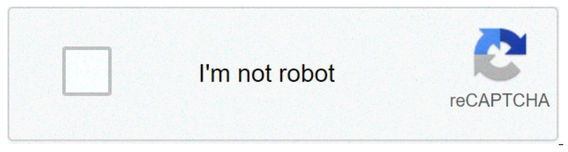

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Hyacinth plant in water

Eichhornia crassipes Family: Pontederiaceae Natural History | Identifying Characteristics | Images | Learn More Water hyacinth, sometimes called water orchid, is an exotic plant that was introduced to the United States, from South America, in the late 1800's. This member of the Pontederiaceae family rapidly regenerates via runners, cuttings, or seeds, and has become one of the most serious pest weeds in the southeastern states. The seeds may lie dormant in the substrate and survive even extreme drought periods. Water hyacinth is considered to be a serious environmental problem for wetlands in the gulf states, since the plants may double in growth in less than 20 days and quickly take over waterways. Expansive mats of growth may cut out light to submergent aquatic life forms, hinder navigation and water flow, and reduce oxygen levels, as these aggressive plants dominate aquatic ecosystems. A single acre of water hyacinths produces as much as 500 tons of decaying plant material per year. The decomposing detritus introduces excessive nutrient loads and depletes available oxygen, thus inhibiting survival of native plants and animals. When growth of the plants can be strictly controlled, water hyacinth may be useful in purifying water, by filtering out excessive toxins and limiting algae. Biological controls are being investigated, such as the introduction of certain weevils and moths, as natural enemies of the plants. In many parts of the world, uses are being sought for these aggressive weeds. In India, dried and ground water hyacinth roots are used to make briquettes of cooking fuel, or as a substitute for wood in the making of high-quality paper. The plants, which are high in nitrogen and potassium, are used as cattle forage, fertilizer, mulch and soil-binders. In Southeast Asia, water hyacinth plants are boiled and chopped for pig feed. Researchers are currently investigating the use of these plants as a source of commercial cellulose. The fibrous roots of water hyacinth provide a sheltered habitat for many aquatic invertebrates and small fish, while the leaves and seeds are eaten by several species of wetland birds and waterfowl. Water hyacinth is sometimes confused with frog's-bit (Limnobium spongia), a similar aquatic perennial. However, the stems of frog's-bit have a flattened side and lack inflated bulbs and their roots are white, instead of the distinctive black color of hyacinth roots. Water hyacinth has become naturalized throughout most of the southeastern United States. Identifying Characteristics Habitat: Water hyacinth grows in shallow freshwater wetlands. It is often seen in pure stands along the edges of ponds, lakes, canals, ditches and slow-moving streams. Size/Form: Water hyacinth is an emergent aquatic perennial that forms rosettes of thick, spongy leaves. Flowers appear on spike-like floral stalks that generally grow about 1' tall. Beneath the water level, the plants have fibrous, black roots. The rosettes are often connected at the waterline by a horizontal stem called a "stolon." Leaves: The leaves are simple and basal, forming a rosette around the flower stalk. In open conditions each petiole is short and consists largely of an inflated bulb that helps the plant float. In more crowded conditions the petioles become longer and thinner and less inflated. The leaf venation is parallel and the leaf margin is smooth. Flowers: The inflorescences are loose, spike-like clusters of tiny lavender blossoms, borne on upright stalks. Each flower has 6 petals. The lower 5 petals are a solid shade of lilac or lavender, but the uppermost petal has a bright yellow dot surrounded by a bluish "halo." Fruits: The fruit is a three-celled capsule, containing many, small seeds. Images Click on any thumbnail to see a photo. Use left and right arrows to navigate. Use "esc" to exit the lightbox. A single flower, with the distinctive uppermost petal. Inflorescence of flowers. Morphology of water hyacinth plants: A - the "attenuated-petiole" rosette form produced in crowded conditions; B - an expanding axillary bud; C - a developing ramet; and D - the "bulbous-petiole" rosette form produced in open conditions. Abbreviations: ar - adventitious root; in - inflorescence; is - leaf isthmus; la - leaf blade; pl - primary leaf; pd - peduncle of flower spike; pt - leaf petiole; sp - spathe; st - stolon. Photo credit: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org Photo credit: Vladimir Dinets, University of Miami, Bugwood.org Photo credit: USDA Agricultural Research Service Archive, USDA Agricultural Research Service, Bugwood.org Cross- and longitudinal-sections through the different shapes of petioles. The "bulbous-petiole" form is on the left and the "attenuated-petiole" form is on the right. Two water hyacinth rosettes showing the black roots and the connecting stolon. Water hyacinth plants on a boat trailer, showing one way the species spreads. Water hyacinth infestation covering the surface of a lake in Alabama. Photo credit: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org Photo credit: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org Photo credit: Tony Pernas, USDI National Park Service, Bugwood.org Photo credit: Graves Lovell, Alabama Department of Conservation and Natural Resources, Bugwood.org Learn More Aquatic plant native to the Amazon basin For other plants known as "water hyacinth", see Eichhornia. Common water hyacinth Scientific classification Kingdom: Plantae Clade: Tracheophytes Clade: Angiosperms Clade: Monocots Clade: Commelinids Order: Commelinales Family: Pontederiaceae Genus: Eichhornia Species: E. crassipes Binomial name Eichhornia crassipesMart. Synonyms Eichhornia crassipes (Mart.) Solms[1] Pontederia crassipes, commonly known as common water hyacinth, is an aquatic plant native to the Amazon basin, and is often a highly problematic invasive species outside its native range. It is the sole species of Pontederia subg. Oshunae.[2] Description This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. (April 2021) (Learn how and when to remove this template message) Water hyacinth is a free-floating perennial aquatic plant (or hydrophyte) native to tropical and sub-tropical South America. With broad, thick, glossy, ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter (3 feet) in height. The leaves are 10–20 cm (4–8 inches) across on a stem which is floating by means of buoyant bulb-like nodules at its base above the water surface. They have long, spongy and bulbous stalks. The feathery, freely hanging roots are purple-black. An erect stalk supports a single spike of 8–15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. When not in bloom, water hyacinth may be mistaken for frog's-bit (Limnobium spongia[3]) or Amazon frogbit (Limnobium laevigatum). One of the fastest-growing plants known, water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant additionally can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years.[4] Some water hyacinths were found to grow between 2 and 5 meters (7 and 16 feet) a day in some sites in Southeast Asia.[5] The common water hyacinth (Pontederia crassipes) are vigorous growers and mats can double in size in one to two weeks.[6] And in terms of plant count rather than size, they are said to multiply by more than a hundredfold in number, in a matter of 23 days. In their native range, these flowers are pollinated by long-tongued bees and they can reproduce both sexually and clonally. The invasiveness of the hyacinth is related to its ability to clone itself and large patches are likely to all be part of the same genetic form. Water hyacinth has three flower morphs and is termed "tristylous". The flower morphs are named for the length of their pistil: long, medium and short.[7] Tristylous populations are however limited to the native lowland South America range of water hyacinth; in the introduced range, the M-morph prevails, with the L-morph occurring occasionally and the S-morph is absent altogether.[8] This geographical distribution of the floral morphs indicates that founder events have played a prominent role in the species' worldwide spread.[9] Habitat and ecology Its habitat ranges from tropical desert to subtropical or warm temperate desert to rainforest zones. The temperature tolerance of the water hyacinth is the following; its minimum growth temperature is 12 °C (54 °F); its optimum growth temperature is 25–30 °C (77–86 °F); its maximum growth temperature is 33–35 °C (91–95 °F), and its pH tolerance is estimated at 5.0–7.5. Leaves are killed by frost and plants do not tolerate water temperatures > 34 °C (93 °F). Water hyacinths do not grow where the average salinity is greater than 15% that of sea water (around 5 g salt per kg). In brackish water, its leaves show epinasty and chlorosis, and eventually die. Rafts of harvested water hyacinth have been floated to the sea where it is killed.[10] Azotobacter chroococcum, a nitrogen-fixing bacteria, is probably concentrated around the bases of the petioles. But the bacteria do not fix nitrogen unless the plant is suffering extreme nitrogen-deficiency.[11] Fresh plants contain prickly crystals.[10] This plant is reported to contain HCN, alkaloid, and triterpenoid, and may induce itching.[12] Plants sprayed with 2,4-D may accumulate lethal doses of nitrates,[13] and other harmful elements in polluted environments.[citation needed] Uses This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. (April 2021) (Learn how and when to remove this template message) Since the water hyacinths are so prolific, harvesting them for industrial use serves also as a means of environmental control. In north-east India, the Philippines, Thailand and Vietnam the water hyacinth's stems are used as a braiding material and a source of fibers. Strings of dried fibers are woven or interlinked together to form a braid or cord used for making bags, footwear, wreaths, hats, vases, Christmas lanterns, and more decorative materials. Dried stems are used for baskets and furniture. Water hyacinth fibers are used as raw material for paper. Since the plant has abundant nitrogen content, it can be used as a substrate for biogas production and the sludge obtained from the biogas. However, due to easy accumulation of toxins, the plant is prone to get contaminated when used as feed. The plant is extremely tolerant of, and has a high capacity for, the uptake of heavy metals, including cadmium, chromium, cobalt, nickel, lead and mercury, which could make it suitable for the biocleaning of industrial wastewater.[14], [15], [16],[17] In addition to heavy metals, Pontederia crassipes can also remove other toxins, such as cyanide, which is environmentally beneficial in areas that have endured gold mining operations.[18] Water hyacinth has been widely introduced in North America, Europe, Asia, Australia, Africa and New Zealand.[19] In many areas it has become an important and pernicious invasive species. In New Zealand it is listed on the National Pest Plant Accord which prevents it from being propagated, distributed or sold. In large water areas such as Louisiana, the Kerala Backwaters in India, Tonlé Sap in Cambodia and Lake Victoria it has become a serious pest. The common water hyacinth has become an invasive plant species on Lake Victoria in Africa after it was introduced into the area in the 1980s.[20] When not controlled, water hyacinth will cover lakes and ponds entirely; this dramatically affects water flow and blocks sunlight from reaching native aquatic plants which often die. The decay processes depletes dissolved oxygen in the water, often killing fish.[21] The plants also create a prime habitat for mosquitos,[22] the classic vectors of disease, and a species of snail known to host a parasitic flatworm which causes schistosomiasis (snail fever).[23] Directly blamed for starving subsistence farmers in Papua New Guinea,[citation needed] water hyacinth remains a major problem where effective control programs are not in place. Water hyacinth is often problematic in man-made ponds if uncontrolled, but can also provide a food source for goldfish, keep water clean[24][25] and help to provide oxygen.[26] Water hyacinth often invades bodies of water that have already been affected by human activities.[citation needed] For example, the plants can unbalance natural lifecycles in artificial reservoirs or in eutrophied lakes that receive large amounts of nutrients. Because of P. crassipes' invasiveness, several biological control agents have been released to control it, including two weevils (Coleoptera: Curculionidae), Neochetina bruchi Hustache and Neochetina eichhorniae Warner, and the moth Niphograpta albiguttalis (Warren) (Lepidoptera: Pyralidae).[27][28] Neochetina eichhorniae causes "a substantial reduction in water hyacinth production" (in Louisiana); it reduces plant height, weight, root length, and makes the plant produce fewer daughter plants. N. eichhorniae was introduced from Argentina to Florida in 1972.[29] A semi-aquatic grasshopper, Cornops aquaticum, is being investigated in South Africa as an additional control agent.[30] United States Introduction into the U. S. There are various accounts as to how the water hyacinth was introduced to the United States.[a] (1884 Exposition) The claim that the water hyacinth was introduced to the U. S. in 1884 at the World's Fair in New Orleans, also known as the World Cotton Centennial,[32] has been characterized as the "first authentic account",[33] as well as "local legend".[34] (Alleged Japanese involvement) At some time, there also appeared versions of the "legend" asserting that the plants had been given away as a gift by a Japanese delegation at the fair.[37] This claim is absent in a pertinent article published in a military engineer's trade journal dating to 1940,[b][38] but appears in a piece penned in 1941 by the director of the wildlife and fisheries division at the Louisiana Department of Conservation, where the author writes, "the Japanese Government maintained a Japanese building" at the fair, and the "Japanese staff imported from Venezuela considerable numbers of water hyacinth which were given away as souvenirs".[c][35] The claim has been repeated by later writers, with various shifts in the details. Thus NAS fellow Noel D. Vietmeyer (1975) wrote that "Japanese entrepreneurs" introduced the plant into the U. S., and the plants had been "collected from the Orinoco River in Venezuela",[36] and the claim was echoed along the same gist by a pair of NASA researchers (Wolverton & McDonald 1979), who asserted that the souvenir plants were carelessly dumped in various waterways.[39] Canadian biologist Spencer C. H. Barrett (2004) meanwhile favored the theory they were first cultivated in garden ponds, after which they multiplied and escaped to the environs.[40] The account gains a different detail as told by children's story-teller Carole Marsh (1992), who says "Japan gave away water hyancinth seeds" during the exposition,[41] and another Southern raconteur, Gaspar J. "Buddy" Stall (1998) assured his readership that the Japanese gave each family a package of those seeds.[42] (Other means of introduction) One paper has also inquired into the role which catalog sales of seeds and plants may have played in the dissemination of invasive plants. It has been found that P. crassipes was offered in the 1884 issue of Bordentown, New Jersey-based Edmund D. Sturtevant's Catalogue of rare water lilies and other choice aquatic plants,[43] and Haage & Schmidt [de] of Germany has offered the plant since 1864 (since the firm was founded).[43] By 1895, it was offered by seed-purveyors in the states of NJ, NY, California, and Florida.[44][d] The Harper's Weekly magazine (1895) printed an anecdotal account stating that a certain man from New Orleans collected and brought home water hyacinths he collected from Colombia, c. 1892, and the plant proliferated in a matter of 2 years.[46] Infestation and control in the Southeast As the hyacinths multiply into mats, they eliminate the presence of fish, and choke waterways for boating and shipping.[47] This effect was well taking hold in the state of Louisiana by the turn of the 20th century.[32] The plant invaded Florida in 1890,[48] and an estimated 50 kg/m2 of the plant mass choked Florida's waterways.[49] The clogging of the St. Johns River was posing a serious threat, and in 1897 the government dispatched a task force of the United States Army Corps of Engineers to solve the water hyacinth problem plaguing the Gulf states such as Florida and Louisiana.[e][51][50] Thus in the early 20th century, the U.S. War Department (i.e., the Army Corps of Engineers) tested various means of eradicating the plants, including the jet-streaming of steam and hot water, application of various strong acids, and application of petroleum followed by incineration.[f] Spraying with saturated salt solution (but not dilute solutions) effectively killed the plants; unfortunately this was considered prohibitively expensive, and the engineers selected Harvesta brand herbicide, whose active ingredient was arsenic acid, as the optimal cost-effective tool for eradication.[52][53] This herbicide was used until 1905, when it was substituted with a different, white arsenic based compound.[53] An engineer charged with the spraying did not think the poison to be a matter of concern, stating that the crew of the spraying boat would routinely catch fish from their working areas and consume them.[54] However, spraying had little hope of completely eradicating the water hyacinth, due to the vastness of escaped colonies and the inaccessibility of some of the infested areas, and the engineer suggested that some biological means of control may be needed. [55] In 1910, a bold solution was put forth by the New Foods Society. Their plan was to import and release hippopotamus from Africa into the rivers and bayous of Louisiana. The hippopotamus would then eat the water hyacinth and also produce meat to solve another serious problem at the time, the American meat crisis.[32] Known as the American Hippo bill, H.R. 23621 was introduced by Louisiana Congressman Robert Broussard and debated by the Agricultural Committee of the U.S. House of Representatives. The chief collaborators in the New Foods Society and proponents of Broussard's bill were Major Frederick Russell Burnham, the celebrated American Scout, and Captain Fritz Duquesne, a South African Scout who later became a notorious spy for Germany. Presenting before the Agricultural Committee, Burnham made the point that none of the animals that Americans ate, chickens, pigs, cows, sheep, lambs, were native to the U.S.; all had been imported by European settlers centuries before, so why should Americans hesitate to introduce hippopotamus and other large animals into the American diet? Duquesne, who was born and raised in South Africa, further noted that European settlers on that continent commonly included hippopotamus, ostrich, antelope, and other African wildlife in their diets and suffered no ill effects. The American Hippo bill nearly passed, but fell one vote short.[32] Ironically, water hyacinths have also been introduced into waters inhabited by manatees in Florida, for the purpose of bioremediation (cf. §Phytoremediation below) of the waters that have become contaminated and fallen victim to algal blooming.[56] The manatees include the water hyacinth in their diet,[56] but it may not be the food of first choice for them.[57] Legality of sale and shipment in the United States In 1956 E. crassipes was banned for sale or shipment in the United States, subject to a fine and/or imprisonment.[58] This law was repealed by HR133 [59][60][116th Congress (2019-2020)] on 12/27/2020. Africa See also: Water hyacinth in Lake Victoria Water hyacinth at Kisumu Port The water hyacinth may have been introduced into Egypt in the late 18th to early 19th century during Muhammad Ali of Egypt's era, but was not recognized as an invasive threat until 1879.[61][62] The invasion into Egypt is dated between 1879 and 1892 by Brij Gopal.[63] Gopal; Junk; Davis (2000) , Biodiversity in Wetlands 2p. 109. The plant (Afrikaans: waterhiasint[64]) arguably invaded South Africa in 1910,[66][67][68] although earlier dates have been claimed.[71][g] The plant was introduced by Belgian colonists to Rwanda to beautify their holdings. It then advanced by natural means to Lake Victoria where it was first sighted in 1988.[73] There, without any natural enemies, it has become an ecological plague, suffocating the lake, diminishing the fish reservoir, and hurting the local economies. It impedes access to Kisumu and other harbors. The water hyacinth has also appeared in Ethiopia, where it was first reported in 1965 at the Koka Reservoir and in the Awash River, where the Ethiopian Electric Light and Power Authority has managed to bring it under moderate control at considerable cost of human labor. Other infestations in Ethiopia include many bodies of water in the Gambela Region, the Blue Nile from Lake Tana into Sudan, and Lake Ellen near Alem Tena.[74] By 2018, it has become a serious problem on Lake Tana in Ethiopia. The water hyacinth is also present on the Shire River in the Liwonde National Park in Malawi. Asia Haldia Municipality Pool, a public water reservoir is being choked by growing water hyacinth population as in December 2019. Water hyacinth was introduced to North America in 1884 and later to Asia, Africa, and Australia. Since there are no natural enemies in the new location, it can multiply quickly and cause disaster. The water hyacinth was introduced to Bengal, India because of its beautiful flowers and shapes of leaves, but turned out to be an invasive weed draining oxygen from the water bodies and resulted in devastation of fish stock.[75] The water hyacinth was referred to as the "(Beautiful) Blue Devil" in Bengal, and "Bengal Terror" elsewhere in India; it was called "German weed" (Bengali: Germani pana) in Bangladesh out of belief the German Kaiser submarine mission[76] was involved in introducing them at the outbreak of World War I; and called "Japanese trouble" in Sri Lanka, due to the rumor that the British had planted them in order to entice Japanese aircraft to land on the insecure pads.[77][78] In Bangladesh, projects have begun to utilize water hyacinth for the construction of floating vegetable gardens.[79] Water hyacinth has also invaded the Tonlé Sap lake in Cambodia. An Osmose project in Cambodia is trying to fight it by having local people make baskets from it. The plant entered Japan in 1884 for horticultural appreciation, according to conventional wisdom,[80][81] but a researcher devoted to the study of the plant has discovered that ukiyo-e artist Utagawa Kunisada (aka Utagawa Toyokuni III, d. 1865) produced a wood-block print featuring the water hyacinth, goldfish, and beautiful women, dated to 1855.[82] The plant is floated on the water surface of filled (glassware) fishbowls,[83] or glazed earthenware waterlily pots (hibachi pots serving as substitute).[84] In the 1930s, water hyacinth was introduced into China as a feed, ornamental plant and sewage control plant, and it was widely planted in the south as an animal feed. Beginning in the 1980s, with the rapid development of China's inland industry, the eutrophication of inland waters has intensified. With the help of its efficient asexual reproduction and environmental adaptation mechanisms, water hyacinth has begun to spread widely in the river basin. The flood-water blue eyes blocked the river and hindered the internal water traffic. For example, many waterways in Zhejiang and other provinces were blocked by the rapidly growing water hyacinth. In addition, a large number of water hyacinths floating in the water will block sunlight from entering the water, and after decay, it will consume a lot of dissolved oxygen in the water, pollute the water quality, and cause a large number of deaths of other aquatic plants. The outbreak of water hyacinth has seriously affected the biodiversity of the local ecosystem and threatened the production, life and health of community residents. In Iraq, water hyacinth which was imported in the 1990s as a decorative plant, caused major problems for water supply systems and fishermen at the Euphrates. Europe In 2016, the European Union banned any sales of the water hyacinth in the EU.[85] Invasive species Water hyacinth breeds quickly, is easy to float and spread, and can quickly cover the water body, resulting in poor water transparency. Therefore, in natural waters, water hyacinth blue competes with other aquatic (floating and submerged) plants and algae for mineral nutrition, sunlight, etc. resources, thereby inhibiting the growth of other aquatic and algal organisms. In 2011, Wu Fuqin et al.[86] tracked the results of Yunnan Dianchi Lake and also showed that water hyacinth could affect the photosynthesis of phytoplankton, submerged plants and algae by water environment quality and inhibit its growth. In addition, the outbreak of water hyacinth blue and its decay stage will consume a large amount of dissolved oxygen in the water body at the same time, and the space for reproduction of underwater animals such as fish will be reduced, and even a large number of fish will die. It is similar to changing the original food chain in the water body, thereby reducing the stability of the ecosystem in this water area.[citation needed] The massive explosive growth of water hyacinth blue often covers the water body where it is located, blocking river channels and waterways, and impeding water transportation. According to reports, a large area of water hyacinth has appeared in the lower reaches of the Han River in Wuhan for 20 consecutive days, posing a direct threat to the safe navigation of ships in the lower reaches of the Yangtze River. On the waters of the Yaojiang, Fenghua, and Minjiang rivers in Ningbo, Zhejiang, ships were also unable to sail because of the phoenix blue.[87] Secondly, water hyacinth can absorb a large amount of harmful heavy metals and other substances. After death, it will rot and sink to the bottom of the water, causing secondary pollution to the water body, destroying the natural water quality, and may even affect the quality of residents' drinking water in severe cases. Third, due to the dense growth of water hyacinth blue, it brings great difficulties to fishermen and often destroys fishing gear, resulting in a large increase in fishing costs.[88] The surface of the water body where water hyacinth grows heavily is often a breeding place for mosquitoes and harmful pathogens, posing a potential threat to the health of local residents.[89] The invasion of water hyacinth also has socioeconomic consequences. Since water hyacinth is comprised up of 95% water, the evapotranspiration rate is high.[90] As such, small lakes that have been covered with the species can dry out and leave communities without adequate water or food supply. In some areas, dense mats of water hyacinth prevents the use of a waterway, leading to the loss of transportation (both human and cargo) as well as a loss of fishing possibilities.[91] Large sums of money are allocated to the removal of water hyacinth from the water bodies as well as figuring out how to destroy the remains harvested.[92] Harvesting water hyacinth mechanically requires a lot of effort. A million tons of fresh biomass would require 75 trucks with a capacity of $40m^3$, per day, for 365 days to get rid of a million tons of water hyacinth.[93] The water hyacinth would then be transferred to a dumping site and allowed to decompose which releases CO_2, CH_4 and nitrous oxides which would all negatively impact the air quality and contribute to global warming.[94] Control Control depends on the specific conditions of each affected location such as the extent of water hyacinth infestation, regional climate, and proximity to human and wildlife.[95] Chemical control Chemical control is the least used out of the three controls of water hyacinth, because of its long-term effects on the environment and human health. The use of herbicides requires strict approval from governmental protection agencies of skilled technician to handle and spray the affected areas. The use of chemical herbicides is only used in case of severe infiltration of water hyacinth.[96] However, the most successful use of herbicides is when it is used for smaller areas of infestation of water hyacinth. This is because in larger areas, more mats of water hyacinths are likely to survive the herbicides and can fragment to further propagate a large area of water hyacinth mats. In addition, it is more cost-effective and less laborious than mechanical control. Yet, it can lead to environmental effects as it can penetrate into the ground water system and can affect not only the hydrological cycle within an ecosystem but also negatively affect the local water system and human health. It is also notable that the use of herbicides is not strictly selective of water hyacinths; keystone species and vital organisms such as microalgae can perish from the toxins and can disrupt fragile food webs.[95] The chemical regulation of water hyacinths can be done using common herbicides such as 2,4-D, glyphosate, and diquat. The herbicides are sprayed on the water hyacinth leaves and leads to direct changes to the physiology of the plant.[97] The use of the herbicide known as 2,4-D leads to the death of water hyacinth through inhibition of cell growth of new tissue and cellular apoptosis.[98] It can take almost a two-week period before mats of water hyacinth are destroyed with 2, 4-D. Between 75,000 and 150,000 acres (30,000 and 61,000 ha) of water hyacinth and alligator weed are treated annually in Louisiana.[99] The herbicide known as diquat is a liquid bromide salt that can rapidly penetrate the leaves of the water hyacinth and lead to immediate inactivity of plant cells and cellular processes. For the herbicide glyphosate, it has a lower toxicity than the other herbicides; therefore, it takes longer for the water hyacinth mats to be destroyed (about three weeks). The symptoms include steady wilting of the plants and a yellow discoloration of the plant leaves that eventually leads to plant decay.[96] Physical control Physical control is performed by land-based machines such as bucket cranes, draglines, or boom or by water based machinery such as aquatic weed harvesters,[100] dredges, or vegetation shredder.[101] Mechanical removal is seen as the best short-term solution to the proliferation of the plant. A project on Lake Victoria in Africa used various pieces of equipment to chop, collect, and dispose of 1,500 hectares (3,700 acres) of water hyacinth in a 12-month period. It is, however, costly and requires the use of both land and water vehicles, but it took many years for the lake to become in poor condition and reclamation will be a continual process.[citation needed] It can have an annual cost from $6 million to $20 million and is only considered a short-term solution to a long-term problem. Another disadvantage with mechanical harvesting is that it can lead to further fragmentation of water hyacinths when the plants are broken up by spinning cutters of the plant-harvesting machinery. The fragments of water hyacinth that are left behind in the water can easily reproduce asexually and cause another infestation.[97] However, transportation and disposal of the harvested water hyacinth is a challenge because the vegetation is heavy in weight. The harvested water hyacinth can pose a health risk to humans because of the plant's propensity for absorbing contaminants, and it is considered toxic to humans. Furthermore, the practice of mechanical harvesting is not effective in large-scale infestations of the water hyacinth, because this aquatic invasive species grows much more rapidly than it can be eliminated. Only one to two acres (1⁄2 to 1 ha) of water hyacinth can be mechanically harvested daily because of the vast amounts of water hyacinths in the environment. Therefore, the process is very time-intensive.[102] Biological control In 2010 the insect Megamelus scutellaris was released by the Agricultural Research Service as a biological control for water hyacinth.[103] As chemical and mechanical removal is often too expensive, polluting, and ineffective, researchers have turned to biological control agents to deal with water hyacinth. The effort began in the 1970s when USDA researchers released into the United States three species of weevil known to feed on water hyacinth, Neochetina bruchi, N. eichhorniae, and the water hyacinth borer Sameodes albiguttalis. The weevil species were introduced into the Gulf Coast states, such as Louisiana, Texas, and Florida, where thousands of acres were infested by water hyacinth. It was found that a decade later in the 1980s that there was a decrease in water hyacinth mats by as much as 33%. However, because the life cycle of the weevils is ninety days, it puts a limitation on the use of biological predation to efficiently suppress water hyacinth growth.[99] These organisms regulate water hyacinth by limiting water hyacinth size, its vegetative propagation, and seed production. They also carry microorganisms that can be pathological to the water hyacinth. These weevils eat stem tissue, which results in a loss of buoyancy for the plant, which will eventually sink.[97] Although meeting with limited success, the weevils have since been released in more than 20 other countries.[citation needed] However, the most effective control method remains the control of excessive nutrients and prevention of the spread of this species.[citation needed] In May 2010, the USDA's Agricultural Research Service released Megamelus scutellaris as an additional biological control insect for the invasive water hyacinth species. Megamelus scutellaris is a small planthopper insect native to Argentina. Researchers have been studying the effects of the biological control agent in extensive host-range studies since 2006 and concluded that the insect is highly host-specific and will not pose a threat to any other plant population other than the targeted water hyacinth. Researchers also hope that this biological control will be more resilient than existing biological controls and the herbicides that are already in place to combat the invasive water hyacinth.[103] Another insect being considered as a biological control agent is the semi-aquatic grasshopper Cornops aquaticum. This insect is specific to the water hyacinth and its family, and besides feeding on the plant, it introduces a secondary pathogenic infestation. This grasshopper has been introduced into South Africa in controlled trials.[30] The introduction of manatees into waterways was reportedly successful in controlling the plant's growth in Guyana.[57] The Rhodes University Center for Biological Control is rearing Megamelus scutellaris en masse for biocontrol at dams in South Africa.[104][105] Uses Bioenergy Because of its extremely high rate of development, Pontederia crassipes is an excellent source of biomass. One hectare (2.5 acres) of standing crop thus produces more than 70,000 m3/ha (1,000,000 cu ft/acre) of biogas (70% CH_4, 30% CO_2).[106] According to Curtis and Duke, one kg (2.2 lb) of dry matter can yield 370 litres (13 cu ft) of biogas, giving a heating value of 22,000 kJ/m3 (590 Btu/cu ft) compared to pure methane (895 Btu/ft3)[107] Wolverton and McDonald report approximately 0.2 m3/kg (3 cu ft/lb) methane,[h] indicating biomass requirements of 350 t/ha (160 short ton/acre) to attain the 70,000 m3/ha (1,000,000 cu ft/acre) yield projected by the National Academy of Sciences (Washington).[109] Ueki and Kobayashi mention more than 200 t/ha (90 short ton/acre) per year.[110] Reddy and Tucker found an experimental maximum of more than 1⁄2 tonne per hectare (1⁄4 short ton/acre) per day.[111] Bengali farmers collect and pile up these plants to dry at the onset of the cold season; they then use the dry water hyacinths as fuel. The ashes are used as fertilizer. In India, one tonne (1.1 short tons) of dried water hyacinth yields about 50 liters ethanol and 200 kg residual fiber (7,700 Btu). Bacterial fermentation of one tonne (1.1 short tons) yields 26,500 ft3 gas (600 Btu) with 51.6% methane (CH_4), 25.4% hydrogen (H_2), 22.1% carbon dioxide (CO_2), and 1.2% oxygen (O_2). Gasification of one tonne (1.1 short tons) dry matter by air and steam at high temperatures (800 °C or 1,500 °F) gives about 40,000 ft3 (1,100 m3) natural gas (143 Btu/ft3) containing 16.6% H_2, 4.8% CH_4, 21.7% CO (carbon monoxide), 4.1% CO_2, and 52.8% N_2 (nitrogen). The high moisture content of water hyacinth, adding so much to handling costs, tends to limit commercial ventures.[109][112] A continuous, hydraulic production system could be designed, which would provide a better utilization of capital investments than in conventional agriculture, which is essentially a batch operation.[10][113] The labor involved in harvesting water hyacinth can be greatly reduced by locating collection sites and processors on impoundments that take advantage of prevailing winds. Wastewater treatment systems could also favorably be added to this operation. The harvested biomass would then be converted to ethanol, biogas, hydrogen, gaseous nitrogen, and/or fertilizer. The byproduct water can be used to irrigate nearby cropland.[10] Phytoremediation, waste water treatment Water hyacinth removes arsenic from arsenic-contaminated drinking water. It may be a useful tool in removing arsenic from tube well water in Bangladesh.[114] Water hyacinth is also observed to enhance nitrification in wastewater treatment cells of living technology. Their root zones are superb micro-sites for bacterial communities.[24] Water hyacinth is a common fodder plant in the third world especially Africa though excessive use can be toxic. It is high in protein (nitrogen) and trace minerals and the goat feces are a good source of fertilizer as well. Water hyacinth is reported for its efficiency to remove about 60–80% nitrogen[115] and about 69% of potassium from water.[116] The roots of water hyacinth were found to remove particulate matter and nitrogen in a natural shallow eutrophicated wetland.[117][118] The plant can also screen heavy metals and various other toxins from contaminated water.[119] The roots of Pontederia crassipes naturally absorb pollutants, including lead, mercury, and strontium-90, as well as some organic compounds believed to be carcinogenic, in concentrations 10,000 times that in the surrounding water.[120] Water hyacinths can be cultivated for waste water treatment (especially dairy waste water).[10][failed verification] Agriculture In places where water hyacinth is invasive, overabundant, and in need of clearing away, these traits make it free for the harvesting, which makes it very useful as a source of organic matter for composting in organic farming. It is used internationally for fertilizer and as animal feed.[121] In Bengal, India the kachuri-pana has been used primarily for fertilizer, compost or mulch, and secondarily as fodder for livestock and fish.[122] In Bangladesh, farmers in the southwestern region cultivate vegetables on "floating gardens" usually with a bamboo-built frame base, with dried mass of water hyacinth covered in soil as bedding. As a large portion of cultivable land goes under water for months during monsoon in this low-lying region, farmers have grown this method for many decades now. The method of this agriculture is known by many names including dhap chash and vasoman chash.[123] In Kenya, East Africa, it has been used experimentally as organic fertilizer, although there is controversy stemming from the high alkaline pH value of the fertilizer.[124] Other uses In various places in the world world-wide, the plant is used for making furniture, handbags, baskets, rope, and household goods/interior products (lampshades, picture frames) by businesses launched by NGOs and entrepreneurs.[121][56] Woven products American-Nigerian Achenyo Idachaba has won an award for showing how this plant can be exploited for profit as woven procuts in Nigeria.[125] Paper Though a study found water hyacinths of very limited use for paper production,[126] they are nonetheless being used for paper production on a small scale. Goswami pointed out in his article that water hyacinth blue has the potential to make tough and strong paper. He found that adding water hyacinth blue pulp to the raw material of bamboo pulp for anti-grease paper can increase the physical strength of paper. Edibility The plant is used as a carotene-rich table vegetable in Taiwan. Javanese sometimes cook and eat the green parts and inflorescence.[10] Vietnamese also cook the plant and sometimes add its young leaves and flower to their salads. Medicinal use In Kedah (Malaysia), the flowers are used for medicating the skin of horses.[10] The species is a "tonic".[127][128] Potential as bioherbicidal agent Water hyacinth leaf extract has been shown to exhibit phytotoxicity against another invasive weed Mimosa pigra. The extract inhibited the germination of Mimosa pigra seeds in addition to suppressing the root growth of the seedlings. Biochemical data suggested that the inhibitory effects may be mediated by enhanced hydrogen peroxide production, inhibition of soluble peroxidase activity, and stimulation of cell wall-bound peroxidase activity in the root tissues of Mimosa pigra.[129] Gallery Floating plant Flowers Close-up of flowers Large pond covered with water hyacinth Inflated petiole Huge swamp field populated by Pontederia crassipes Explanatory notes ^ Including indication that these were grown in nurseries and landscapes soon after the American Civil War (ended 1865).[31] ^ Note that military engieers were tasked with the removal of water hyacinths in the South, as explained below. ^ Brown (1941) also wrongly claims the species to be "a native to Japan", p. 9. Brown appears in a photograph on p. 12. ^ It might be also noted that when the World's Fair returned to the U.S. in 1993 and was held in Chicago (World's Columbian Exposition), Edmund D. Sturtevant was there displaying his water-lilies.[45] ^ The term "board of engineer officer" is used, but the biography from one of its members, in the West Point graduate roll, shows he was from the Army Corps of Engineers.[50] ^ The 1903 Experiment Report has "petroleum", whereas Klorer 1909, p. 443 writes "Beaumont fuel oil". ^ The more ambitious by Kitunda (2017), p. xv dating to 1829 due to William Townsend Aiton of Kew Gardens does not pan out, since the pointed source, Curtis's Botanical Magazine (1829) merely states Aiton made the plant available then to Glasgow Botanic Gardens.[72] ^ i.e., 200 liters out of the "350 to 411 liters of biogas per kg dry weight of water hyacinths (5.7 to 6.6 scf per dry lb)" reported by this team with Barlow.[108]

References ^ "Eichhornia crassipes". Global Invasive Species Database (GISD). ^ Pellegrini, M. O. O.; Horn, C. N. & Alemida, R. F. (2018). "Total evidence phylogeny of Pontederiaceae (Commelinales) sheds light on the necessity of its recircumscription and synopsis of Pontederia L." PhytoKeys (108): 25–83. doi:10.3897/phytokeys.108.27652. PMC 6160854. PMID 30275733. ^ "Limnobium spongia". UF / IFAS Center for Aquatic and Invasive Plants. ^ Sullivan, Paul R; Wood, Rod (2012). Water hyacinth (Eichhornia crassipes (Mart.) Solms) seed longevity and the implications for management (PDF). 18th Australasian Weeds Conference. Melbourne. ^ Gopal, Brij (1987). Water Hyacinth (Aquatic Plant Studies). Elsevier Science. ISBN 978-0444427069. ^ Dickinson, Richard; Royer, France (2014). Weeds of North America. University of Chicago Press. p. 625. ISBN 978-0-226-07658-4. Water hyacinth forms large floating mats.. Under ideal conditions populations may double in size every 6–18 days. ^ "Eichhornia crassipes (water hyacinth)". Invasive Species Compendium. CABI. Retrieved November 14, 2017. ^ Barrett, Spencer C.H. (1977) Tristyly in Eichhornia crassipes (Water Hyacinth). Biotropica, 9: 230–238 ^ Barrett, Spencer C.H. (1989) Waterweed invasions. Scientific American, 260: 90–97. ^ a b c d e f g Duke, J. (1983). "Eichhornia crassipes (Mart.) Solms". Handbook of Energy Crops. ^ Matai, S.; Bagchi, D.K. (1980), Gnanam, A.; Krishnaswamy, S.; Kahn, J.S. (eds.), "Water hyacinth: a plant with prolific bioproductivity and photosynthesis", Proceedings of the International Symposium on Biological Applications of Solar Energy, 1–5 December 1978, MacMillan Co. of India, Madras, pp. 144–148 apud Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Medicinal plants of east and southeast Asia. By L.M Perry. 1980. MIT Press, Cambridge. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Tropical feeds. Feed information summaries and nutritive values. By B. Gohl. 1981. FAO Animal Production and Health Series 12. FAO, Rome. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Upadhyay, Alka R.; B. D. Tripathi (2007). "Principle and Process of Biofiltration of Cd, Cr, Co, Ni & Pb from Tropical Opencast Coalmine Effluent". Water, Air, & Soil Pollution. Springer. 180 (1–4): 213–223. Bibcode:2007WASP..180..213U. doi:10.1007/s11270-006-9264-1. S2CID 97353113. ^ Abou-Shanab, R. A. I.; Angle, JS; Van Berkum, P; et al. (2007). "Chromate-Tolerant Bacteria for Enhanced Metal Uptake by Eichhornia Crassipes (MART.)". International Journal of Phytoremediation. 9 (2): 91–105. doi:10.1080/15226510701232708. PMID 18246718. S2CID 21893402. ^ Maine, M.A.; Sune, N; Hadad, H; Sanchez, G; Bonetto, C; et al. (2006). "Nutrient and metal removal in a constructed wetland for wastewater treatment from a metallurgic industry". Ecological Engineering. Elsevier. 26 (4): 341–347. doi:10.1016/j.ecoleng.2005.12.004. ^ Skinner, Kathleen; Wright, N; Porter-Goff, E; et al. (2007). "Mercury uptake and accumulation by four species of aquatic plants". Environmental Pollution. Elsevier. 145 (1): 234–237. doi:10.1016/j.envpol.2006.03.017. PMID 16781033. ^ Ebel, Mathias; Evangelou, MW; Schaeffer, A; et al. (2007). "Cyanide phytoremediation by water hyacinths (Eichhornia crassipes)". Chemosphere. Elsevier. 66 (5): 816–823. Bibcode:2007Chmsp..66..816E. doi:10.1016/j.chemosphere.2006.06.041. PMID 16870228. ^ Gannon, Mike (January 15, 2014). "Water Hyacinth – In and Out of Your Water Garden". Full Service Aquatics. ^ Chepkoech, Anita (February 7, 2017). "Removal of Water Hyacinth Could Take Longer, Expert Says". Daily Nation. ^ Voiland, Adam (June 1, 2016). "Seven Things You Didn't Know About Water Hyacinth". Earth Observatory. Retrieved November 21, 2017. ^ "Non-native Invasive Freshwater Plants — Water Hyacinth (Eichornia crassipes) — Technical Information". Washington State Department of Ecology. Archived from the original on November 15, 2017. Retrieved November 21, 2017. ^ Coles, G.C.; Kabatereine, N.B. (June 2008). "Water hyacinth and the transmission of schistosomiasis". Transactions of the Royal Society of Tropical Medicine and Hygiene. 102 (6): 619–620. doi:10.1016/j.trstmh.2008.01.009. PMID 18374376. ^ a b Todd, J.; Josephson, B. (May 1996). "The design of living technologies for waste treatment". Ecological Engineering. 6 (1–3): 109–136. doi:10.1016/0925-8574(95)00054-2. S2CID 13068184. ^ Sheffield, C.W. (June 1967). "Water Hyacinth For Nutrient Removal" (PDF). Journal of Aquatic Plant Management (JAPM). 6: 27–30. Retrieved July 31, 2013. ^ Hanson, Sarah (March 20, 2013). "Eichhornia crassipes – The 'Jekyll and Hyde' of the freshwater world". Tropical Biodiversity. Retrieved November 21, 2017. ^ Julien, M.H., and Griffiths, M.W. (1998), Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds (4th ed.), Oxon, UK: CABI Publishing, CAB International. ^ "Biological Control of Weeds — A World Catalogue of Agents and their Target Weeds". iBiocontrol. The University of Georgia – Center for Invasive Species and Ecosystem Health. Retrieved November 14, 2017. ^ Goyer, Richard A.; Stark, John D. (1981). "Suppressing water hyacinth with an imported weevil". Louisiana Agriculture. 24 (4): 4–5. ^ a b Amédégnato, Christiane; Devriese, Hendrik (2008), Balian, E.V.; Lévêque, C.; Segers, H.; Martens, K. (eds.), "Global diversity of true and pygmy grasshoppers (Acridomorpha, Orthoptera) in freshwater", Freshwater Animal Diversity Assessment, Springer Science & Business Media, p. 542, ISBN 978-1-4020-8259-7. Reprinted from Hydrobiologia, 595 (2008), doi:10.1007/s10750-007-9132-z. ^ Penfound & Earle (1948), p. 449: "some evidence.. cultivated as greenhouse and landscape exotic shortly after the War between the States." ^ a b c d e Mooallem, John (2013). "American Hippopotamus". The Atavist. Vol. 32. New York. ASIN B00HEWJTF4. Retrieved November 14, 2017; Mooallem's piece was also featured in Miller, Greg (December 20, 2013). "The Crazy, Ingenious Plan to Bring Hippopotamus Ranching to America". Wired. ISSN 1059-1028. ^ Penfound & Earle (1948), p. 449. ^ Douglas, Lake (2011). Public Spaces, Private Gardens: A History of Designed Landscapes in New Orleans. LSU Press. pp. 54–55, 246 nn26–27. ISBN 978-0-807-13838-0. ^ a b Brown, James, Major (1941). "Water hyacinth control in fishing waters". Louisiana Conservation Review. Vol. 10 no. 2. Department of Conservation, State of Louisiana. p. 9. Alt URL ^ a b Vietmeyer (1975), p. 65. ^ Claimed in Major James Brown (1941),[35] Vietmeyer (1975),[36] Wolverton & McDonald (1979), p. 2, Barrett (2004), p. 92, and Mooallem (2013)[32] as delineated below. ^ Wunderlich, William E. (1940). "Machines Combat Aquatic Growth". The Military Engineer. Society of American Military Engineers. 33 (1): 517. ^ Wolverton & McDonald (1979), p. 2: " Japanese exhibitors coming to the 1884 Cotton States Exposition in New Orleans, Louisiana, brought along this aquatic plant because of its beautiful lavender flowers. They had collected the water hyacinths from the Orinoco River in Venezuela. These plants were given away at the exposition as souvenirs". ^ Barrett (2004), p. 92: "..In that year water hyacinths imported from the lower Orinoco River in Venezuela were distributed as gifts by a Japanese delegation". ^ Douglas, Lake (1992). Loony Louisiana!. Carole Marsh Louisiana Bks. ISBN 0-793-37321-2. ^ Stall, Gaspar J. "Buddy" (1998). Buddy Stall's Louisiana Potpourri. Pelican Publishing. p. 81. ISBN 1-56554-427-7. ^ a b Mack, Richard N. (1991). "The Commercial Seed Trade: An Early Disperser of Weeds in the United States". Economic Botany. Springer on behalf of New York Botanical Garden Press. 45 (2): 265–266. doi:10.1007/BF02862053. JSTOR 4255340. S2CID 36826088. ^ Mack (1991), pp. 265–266, 262 (Table 1, Eicchornia crassipes) ^ Tricker, William (August 1, 1910). "The Water Garden: a quarter century of aquatics". Gardening. Vol. 18 no. 430. p. 338. ^ "This Busy World", Harper's Weekly, 39, May 4, 1895 ^ Penfound & Earle (1948), p. 450. ^ Webber 1897, p. 11 apud Penfound & Earle 1948, p. 449 ^ "A Troublesome 'Water Weed'". Popular Science Monthly. LII: 429. January 1898. Retrieved November 14, 2017. ^ a b Washington Cullum, George; Holden, Edward Singleton, eds. (1901). William H. H. Benyaurd. Biographical Register of the Officers and Graduates of the U.S. Military Academy, at West Point, N.Y. Houghton, Mifflin. pp. 138–139. ^ Klorer 1909, p. 43. ^ "Report on Experiments for Destruction of the Water Hyacinth in the Waters of Florida", Annual Report of the Department of War, 12 (4), p. 2433, 1903 ^ a b Klorer 1909, pp. 42–44. ^ Klorer 1909, p. 45. ^ Klorer 1909, p. 47. ^ a b c Doughty, Robin W.; Turner, Matt Warnock (2019). Unnatural Texas?: The Invasive Species Dilemma. Texas A&M University Press. pp. 54–55, 246 nn26–27. ISBN 978-1-623-49705-7. ^ a b Barrett (2004), p. 96. ^ "Transportation of water hyacinths". Bill No. 18 U.S. Code § 46 of 1 August 1956. United States Congress. ^ Cuellar, Henry (December 27, 2020). "H.R.133 - 116th Congress (2019-2020): Consolidated Appropriations Act, 2021". www.congress.gov. Retrieved December 29, 2020. ^ "TITLE X--CLEAN UP THE CODE ACT OF 2019 SEC. 1002. REPEALS. The following provisions of title 18, United States Code, are repealed: (1) Section 46 relating to transportation of water hyacinths.". Act of 27 December 2020. ^ Kitunda (2017), pp. xxiv, 6. ^ Hussein, Walaa (September 7, 2016). "How this invasive flower is taking over the Nile". Al-Monitor. CAIRO. ^ Gopal & Sharma 1981. ^ a b Stirton, C. H. (1983). Plant Invaders: Beautiful, But Dangerous : a Guide to the Identification and Control of Twenty-six Plant Invaders of the Province of the Cape of Good Hope. Department of Nature and Environmental Conservation of the Cape Provincial Administration. p. 68. ISBN 978-0-798-40094-7. ^ Ashton, P. J.; Scott, W. E.; Sten, D.J.; Wells, R. J. (1979), "The chemical control programme against the water hyacinth Eichhornia crassipes (Mart.) Solm on Hartbeespoort Dam", South African Journal of Science, 75: 303–306CS1 maint: ref duplicates default (link) ^ Dutoit. R., (1938). "Water hyacinth". Farming South Africa 13, 16–17, apud Ashton et al. (1979), p. 303 harvp error: multiple targets (2×): CITEREFAshtonScottStenWells1979 (help)[65] ^ Gopal 1987. ^ apud Gopal; Junk; Davis (2000) , Biodiversity in Wetlands 2p. 109. ^ Kluge. R. L. (1978). Eichhornia crassipes. In Plant Invaders: Beautiful but Dangerous, edit. C. H. Stirton ^ Wise, R.M.; Wilgen, B.W. van; Hill, M.P.; Schulthess, F.; Tweddle, D.; Chabi-Olay, A.; Zimmermann, H.G. (February 2007), The Economic Impact and Appropriate Management of Selected Invasive Alien Species on the African Continent FINAL REPORT (PDF), Global Invasive Species Programme, p. 7. CSIR Report Number: CSIR/NRE/RBSD/ER/2007/0044/C ^ The 1884 dating given by R. L. Kluge (1978)[69] (also C. H. Stirton (1983)[64]) is refuted by Ashton et al. (1979), p. 303 harvp error: multiple targets (2×): CITEREFAshtonScottStenWells1979 (help) as a mistake for the year it was introduced into the U. S., 1884 (year of the World's Fair in New Orleans, Louisiana). Kitunda (2017), pp. 107–108 cites Zimmermann, H. G. et al. (2007), that the plant was distributed at the 1904 St. Louis World's Fair, aka "Louisiana Purchase Exposition", and this was one possible route of transmission to S. Africa in 1910.[70] ^ Hooker, William Jackson (1829) "#2932 Pontederia azurea. Large-flowered Pnotederia", Curtis's Botanical Magazine, New Series 3 (=Vol. 56) ^ Thielke, Thilo (September 2, 2008). "Die grüne Pest" [The Green Pest]. Spiegel Online (in German). Retrieved September 2, 2008. ^ Rezene, F. (2005). "Water Hyacinth (Eichhornia crassipes): A Review of its Weed Status in Ethiopia". Arem. 6: 105–111. Cited in Yirefu, F.; Tafesse, A.; Gebeyehu, T.; Tessema, T. (2007). "Distribution, Impact and Management of Water Hyacinth at Wonji-Shewa Sugar Factory" (PDF). Eth. J. Of Weed MGT. 1 (1): 41–52. Archived from the original (PDF) on February 22, 2014. ^ Gopal & Sharma (1981), apud Petr, T. (2000) Interactions Between Fish and Aquatic Macrophytes in Inland Waters: A Review, p. 84 ^ Husain, Anwar (July 1969). "Silent Scourges of East Pakistan". Perspective. Vol. 3 no. 1. p. 261. ^ Vietmeyer (1975), p. 67. ^ Monsod (1979), p. 30. ^ Helvetas Bangladesh (February 6, 2013). "How to do Floating Vegetable Garden-step by step". Retrieved March 21, 2019. ^ Kadono (2004), p. 163. ^ Ishii et al. (2001), p. 28. ^ Ishii et al. (2001), pp. 29–30. ^ "Hotei-aoi ほてい-あおい【布袋葵】", Kojien, 4th ed., 1991. ^ Kaneko, Yukiko (2006). Chotto wa no aru kurashi ga nandaka totemo wakuwaku suru ちょこっと和のある暮らしが なんだかとてもワクワクする！. Subarusha. ISBN 978-4-883-99555-4. ^ Marks, Simon (December 14, 2016). "Dutch breeders hit back at EU's invasive alien species ban". Politico. Retrieved September 10, 2020. ^ Li, Xuebao; Wu, Zhenbin; He, Guangyuan (May 1995). "Effects of low temperature and physiological age on superoxide dismutase in water hyacinth (Eichhornia crassipes Solms)". Aquatic Botany. 50 (2): 193–200. doi:10.1016/0304-3770(94)00417-k. ISSN 0304-3770. ^ XIA, H; MA, X (May 2006). "Phytoremediation of ethion by water hyacinth (Eichhornia crassipes) from water". Bioresource Technology. 97 (8): 1050–1054. doi:10.1016/j.biortech.2005.04.039. ISSN 0960-8524. PMID 15982870. ^ Twongo, T. (August 13, 2019). "Growing Impact of Water Hyacinth on Nearshore Environments on Lakes Victoria and Kyoga (East Africa)". The Limnology, Climatology and Paleoclimatology of the East African Lakes. Routledge. pp. 633–642. doi:10.1201/9780203748978-35. ISBN 978-0-203-74897-8. ^ Kong, Fanbin; Xiong, Kai; Zhang, Ning (September 29, 2014). "Determinants of Farmers' Willingness to Pay and Its Level for Ecological Compensation of Poyang Lake Wetland, China: A Household-Level Survey". Sustainability. 6 (10): 6714–6728. doi:10.3390/su6106714. ISSN 2071-1050. ^ Jamal, Tazim (September 30, 2019). "Tourism ethics: a perspective article". Tourism Review. 75 (1): 221–224. doi:10.1108/tr-05-2019-0184. ISSN 1660-5373. ^ Villamagna, A. M.; Murphy, B. R. (2010). "Ecological and socio-economic impacts of invasive water hyacinth (Eichhornia crassipes): a review". Freshwater Biology. 55 (2): 282–298. doi:10.1111/j.1365-2427.2009.02294.x. ISSN 1365-2427. ^ Wyk, E. van; Wilgen, B. W. van (January 1, 2002). "The cost of water hyacinth control in South Africa: a case study of three options". African Journal of Aquatic Science. 27 (2): 141–149. doi:10.2989/16085914.2002.9626585. ISSN 1608-5914. S2CID 218644199. ^ Water Hyacinth. August 9, 2017. doi:10.1201/9781315151809. ISBN 9781315151809. ^ Sarika, D.; Singh, Jiwan; Prasad, Ravi; Vishan, Isha; Varma, V. Sudharsan; Kalamdhad, Ajay S. (September 2014). "Study of physico-chemical and biochemical parameters during rotary drum composting of water hyacinth". International Journal of Recycling of Organic Waste in Agriculture. 3 (3): 9. doi:10.1007/s40093-014-0063-1. ISSN 2195-3228. S2CID 86070957. ^ a b Villamagna, Amy; Murphy, Brian (August 27, 2009). "Ecological and socio-economic impacts of invasive water hyacinth (Eichhornia crassipes): a review". Freshwater Biology. 55 (2): 282–298. doi:10.1111/j.1365-2427.2009.02294.x. ^ a b "Water Hyancith". California State Parks: Division of Boating and Waterways. State of California: Division of Boating and Waterways. Archived from the original on November 14, 2014. ^ a b c Jiménez, Maricela. "Progress on water hyacinth (Eichhornia crassipes) management". Food and Agriculture Organization of the United Nations. Retrieved November 4, 2014. ^ Jiménez, VM (November 2005). "Involvement of plant hormones and plant growth regulators on in vitro somatic embryogenesis". Plant Growth Regulation. 47 (2–3): 91–110. doi:10.1007/s10725-005-3478-x. S2CID 2458933. ^ a b Sanders, Dearl; Jonhson, Seth; Kelso, Bill (Fall 2010). "Invasive Aquatic Weeds in Louisiana". Louisiana Agriculture. 53 (4): 34–37. Retrieved October 13, 2014. ^ "Aquatic Weed Harvester". Aquarius Systems. ^ "Vegetation Shredders". Aquarius Systems. ^ Malik, Anushree (January 2007). "Environmental challenge vis a vis opportunity: The case of water hyacinth". Environment International. 33 (1): 122–138. doi:10.1016/j.envint.2006.08.004. PMID 17010439. ^ a b "Scientists Release Biocontrol for Waterhyacinth". United States Department of Agriculture, Agricultural Research Service. ^ "Our mass rearing team collected over 40... - Centre for Biological Control - CBC | Facebook". Facebook. ^ "Sisonke". Center for Biological Control - Rhodes University. September 17, 2014. Retrieved November 11, 2020. ^ National Research Council (1976). Making Aquatic Weeds Useful: Some Perspectives for Developing Countries. Washington, DC: The National Academies Press. doi:10.17226/19948. ISBN 978-0-309-33457-0. Retrieved November 15, 2017. ^ Curtis, C.R.; Duke., J.A.(1982) An assessment of land biomass and energy potential for the Republic of Panama, vol. 3. Institute of Energy Conversion. Univ. Delaware. apud Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Wolverton, B.C.; Barlow, R.M.; McDonald, R.C. (1976), Tourbier, J.; Pierson, R. W., Jr. (eds.), "17. Application of Vascular Aquatic Plants for Pollution Removal, Energy, and Food Production in a Biological System", Biological Control of Water Pollution, University of Pennsylvania Press, pp. 141–149, apud Wolverton & McDonald (1979), p. 7 ^ a b Wolverton, B.C.; McDonald, R.C. (1981) "Energy from vascular plant wastewater treatment systems – Eichhornia crassipes, Spirodela lemna, Hydrocotyle ranunculoides, Pueraria lobata, biomass harvested for fuel production", Economic Botany 35 (2), pp. 224–232, doi:10.1007/BF02858689, apud Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Cultivation of new biomass resources. By K. Ueki and T. Kobayashi. 1981. Energy Develop. in Japan. 3(3):285–300. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Productivity and nutrient uptake of water hyacinth Eichhornia crassipes. By K.R. Reddy and J.C. Tucker. 1983. 1. Effect of nitrogenous source. Econ. Bot. 37(2):237–247. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ The wealth of India. By C.S.I.R. (Council of Scientific and Industrial Research). 1948–1976. 11 vols. New Delhi. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Benemann, J.R. (1981) "Energy from fresh and brackish water aquatic plants", pp. 99–121. In: Klass, D.L. (ed.), Biomass as a non-fossil fuel source. ACS Symposium Series 144. ACS. Washington. Cited in Duke (1983) harvp error: multiple targets (2×): CITEREFDuke1983 (help). ^ Misbahuddin, M.; Fariduddin, A.T.M. (2002). "Water Hyacinth Removes Arsenic from Arsenic-Contaminated Drinking Water". Archives of Environmental Health. 57: 516- 518. ^ Fox, LJ; Struik, PC; Appleton, BL; Rule, JH; et al. (2008) Nitrogen phytoremediation by water hyacinth (Eichhornia crassipes (Mart.) Solms). Water Air Soil Pollut 194:199–207 ^ Zhou, W; Zhu, D; Tan, L; Liao, S; Hu, H; David, H; et al. (2007) Extraction and retrieval of potassium from water hyacinth (Eichhornia crassipes). Biores Tech 98:226–231 ^ Billore, SK; Bharadio, R; Kumar, A; et al. (1998) Potential removal of particulate matter and nitrogen through roots of water hyacinth in a tropical natural wetland. Curr Sci 74:154–156 ^ Ansari, Abid; Gill, Sarvajeet; Khan, Fareed; Ghauri, Naeem (2014). Phytoremediation Systems for the Recovery of Nutrients from Eutrophic Waters. Eutrophication: Causes, Consequences and Control. 2. pp. 239–248. doi:10.1007/978-94-007-7814-6_17. ISBN 978-94-007-7813-9. ^ Niering, William A.; Olmstead, Nancy C. (1985) [1979]. The Audubon Society Field Guide to North American Wildflowers, Eastern Region. Knopf. p. 711. ISBN 0-394-50432-1. ^ "UNKNOWN". Biology Briefs. BioScience. 26 (3): 224. March 1976. doi:10.2307/1297259. JSTOR 1297259. Cite uses generic title (help) ^ a b Aguilo, Patricia; L'Esperance, Amanda; Mbau, Elizabeth; Palmer, Phillip; Patel, Asmita; Sparkman, Tim (May 10, 2007). "Attracting Investment to Kisumu: Opportunities and Challenges" (PDF). Columbia University. p. 78. Archived from the original (PDF) on September 16, 2012. ^ Datta, S. C.; Banerjee, A. K. (1978). "Useful Weeds of West Bengal Rice Fields". Economic Botany. 32 (3): 302. doi:10.1007/BF02864704. JSTOR 4253961. S2CID 29531285. ^ Habiba, Umma; Shaw, Rajbi (2012), Shaw, Rajib (ed.), "6. Bangladesh Experiences of Community-Based Disaster Risk Reduction", Community Based Disaster Risk Reduction, Emerald Group Publishing, p. 102, ISBN 978-0-857-24867-1 ^ "Eichhornia crassipes". Global Invasive Species Database. ^ Idachaba, Achenyo (May 2015). "How I turned a deadly plant into a thriving business". TED. ^ Nolad, W.J.; Kirmse, D.W. (May 1974). "The Papermaking Properties of Waterhyacinth" (PDF). Journal of Aquatic Plant Management (JAPM). 12: 90–97. ^ Duke, J.A.; Wain, K.K (1981) Medicinal plants of the world. 3 vols. ^ Oudhia, P. (Winter 2001). "Traditional medicinal knowledge about a noxious weed, jal kumbhi (Eichhornia crassipes), in Chhattisgarh (India)" (PDF). AQUAPHYTE Online. 21 (2). ISSN 0893-7702. ^ Chai, TT; Ngoi, JC; Wong, FC (2013). "Herbicidal potential of Eichhornia crassipes leaf extract against Mimosa pigra and Vigna radiata". International Journal of Agriculture and Biology. 15 (5): 835–842. Bibliography Barrett, Spencer C. H. (October 2004). "Waterweed Invasions". Scientific American. 261 (4): 90–97. doi:10.1038/scientificamerican1089-90. JSTOR 24987444. Duke, J. (1983). Handbook of Energy Crops. Purdue University. (Complete List of References) Gopal, Brij; Sharma, K. P. (1981). Water-hyacinth (Eichhornia Crassipes): The Most Troublesome Weed of the World. Hindasia. Ishii, Takeshi; Ninjyou, Hiroyuki; Norinao, Hideki; Maeda, Hironobu; Yamashina, Youko (2001), "世界に分布するホテイアオイとその水質浄化並びに資源としての有効利用の研究（I）" [A Study on Water Hyacinth all over the World; The Usefulness for Water Purification and Agricultural (or Natural) Resources (I)], Water Science / Suiri Kagaku 水利科学 (in Japanese), 45 (2): 17–33, doi:10.20820/suirikagaku.45.2_17 Kadono, Yasuro (2004). "Alien aquatic plants naturalized in Japan: history and present status" (PDF). Global Environmental Research. 8 (2): 163–169. Kitunda, Jeremiah Mutio (2017). A History of the Water Hyacinth in Africa: The Flower of Life and Death from 1800 to the Present. Lexington Books. ISBN 978-1-498-52463-6. Klorer, John (1909), "The Water Hyacinth Problem", Journal of the Association of Engineering Societies, 42: 42–48 Monsod, Godofredo G. (1979). Man and the water hyacinth. Vantage Press. ISBN 9780533038244. Penfound, Wm. T.; Earle, T. T. (October 1948). "The Biology of the Water Hyacinth". Ecological Monographs. 18 (4): 447–472. doi:10.2307/1948585. JSTOR 1948585. Vietmeyer, Noel D. (1975). "Beautiful Blue Devil". Natural History. 84 (9): 65–73. Webber, H. J. (1897). "The Water Hyacinth, and its Relation to Navigation in Florida". U. S. Dept. Agr. Div. Bot. Bulletin (18): 1–20. Wolverton, Billy C.; McDonald, Rebecca C. (1979). "The Water Hyacinth: From Prolific Pest to Potential Provider". Ambio. Springer on behalf of Royal Swedish Academy of Sciences. 8 (1): 2–9. JSTOR 4312402. External links Wikimedia Commons has media related to Eichhornia crassipes. Wikispecies has information related to Eichhornia crassipes. Eichhornia crassipes Eichhornia crassipes in West African plants – A Photo Guide. Species Profile – Water Hyacinth (Eichhornia crassipes), National Invasive Species Information Center, United States National Agricultural Library. Lists general information and resources for Water Hyacinth. Eichhornia crassipes Israel Wildflowers and native plants Practical uses of Water Hyacinth IUCN Leaflet on E. crassipes in the context of Lake Tanganyika "Water hyacinth", AquaPlant Profile Retrieved from "

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