing practices of mechanical waterway maintenance tend to cut off plants and spread the fragments.

Agricultural practices

The use of water hyacinth as pig fodder has contributed to its spread in China. The species was distributed widely into almost all provinces in the 1950s and 1960s, and after artificial transplanting and mass rearing and breeding, water hyacinth was distributed further in the 1970s (Ding *et al*., 2001).

The use as a fertilizer can spread the outbreak for it has not been demonstrated that composting or vermicomposting techniques destroy the seeds or their germinability. This also applies to the use of *E. crassipes* in biogas production.

Movement in trade

Because of its attractive purple flower, *E. crassipes* is a favourite amongst ornamental pond and garden enthusiasts. As a result humans have spread it widely and due to its fast growth rate it now flourishes in all continents. Most spread can be attributed to deliberate planting of water hyacinth in ponds or dams as an ornamental, or use in aquariums.

An emerging mode of spread is via internet sales to aquarium owners and water gardeners.

Impact

Effects on plants

The most important impacts of *E. crassipes* on crop yield are caused by water loss. *E. crassipes* increases water loss due to evapo-transpiration. Estimates of increased water loss vary from 2.67 times (Lallana *et al*., 1987) to 3.2 times (Penfound & Earl, 1948) from a mat of *E. crassipes* in comparison to open water. Lallana *et al*. (1987) calculated that *E. crassipes* caused an increase in water loss of about 70 000 L/ha/d from a dam in Argentina. Furthermore, there is a direct cost to irrigation infrastructure including irrigation canals and pumps (Gopal, 1987).

E. crassipes impacts agriculture production worldwide. For example, in Portugal, negative impacts have caused major economic losses to rice fields and local farmers of the Sado River Basin (Guerreiro, 1976; Moreira *et al*., 1999). *E. crassipes* impacts rice production in 3 ways: direct suppression of the crop and inhibition of its germination, water loss and increase in costs in harvesting since the plants get caught up in mechanical harvesters. Globally, Gopal (1987) reported impacts on rice production with inhibition of the seed germination in India, Sri Lanka, Bangladesh (cost of 15 millions dollars according to Gopal (1987)), Burma, Malaysia, Indonesia, Thailand, Philippines, Japan, and Portugal. According to Parson & Cuthbertson (2001), losses are staggering, for example, in the Indian State of West Bengal, it causes an annual loss of paddy rice valued at 110 million rupees. Impacts are also reported on rape seed in Japan (Gopal, 1987).

E. crassipes has been reported to be an alternative host for the Asian corn borer, *Ostrinia furnacalis* Guenee and the rice root nematode, *Hirschmanniella oryzae* (van Breda de Haan) Luc & Goody (Groves *et al*., 1995).

Figures on general costs of control are available throughout the world, though, a separation between costs for agricultural purposes and other purposes cannot be made.

Between 1980 and 1991, Florida spent over 43 million USD on suppression of *E. crassipes* and *Pistia stratiotes* (Schmitz *et al*., 1993). Currently, annual costs for *E. crassipes* management range from 500 000 USD in California to 3 million USD in Florida (Mullin *et al*., 2000). The largest infestations of *E. crassipes* in the USA occur in Louisiana where the Department of Fisheries treats about 25 000 acres of *E. crassipes* with herbicides per year, at an annual cost of 2 million USD.

In Spain, the management cost to remove nearly 200 000 tonnes of the plant from approximately 75 km of river was 14 680 000 euros for 2005 to 2008 in the Guadiana river (Cifuentes *et al*., 2007). It represents 65 723 working days and necessitated the use of crane trucks equipped with a grapple, backhoes with bucket, and 35 meter boom cranes (Ruiz Téllez *et al*., 2008).

In Portugal, the management in the Municipality of Agueda cost 278 000 euros from December 2006 to May 2008, including the purchase of a mechanical harvester and its monthly running costs, as well as almost 1800 labour hours. Three persons where employed for this purpose in 2006 and 2007, and one during 2008 (Laranjeira, 2008). A water harvester and a truck were used.

Moreira *et al*. (2005) and Santos (2003) report that 470 000 euros were spent from 1999 to 2004 near Leziria Grande de Vila Franca de Xira (Portugal) for an integrated management programme.

Environmental and social impacts

Dense mats of *E. crassipes* reduce the amount of light reaching submerged plants, thus depleting oxygen in aquatic communities (Ultsch, 1973). The resultant lack of phytoplankton (McVea & Boyd, 1975) alters the composition of invertebrate communities (O'Hara, 1967; Hansen *et al*., 1971), ultimately affecting fisheries. Spanish researchers (GIC, 2006) have reported losses of plankton diversity in the Guadiana River in 2005.

Drifting mats scour vegetation, destroying native plants and wildlife habitats. *E. crassipes* also competes with other plants, often displacing wildlife forage and habitats (Center *et al*., 1999). Higher sediment loading occurs under *E. crassipes* mats due to increased detritus production and siltation. Annual fish and wildlife losses associated with *E. crassipes* infestations in six South-Eastern states of the USA exceeded $4 million per year in 1947 (Tabita & Woods, 1962).

Midgley *et al*. (2006) investigated the impact of *E. crassipes* on abundance and diversity of benthic invertebrates and chlorophyll *a* at a site in the Eastern Cape Province of South Africa. They showed that species richness, diversity and abundance and the concentration of chlorophyll *a* were significantly negatively affected by a cover of *E. crassipes*. The plant has also been linked to a reduction in the diversity of water fowl on the Nseleni River, KwaZulu-Natal, South Africa (Jones, 2001).

Because the invasive turtle *Trachemys scripta* feeds on *E. crassipes*, it can increase its populations. This invasive turtle is already present in the Guadiana in Spain (Mesén, 1993), as well as in other parts of Spain, France, Italy and Poland (Global Invasive Species Database 2008b).

Recreation and tourism
In some areas of the world, *E. crassipes* infestations have had a negative effect on waterfront real estate values and consumer driven recreational use of water bodies (GIC, 2006). In Spain and Portugal, impacts have been noted in fisheries, recreation water sport, boat navigation, in addition to aesthetic impacts (GIC, 2006; Laranjeira, 2008). This has also affected tourism.

Water quality
E. crassipes has a negative effect on the quality and quantity of potable water. *E. crassipes* blocks light penetration to the water column and leads to a reduction in oxygenation of the water and a build-up of sulphur dioxide, causing the water to smell and taste bad. The water treatment plant for Lusaka in Zambia was forced to retain the water in the plant for further treatment due to a reduction in the water quality drawn from the Kafue River that was infested with *E. crassipes* (Hill & Cilliers, 1999).

Hydroelectric power production
E. crassipes threatens the production of electricity through hydropower generation throughout Africa. A few examples have been noted in the literature. The hydropower station at the Kafue Gorge Dam in Zambia is responsible for supplying 900MW of power to the country. At the height of the *E. crassipes* problem on the dam, at least one of the 5 turbines was forced to be shut down for a day per week. This was due to the increased concentration of nitrous oxides in the water that caused a certain amount of corrosion on the turbines. The hydropower dams on the Shire River in Malawi and the Owen Falls Dam at Jinga in Uganda on the Nile River are also frequently forced to stop production due to *E. crassipes* clogging the intakes for the water cooling system. No estimates of costs of this are available, but it must amount to several million USD per year (Wise *et al*., 2007).

The impact of the plant in 2007/2008 on the Victoria Falls Power Station amounted to 946 822 USD (Nang'alelwa, 2008).

Human health
E. crassipes infestations intensify mosquito problems by hindering insecticide application, interfering with predators such as fish, increasing habitat for species that attach to plants, and impeding runoff and water circulation (Seabrook, 1962). Despite there being numerous references attributing an increase in malaria to *E. crassipes* infestations, in one of the quantified surveys, Mailu (2001) was unable to show a correlation between the explosion of *E. crassipes* on Lake Victoria and an increase in the disease. *E. crassipes* provides the ideal habitat for the snail vectors (*Biomphalaria* spp. and *Bulinus* spp.) of the bilharzia schistosome and there is some evidence from Ghana that increased infestations of *E. crassipes* are linked to an increase in the prevalence of this disease. It also blocks access to water points and, as such, has been linked to an increase in cholera and typhoid (Navarro & Phiri, 2000). Furthermore, *E. crassipes* harbours venomous snakes, crocodiles and hippos making the collection of water dangerous, sometimes fatal (Gopal, 1987; Navarro & Phiri, 2000).

Case study

Lake Victoria is the world's largest fresh water tropical lake and has been heavily impacted by *E. crassipes*. The weed was first recorded on the lake in around 1990 but by 1998 covered some 20 000 ha of the lake (Albright *et al*., 2004). The lake basin supports some 25 million people and has an estimated value of some USD 4 billion annually, with fishing benefiting the livelihood of at least 500 000 people and having a potential sustainable fishery export value of USD 288 million (Albright *et al*., 2004). *E. crassipes* severely threatened the economic activities on the lake and the development of the region. Economic impacts in Uganda in 1995 were estimated by Mailu (2001) at:

– Maintaining a clear passage for ships to dock at Port Bell in Uganda were USD 3–5 million
– Clearing the intake screens at Owen Falls hydroelectric plant were USD 1 million
– Losses in fisheries were about USD 0.2 million
– Losses in beaches, water supply for domestic, stock and agricultural purposes were USD 0.35 million.

Sociological impacts such as lack of clean water, increase in vector-borne diseases, migration of communities, social conflict and biodiversity losses were not calculated.

Summary of invasiveness

Water hyacinth is one of the world's worst aquatic weeds highlighted by the fact that it has invaded every continent except Antarctica (Global Invasive Database 2008a). The plant has the ability to reproduce both sexually and vegetatively, and to double its biomass every 10 days under favourable conditions. It has huge detrimental economic impacts: it is a threat to agriculture, plant health, environment, public safety, recreation activities, water quality and quantity and human health.

Control

See EPPO PM9 on *Eichhornia crassipes*.

Regulatory status

E. crassipes is on the USDA/APHIS noxious weeds list, it is a class 1 noxious weed in Australia, a prohibited weed in New Zealand, a Category 1 weed in South Africa.

In Scotland (UK), the Scottish Wildlife and Countryside Act prohibits the release of *E. crassipes* into the wild. In Portugal, the Decreto – Lei n° 565/99 prohibits the release and spread of exotic invasive plants in nature, *E. crassipes* is on this list. Penalties will be applied to those using any listed invasive species. Additionally, the D.L. n° 165/74 of 22 of April also prohibits the trade, transportation and possession of *E. crassipes*. Cultivation of the plant is forbidden and any stock should be destroyed (PT, 1974, 1999).

Acknowledgements

This datasheet has been written by Julie Coetzee, from Rhodes University, South Africa.

Trinidad Ruiz Telléz from the University of Extremadura (Spain) is also acknowledged for her contribution.

References

Albright TP, Moorhouse TG & McNabb TJ (2004) The rise and fall of water hyacinth in Lake Victoria and the Kagera River Basin, 1989–2001. *Journal of Aquatic Plant Management* **42**, 73–84.

APG II (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnaean Society* **141**, 399–436.

Barrett SCH (1977) Tristyly in *Eichhornia crassipes* (Mart.) Solms (water hyacinth). *Biotropica* **9**, 230–238.

Barrett SCH (1980) Sexual reproduction in *Eichhornia crassipes* (Water Hyacinth) II. Seed production in natural populations. *Journal of Applied Ecology* **17**, 113–124.

Barrett SCH & Forno IW (1982) Style morph distribution in New World populations of *Eichhornia crassipes* (Mart.) Solms-Laubach (water hyacinth). *Aquatic Botany* **13**, 299–306.

Boillot M, Girard P & Mignard B (1983) Methanol production from water hyacinth. *Bulletin de la Direction des études et recherches* – Electricité de France. Série A, nucléaire, hydraulique, thermique. **3–4**, 51–58. ISSN 0013-449X CODEN EFDNAX http://cat.inist.fr/?aModele=afficheN&cpsidt=9466361 Last accessed on 2008-06-12.

Center TD & Spencer NR (1981) The phenology and growth of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) in a eutrophic North-central Florida lake. *Aquatic Botany* **10**, 1–32.

Center TD, Dray FA Jr, Jubinsky GP & Grodowitz MJ (1999) Biological control of water hyacinth under conditions of maintenance management: can herbicides and insects be integrated? *Environmental Management* **23**, 241–256.

Center TD, Hill MP, Cordo H & Julien MH (2002) Waterhyacinth. In: *Biological Control of Invasive Plants in the Eastern United States* (Ed. van Driesche RG, Lyon S, Blossey B, Hoddle MS & Reardon R), pp. 41–64. USDA Forest Service, Morgantown, WV.

Cifuentes N, Hurtado A & Ruiz T (2007) (Integrated control of the water hyacinth *Eichhornia crassipes*) in the Guadiana river in Spanish. Invasiones Biológicas, un facto de cambio global. *EEI 2006 Actualización de Conocimientos* **1**, 266–269. GEIB Grupo Especialista en Invasiones Biológicas. Dep.Leg LE2069-2007, Spain.León.

Cook CDK (1998) Pontederiaceae. In: *Families and Genera of Vascular Plants IV* (Ed. Kubitzki K), pp. 395–403. Springer-Verlag, Berlin.

Delgado Arroyo MM (1989) Evaluacion del potential energetico, alimentario y descontaminante del Jacinto de Agua (*Eichhornia crassipes*). Universidad complutense de Madrid. Faculdad de Ciencias Químicas. Departamento de Químicas Industrial. Coleccíon Tesis Doctorales. N°83/89.

Ding J, Wang R, Fu W & Zhang G (2001) Water hyacinth in China: its distribution, problems and control status. In: *Proceedings of the 2nd Meeting of the Global Working Group for the Biological and Integrated Control of Waterhyacinth, Beijing, China* (Ed. Julien MH, Hill MP, Center TD & Ding J), pp. 29–32. Australian Centre for International Agricultural Research, Canberra, Australia, 9–12 October 2000.

Eckenwalder JE & Barrett SCH (1986) Phylogenetic systematics of Pontederiaceae. *Systematic Botany* **11**, 373–391.

Edwards D & Musil CJ (1975) *Eichhornia crassipes* in South Africa-a general review. *Journal of the Limnological Society of Southern Africa* **1**, 23–27.

Febrero I, Romero O, Ruiz L & Gonzáles R (2005) *Water Hyacinth (*Eichhornia crassipes*) an Alternative for the Feeding of Pigs*. Revista electrónica de veterinaria, vol. VI N° 5.

Gajalakshmi S, Ramasamy EV & Abbasi SA (2002) High-rate composting–vermicomposting of water hyacinth (Eichhornia crassipes, Mart. Solms). *Bioresource Technology* **83**, 235–239.

GIC, Grupo de Investigación en Biología de la Conservación de la Universidad de Extremadura (2006) Informe sobre Distribución y Biología Reproductora del jacinto de Agua en el Guadiana, 12 vols., Diciembre de 2006, Confederación Hidrógráfica del Guadiana, Ministerio de Medio Ambiente, Badajoz, España, Vol. 1 (135 gpp), Vol. 2 (247 pp), Vol. 3 (80 pp), Vol. 4 (342 pp), Vol. 5 (394 pp), Vol. 6 (102 pp), Vol. 7 (49 pp), Vol. 8 (127 pp), Vol, 9 (87 pp), Vol. 10 (558 pp), Vol. 11 (121 pp), Vol. 12 (386 pp).

Global Invasive Species Database (2008a) *Eichhornia crassipes*. http://www.issg.org/database/species/ecology.asp?si=70&fr=1&sts=sss&lang=EN [accessed on 2008-06-12].

Global Invasive Species Database (2008b) *Trachemys scripta elegans*. http://www.issg.org/database/species/ecology.asp?si=71&fr=1&sts=sss&lang=EN [accessed on 2008-06-12].

Gopal B (1987) *Water Hyacinth*. Elsevier, Amsterdam.

Gossett DR & Norris WE Jr (1971) Relationship between nutrient availability and content of nitrogen and phosphorous in tissues of the aquatic macrophyte, *Eichhornia crassipes* (Mart.) Solms. *Hydrobiologia* **38**, 15–28.

Groves RH, Shepherd RCH & Richardson RG (eds) (1995) *The Biology of Australian Weeds*, Volume 1, R.G. and F.J. Richardson Publications, Melbourne (AU).

Guerreiro AR (1976) [The water Hyacinth (*Eichhornia crassipes*) (Mart) Solms in Portugal] In Portuguese. *II Simposio Nacional de Herbologia, Oeiras (Portugal)* **1**, 1–18.

Gunnarsson CC & Petersen CM (2007) Water hyacinths as a resource in agriculture and energy production: a literature review. *Waste Management* **27**, 117–129.

Hansen KL, Ruby EG & Thompson RL (1971) Trophic relationships in the water hyacinth community. *Quarterly Journal of the Florida Academy of Science* **34** (2), 107–113.

Harley KLS (1990) The role of biological control in the management of water hyacinth, *Eichhornia crassipes*. *Biocontrol News and Information* **11**, 11–22.

Hill MP & Cilliers CJ (1999) A review of the arthropod natural enemies, and factors that influence their efficacy, in the biological control of water hyacinth, *Eichhornia crassipes* (Mart.) Solms-Laubach (Pontederiaceae), in South Africa. In: Biological Control of Weeds in South Africa (1990–1998). *African Entomology (Memoir No. 1)* (Ed. Olckers T & Hill MP), pp. 103–112. Agricultural Research Council, Pretoria (ZA).

Jones RV (2001) Integrated Control of Water Hyacinth on the Nseleni/Mposa Rivers and Lake Nsezi, Kwa Zulu-Natal, South Africa. Biological an Integrated Control of Water Hyacinths, *Eichhornia crassipes*. ACIAR Proceedings.

Julien MH, Harley KLS, Wright AD, Cilliers CJ, Hill MP, Center TD *et al.* (1996) International co-operation and linkages in the management of water hyacinth with emphasis on biological control. In: *Proceedings of* *the IX International Symposium on Biological Control of Weeds*, 21–26 January 1996, Stellenbosch, South Africa. (Ed. Moran VC & Hoffman JH), pp. 273–282. University of Cape Town, Cape Town (ZA).

Julien MH, Griffiths MW & Wright AD (1999) Biological control of water hyacinth. The weevils Neochetina bruchi and N. eichhorniae: biologies, host ranges, and rearing, releasing and monitoring techniques for biological control of *Eichhornia crassipes*. Monograph No. 60. Australian Centre for International Agricultural Research (ACIAR), Canberra (AU). 87 p.

Lallana VH, Sebastian RA & Lallana MDC (1987) Evapotranspiration from *Eichhornia crassipes*, *Pistia stratiotes*, Salvinia herzogii and *Azolla caroliniana* during summer in Argentina. *Journal of Aquatic Plant Management* **25**, 48–50.

Langeland KA & Burks KC (1998) *Identification and Biology of Non-Native Plants in Florida's Natural Areas*. UF/IFAS, Gainesuille (US), 165 p.

Laranjeira C (2008, in preparation) *Eichhornia crassipes* control in the largest Portuguese natural freshwater lagoon – a case of success. *EPPO Bulletin*/*Bulletin OEPP*.

Lindsey K & Hirt HM (1999) *Use Water Hyacinth! A Practical Handbook of Uses for Water Hyacinth from Across the World*. Anamed, Winnenden (DE).

Mailu AM (2001) Preliminary assessment of the social, economic and environmental impacts of water hyacinth in the Lake Victoria basin and the status of control. In: *Proceedings of the 2nd Meeting of the Global Working Group for the Biological and Integrated Control of Waterhyacinth, Beijing, China*, 9–12 October 2000. (Ed. Julien MH, Hill MP, Center TD & Ding J), pp. 130–139. Australian Centre for International Agricultural Research, Canberra (AU).

Matthews LJ (1967) Seedling establishment of water hyacinth. *PANS(C)* **13**, 7–8.

Mesén A & Arturo R (1993) *Las Tortugas Continentales de Costa Rica ICER*. San Pedro de Montes de Oca, Costa Rica.

Methy M, Alpert P & Roy J (1990) Effects of light quality and quantity on growth of the clonal plant Eichhornia crassipes. *Oecologia* **84**, 265–271.

Midgley JM, Hill MP & Villet MH (2006) The effect of water hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach (Pontederiaceae), on benthic biodiversity in two impoundments on the New Year's River, South Africa. *African Journal of Aquatic Science* **31**, 25–30.

Moreira I, Ferreira T, Monteiro A, Catarina gand L & Vasconcelos T (1999) Aquatic weeds and their management in Portugal: insights and the internacional context *Hydrobiologia* **415**, 229–234.

Moreira JF, Serrasqueiro PM, Moreira I, Santos AC & Monteiro AC (2005) *Combate ao caniço nos taludes das valas e dos valados da Lezíria Grande de Vila Franca de Xira*. I Congresso Nacional de Rega e Drenagem 5 a 7 Dezembro 2005, Beja.

Mullin BH, Anderson LWJ, DiTomaso JM, Eplee RE & Getsinger KD (2000) Invasive plant species. Issue Paper No. 13. Council for Agricultural Science and Technology, Ames (US).

Muramoto S & Oki Y (1983) Removal of some heavy metals from polluted water by water hyacinth (*Eichhornia crassipes*). *Bulletin of Environmental Contamination and Toxicology* **30**, 170–177.

Muramoto S, Aoyama I & Oki Y (1991) Effect of salinity on the concentration of some elements in water hyacinth (*Eichhornia crassipes*) at critical levels. *Journal of Enviromental Siences and Health* **A26**, 205–215.

McVea C & Boyd CE (1975) Effects of water hyacinth cover on water chemistry, phytoplankton, and fish in ponds. *Journal of Environmental Quality* **4** (3), 375–378.

Nang'alelwa M (2008, in preparation) Environmental and Socio-economic impacts of Eichornnia crassipes in the Victoria Falls/Musi-oa-Tunya Pilot Site, Livingstone, Zambia. *EPPO Bulletin*/*Bulletin OEPP*.

Navarro L & Phiri G (2000) *Water Hyacinth in Africa and the Middle East. A Survey of Problems and Solutions*. International Development Research Centre, Ottawa (CA).

O'Hara J (1967) Invertebrates found in water hyacinth mats. *Quarterly Journal of the Florida Academy of Science* **30** (1), 73–80.

Owens CS & Madsen JD (1995) Low temperature limits of waterhyacinth. *Journal of Aquatic Plant Management* **33**, 63–68.

Parsons WT & Cuthbertson EG (2001) *Noxious weeds of Australia*, 2nd edn. Inkata Press Melbourne & Sydney (AU).

Penfound WMT & Earle TT (1948) The biology of the waterhyacinth. *Ecological Monographs* **18**, 448–473.

Reddy KR, Agami M & Tucker JC (1989) Influence of nitrogen supply rates on growth and nutrient storage by water hyacinth (*Eichhornia crassipes*) plants. *Aquatic Botany* **36**, 33–43.

Reddy KR, Agami M & Tucker JC (1990) Influence of phosphorus supply on growth and nutrient storage by water hyacinth (*Eichhornia crassipes*) plants. *Aquatic Botany* **37**, 355–365.

Ruiz Téllez T, Martín de Rodrigo López E, Lorenzo Granado G, Albano Pérez E & Sánchez Gurzmán JM (2008) The Water Hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). *Aquatic Invasions* **3** (1), 42–53.

Sankar Ganesh P, Ramasamy EV, Gajalakshmi S & Abbasi SA (2005) Extraction of volatile fatty acids (VFAs) from water hyacinth using inexpensive contraptions, and the use of the VFAs as feed supplement in conventional biogas digesters with concomitant final disposal of water hyacinth as vermicompost. *Biochemical Engineering Journal* **27**, 17–23.

Santos ACRF (2003) Controlo de infestantes aquáticas e comparação de dois meios de luta (química e mecânica) nas valas de rega e drenagem da Lezíria Grande de Vila Franca de Xira. *Relatório de Estágio para Acreditação na Ordem dos Engenheiros, Engenharia Agronómica*. Instituto Superior de Agronomia, Lisboa (PT).

Sato H (1988) The growth analysis of water hyacinth, Eicchornia crassipes Solms, in different water temperature conditions. *Ecological Research* **3**, 131–144.

Schmitz DC, Schardt JD, Leslie AJ, Dray FA, Osborne JA Jr & Nelson BV (1993) The ecological impact and management history of three invasive alien plant species in Florida. In: *Biological Pollution. The Control and Impact of Invasive Exotic Species* (Ed. McKnight BN) pp. 173–194. Indiana Academy of Science, Indianapolis (US).

Seabrook EL (1962) The correlation of mosquito breeding to hyacinth plants. *Hyacinth Control Journal* **1**, 18–19.

Strange A, Rudall PJ & Prychid CJ (2004) Comparative floral anatomy of Pontederiaceae. *Botanical Journal of the Linnaean Society* **144**, 395–408.

Tabita A & Woods JW (1962) History of hyacinth control in Florida. *Hyacinth Control Journal* **1**, 19–23.

Téllez TR, López EM, Granado G, Pérez EA, López RM & Sánchez Guzmán JM (2008) The Water Hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). *Aquatic Invasions* **3** (1), 42–53.

Ueki K, Ito M & Oki Y (1976) *Waterhyacinth and Its Habitats in Japan*. Proceedings of 5th Asian Pacific Weed Science Society Conference, Tokyo (JP).

Ultsch GR (1973) The effects of waterhyacinth (*Eichhornia crassipes*) on the microenvironment of aquatic communities. *Archiv fuer Hydrobiologie* **72**, 460–473.

Wilson JR, Holst N & Rees M (2005) Determinants and patterns of population growth in water hyacinth. *Aquatic Botany* **81**, 51–67.

Williamns AE, Duthie HC & Hecky R (2005) Water hyacinth in Lake Victoria: why did it vanish so quickly and will it return) *Aquatic Botany* **81**, 300–314.

Wise RM, van Wilgen BW, Hill MP, Schulthess F, Tweddle D, Chabi-Olay A *et al*. (2007) The economic impact and appropriate management of selected invasive alien species on the African continent. Global Invasive species Programme. CSIR Report No. CSIR/NRE/RBSD/ER/2007/0044/C.

Wright AD & Purcell MF (1995) *Eichhornia crassipes* (Mart.) Solms-Laubach. In: *The Biology of Australian Weeds* Vol. 1 (Ed. Groves RH, Shepherd RCH, Richardson RG & Richardson FJ), pp. 111–121. Melbourne (AU).

Xie Y & Yu D (2003) The significance of lateral roots in phosphorus (P) acquisition of water hyacinth (*Eichhornia crassipes*). *Aquatic Botany* **75**, 311–321.

Zhu YL, Zayed AM, Qian JH, Souza M & Terry N (1999) Phytoaccumulation of trace elements by wetland plants: II. Water hyacinth. *Journal of Environmental Quality* **28**, 339–344.