EPPO Datasheet: *Salvinia molesta*

Last updated: 2020-04-23

IDENTITY

Preferred name: *Salvinia molesta*
Authority: Mitchell
Taxonomic position: Plantae: Pteridophyta: Pteridopsida: Salviniales: Salviniaceae: Salvinioideae
Other scientific names: *Salvinia adnata* Desvaux
Common names: African payal, African pyle, Australian azolla, Kariba weed, aquarium watermoss, giant azolla, giant salvinia, salvinia moss, water fern, water spangles
view more common names online...
EPPO Categorization: A2 list
view more categorizations online...
EU Categorization: IAS of Union concern
EPPO Code: SAVMO

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GEOGRAPHICAL DISTRIBUTION

History of introduction and spread

Salvinia molesta is native to Brazil in the subtropical zone (between latitudes 24°05' S and 32°05' S) at elevations up to 900 m (McFarland *et al.*, 2004). Its status in other countries of South America appears less certain (e.g. compare Holm *et al.*, 1979; CABI, 2016; EPPO, 2016).

Salvinia molesta has spread widely throughout the world, becoming an invasive alien species in many regions. The species is widespread in Africa (occurring in over 20 countries), the Indian subcontinent, Southeast Asia, Australia, New Zealand, the Southern USA and some Paci?c islands (Thomas & Room, 1986).

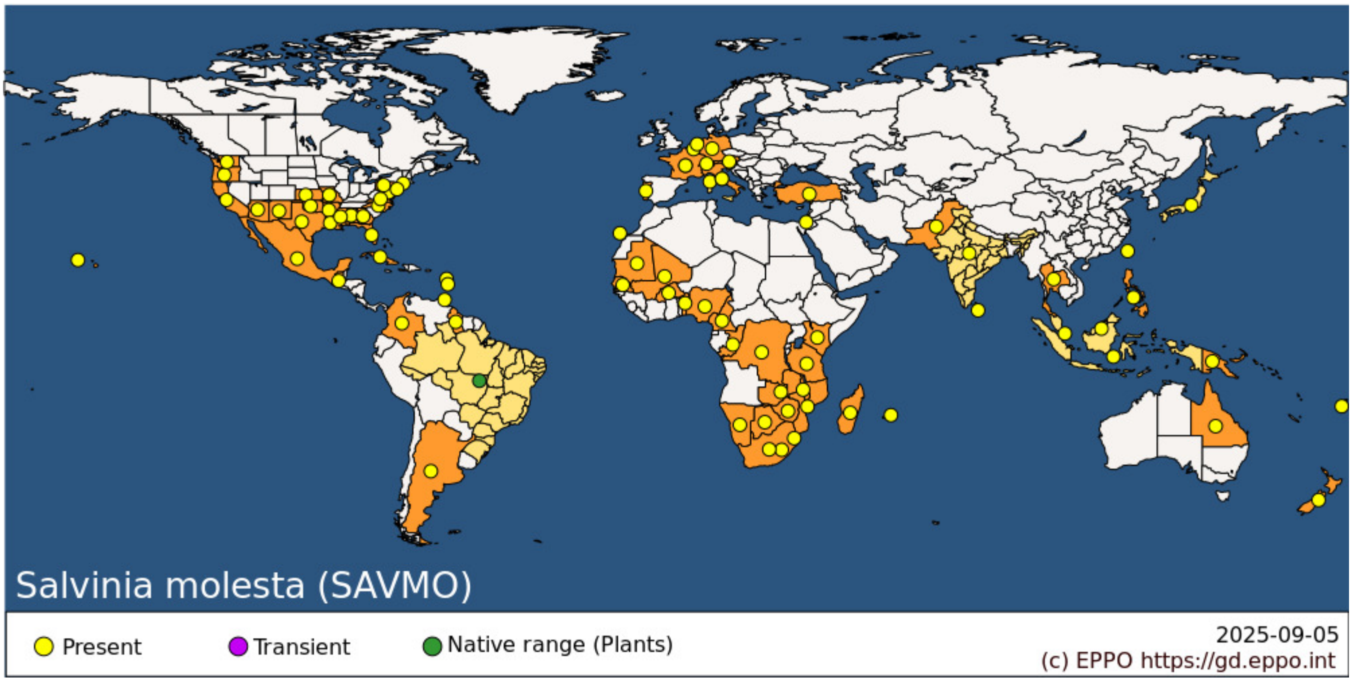
The ?rst population established outside the native range was in Sri Lanka in 1939 where it was introduced via the Botanical Department of the University of Colombo (Oliver, 1993). *Salvinia molesta* was introduced into Papua New Guinea in 1972, where a few plants were introduced into the Sepik River ?oodplain. Eight years later, the infestation had reached over 250 km2 (Oliver, 1993). Sundaresan & Reddy (1979) reported on two large infestations in Fiji (the Rewa Delta and the Waidalice River), noting impacts on rice ?elds. In Australia, *S. molesta* was ?rst recorded in 1952. By 1976 the species had spread to many rivers and lakes, overtaking the occurrence of other aquatic plant pests such as *Eichhornia crassipes* (Cronk & Fuller, 2001).

Major infestations of *S. molesta* have occurred in lake/ riparian systems in Africa, including the Chobe–Linyata–Kwando River systems, Lake Naivasha and Lake Kariba on the Zambezi. In the case of the latter, in 1962 at the peak occurrence of the species, over a quarter of the lake was covered by the plant (McFarland *et al.*, 2004).

Salvinia molesta was ?rst observed in the wild in the USA in South Carolina in 1995 (Jacono & Pitman, 2001). In 1998, the species was identi?ed in Texas and Louisiana; both states are still dealing with new infestations of this weed. Florida, Alabama, Mississippi, Hawaii, Arizona, California and Georgia all reported initial infestations of S. molesta in 1999. North Carolina ?rst reported a population of *S. molesta* in 2000. The latest state to report the presence of *S. molesta* was Virginia in 2004. In Florida, before the species had been recorded in the wild it had been intercepted at two aquatic plant nurseries as a contaminant of aquatic plant shipments from Sri Lanka (Oliver, 1993).

In the EPPO region, *S. molesta* has been found in Austria, Belgium, France (Corsica), Germany, Italy, Israel, the Netherlands and Portugal, but it is not clear if reports represent established populations. In France, the species was ?rst found in Corsica in 2010, in a water reservoir (Paradis & Miniconi, 2011). In 2013, it was also found in a small ditch near the Salagou Lake, 40 km northwest of Montpellier where a few plants were observed together with *Myriophyllum aquaticum*. Following identi?cation, the plants were immediately removed (G Fried, pers. comm., 2016). In Italy, the species was found in the Fosso del Acqua Calda canal near Pisa in 2000 (Garbari *et al.*, 2000), and in the Rome area (the Pozzo del Merro lake, Lazio) in 2003 (Buccomimo *et al.*, 2010; Giardini, 2004). *Salvinia molesta* was eradicated from Rome in 2012 (CABI, 2016). In Portugal the species is found in Odemira, in the Algarve (EPPO, 2016). In Germany, it is reported as a casual from the Rhineland-Palatinate (GEFD, 2016). It is not clear whether this species remains present in older localities, such as that noted by Margot (1983) in Belgium (Verloove, 2006). In Israel, *S. molesta* is classi?ed as a casual species (Dufour-Dror, 2012).

Distribution



EPPO Region: Austria, Belgium, France (mainland, Corse, Mainland France), Germany, Israel, Italy (mainland, Mainland Italy), Netherlands, Portugal (mainland), Spain (Islas Canárias), Switzerland, Türkiye
Africa: Benin, Botswana, Burkina Faso, Cameroon, Congo, Congo, The Democratic Republic of the, Eswatini, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa, Tanzania, United Republic of, Zambia, Zimbabwe
Asia: India, Indonesia, Israel, Japan, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand
North America: Mexico, United States of America (Alabama, Arizona, Arkansas, California, Connecticut, Florida, Georgia, Hawaii, Kansas, Louisiana, Maryland, Mississippi, Missouri, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Pennsylvania, Texas, Virginia, Washington)
Central America and Caribbean: Cuba, Guadeloupe, Guatemala, Martinique, Trinidad and Tobago
South America: Argentina, Brazil, Colombia, Guyana
Oceania: Australia (Queensland), Fiji, New Zealand, Papua New Guinea

MORPHOLOGY

Plant type

Perennial ?oating aquatic fern.

Description

Salvinia molesta is a free-?oating fern with three growth stages (primary, secondary and tertiary) (Julien *et al.*, 2009). The small-leaved primary stage is typical of plants invading open water. The secondary form is slightly larger with leaves slightly folded, and the tertiary stage is typical of mature stands with larger deeply folded and densely packed leaves. Misidenti?cation may occur between *Salvinia natans* and the primary and secondary stage of *S. molesta* given that *S. natans* will be the *Salvinia* species that is most familiar to botanists in the EPPO region. According to Kasselmann (1995), *S. molesta* is especially misidenti?ed as *Salvinia auriculata*.

The species' fronds are positioned in whorls of three along a rhizome, with individual plants growing up to 30 cm. One of the fronds is submerged and is root-like in appearance. The two ?oating fronds have oblong to obovate or orbicular lamina, a rounded or cordate base and emarginate apex; these fronds typically measure around 2.5 x (2.4–3) cm (length x width; Lin *et al*., 2013), although the ?oating fronds of some forms can be considerably smaller, and larger forms (up to 5 cm, rarelylarger) have also been reported (Harley & Mitchell, 1981). The ?oating fronds are oppositely positioned, and are either ?at or infolded along the costa; when infolded their appearance has been compared to the wings of a butter?y. Egg-beater-shaped hairs on the upper (adaxial) surface of the ?oating leaves are a notable feature of *S. molesta*, and serve to distinguish it from the European native *S. natans*, in which the ends of the 'beater' are not joined together (Booy *et al*., 2015); *S. natans* is also a smaller species. As plants develop lateral branches in crowded conditions they can become interlocked, producing a mat; additional growth can lead to plants overgrowing each over, resulting in mats that are 3–4 plants thick (Harley & Mitchell, 1981). Mats as thick as 1 m have also been reported as a result of the overgrowing and interweaving of dead and living plants (Harley & Mitchell, 1981; Thomas & Room, 1986). Sporocarps are in long chains of up to 55, around 1 mm in diameter; however, the plant is sterile, and the sporocarps contain only empty sporangia or deformed spores.

BIOLOGY AND ECOLOGY

General

Mats of *S. molesta* can cause similar problems to those caused by excessive growth of other ?oating plants; for example, they can reduce access to the water for recreation; interfere with various engineering structures such as weirs, ?oodgates or locks; block drains and cause ?ooding; stop livestock reaching water; prevent photosynthesis in the water below the mat; degrade potable water; have negative impacts on native animals and plants more generally by signi?cantly altering aquatic ecosystems; reduce the aesthetic appeal of water bodies; and favour the spread of certain diseases by mosquitoes and snails (Mitchell, 1978; Oliver, 1993).

Habitats

Salvinia molesta is most often found in stagnant or slow?owing waters such as lakes, slow-?owing rivers or streams, wetlands, rice paddies, irrigation channels, ditches, ponds and canals (EPPO, 2016).

Environmental requirements

Salvinia molesta grows best in sheltered, still, tropical waters, but in temperate climates the plant can withstand occasional frosts and freezing of the water surface (Harley & Mitchell, 1981). However, the plant is killed if very low temperatures persist (Harley & Mitchell, 1981). Owens *et al.* (2004) report that plants can withstand short (48 h) air frosts of -3°C in experimental ponds, and that complete freezing of the water layers occupied by *S. molesta* was required to completely destroy the plant. Note that the mats often formed by this species can increase its resistance to frosts above the level that would be expected from its intrinsic physiological tolerance; however, below 10°C growth rates are markedly reduced, and dense mats have apparently not been observed (Harley & Mitchell, 1981).

In the USA, thick mats of the plant (up to 30 cm) can withstand temperatures of -10°C for periods of 48–72 h (M Netherland, US Army Engineer Research and Development Center, pers. comm., 2016). Other work using growth chambers has indicated that *S. molesta* is killed when its buds are exposed to temperatures of ?-3 or >43°C for more than 2–3 h (Whiteman & Room, 1991).

Salvinia molesta will tolerate a wide range of variation in water nutrient content, but its rate of growth is most rapid in nutrient-rich conditions. Plants can survive in waters with a salinity of around 20% of that of sea water, although rates of growth are decreased under these conditions (Harley & Mitchell, 1981). With respect to the above information, it is worth noting that experiments and observations relating to the environmental requirements of *S. molesta* may not necessarily cover the entire range of its niche, particularly if invasive populations around the world represent different genotypes or independent hybridization events. In some waters the species can alter the water chemistry from a more alkaline to an acidic habitat, which favours its growth (Owens *et al.*, 2004). The optimum growth rate is in waters around pH 6–7 (Cary & Weerts, 1984; McFarland et al., 2004; Owens et al., 2004). *Salvinia molesta* is capable of high relative growth rates: reported doubling times for leaves are 2.2 days in mid-summer and 40–60 days in winter for Queensland, Australia (Farrell, 1979).

Natural enemies

There are no known natural enemies for *S. molesta* within the EPPO region. According to McFarland *et al.* (2004), the weevil *Cyrtobagus salviniae* Calder and Sands is recognized throughout the world as the method of choice for management of *S. molesta.* The insect has been released in 22 countries around the world including Australia, Fiji, India, Kenya, Namibia, South Africa, Sri Lanka, the USA, Zambia and Zimbabwe (Doeleman, 1990).

Uses and bene?ts

Salvinia molesta is widely sold as an ornamental species within the EPPO region. The species is also sold/exchanged between aquarists. The species regularly features on aquatic plant websites.

Harley & Mitchell (1981) state that the dense growth of the plant could be used for removing excess nutrients or pollutants from water bodies, with the removed biomass being a ‘satisfactory’ mulch. However, this methodology is rarely practised due to it being generally found to be uneconomical (McFarland *et al.*, 2004). Vandecasteele *et al.* (2005) and Henry-Silva & Camargo (2006) argued that the plant was ef?cient in the removal of nutrients (mainly total nitrogen and total phosphorus). In addition, Vandecasteele *et al.* (2005) highlight that the potential of using the biomass as plant compost, in biogas production and for animal feed should be considered.

PATHWAYS FOR MOVEMENT

The pathway plants for planting is considered the main entry pathway into the EPPO region (EPPO, 2017). From this pathway, individuals may transfer to suitable habitats through either intentional introduction into the environment or unintentionally through the disposal of aquarium material. In addition to the aforementioned pathways, there is the potential that the species may enter the EPPO region as a contaminant of leisure equipment, for example ?shing or canoeing gear (EPPO, 2017). Although this is not likely to be a signi?cant pathway, awareness-raising campaigns on the movement of invasive alien plants by this pathway may help to reduce its entry along this pathway. For example, the ‘Check, Clean and Dry’ campaign in Great Britain highlights the need to inspect and treat recreational material following use.

IMPACTS

Effects on plants

Mats of *S. molesta* can cause similar problems to those caused by excessive growth of other ?oating plants; for example, mats will prevent photosynthesis in the water below the mat (the impact in any given situation will depend on the thickness of the mat). *Salvinia molesta* can increase sedimentation by slowing the water ?ow, especially in shallow water bodies. Mat formation can have negative impacts on native animals and plants more generally by signi?cantly altering aquatic habitats, this can result in the creation of ?oating ‘sudd’ islands in larger water bodies, or succession to terrestrial habitat for smaller areas (Cook & Gut, 1971; Thomas, 1981). In general, dense monospeci?c growth of any aquatic plant species can incur impacts on native plant communities (Carpenter & Lodge, 1986). This can completely transform and alter trophic dynamics, resulting in long-term changes.

Environmental and social impact

The presence of a mat of *S. molesta* is likely to degrade the water quality beneath it by blocking sunlight, resulting in decreases in dissolved oxygen and pH, and increases in concentrations of CO2 and H2S (Mitchell, 1969; McFarland *et al.*, 2004). Decomposition may further decrease oxygen levels, affecting ?sh and other organisms (Hattingh, 1961). The combination of a high growth rate with slow decomposition is likely to signi?cantly affect water body nutrient dynamics, with likely impacts on all trophic levels (Oliver, 1993). The accumulation of *S. molesta* litter at the bottom of a water body may also reduce habitat suitability for breeding ?sh (Sculthorpe, 1985). McFarland *et al.* (2004) note the impacts of *S. molesta* on three endangered Hawaiian waterbirds.

Recorded economic impacts include interference with engineering structures such as weirs, ?oodgates or locks; *S. molesta* mats blocking drains and causing ?ooding; mats stopping livestock reaching water; and the degradation of potable water through decomposition processes (Oliver, 1993; McFarland *et al.*, 2004). *Salvinia molesta* has also been reported as a serious pest of rice paddy ?elds in Sri Lanka, Fiji, India and Borneo (Sundaresan & Reddy, 1979; Thomas & Room, 1986; GISP, 2007). However, it is not clear if these impacts can occur in intensive agricultural systems.

Salvinia molesta mats can reduce access to the water for recreation (e.g. swimming, ?shing, boating or canoeing) and reduce the aesthetic appeal of water bodies; in addition, water bodies altered by *Salvinia* mats may favour the spread of diseases such as elephantiasis, encephalitis, malaria and dengue fever (Oliver, 1993) by providing habitat for the mosquito vectors. This may also apply to the snail-mediated disease bilharzia (M Hill, Department of Zoology and Entomology, Rhodes University, ZA, pers. comm., 2016).

CONTROL

Manual control has been successful in reducing infestations, but annual repetition has been required to maintain control (Cook, 1976; Murphy, 1988). Hand removal and giant nets have been used in Australia (Miller & Pickering, 1980). Oliver (1993) concludes that mechanical harvesting is not economically competitive compared to chemical control, and that the large biomass associated with severe infestations can make the use of both harvesting machines and hand removal impractical.

Physical removal using booms to accumulate or control the location of mats and machines to collect and remove the weed have been used in many instances, though rarely with great success and always at great expense, for example on the Hawkebury River, Australia (Coventry, 2006).

Chemical control would require repeated application where all plants need to be treated otherwise re-infestation is likely to occur. Oliver (1993) reviewed chemical control, noting that glyphosate (Mitchell, 1979), diquat (Kam-Wing & Furtado, 1977) and 2,4-D have all been successfully used to control, or to contribute to the control of, *S. molesta* in different parts of the world. Detergents and mixtures of detergents with other agents have also been used (Oliver, 1993). Surfactants are normally used to increase plant penetration of chemical agents. Emierine et al. (2010) showed that *S. molesta* was not controlled by imazamox under a controlled experiment. Control of *S. molesta* did not exceed 39% with imazamox or imazapyr but was 89% with glyphosate. It should be highlighted that the availability of products containing these active substances will vary nationally and other products may be available and effective. Indications of the approved uses for each active substance may be incomplete. Products should be used following the instructions on the label and in line with the relevant plant protection product regulations.

Apart from the weevil *C. salviniae*, other species considered as biological control agents include the aquatic grasshopper *Paulinia acuminata* De Geer, the pyralid moth *Samea multiplicalis* Guenee, the weevil *Cyrtobagus singularis* Hustache and the grass carp *Ctenopharyngodon idella* Val., although none of these has been found to be as effective as *C. salviniae* (Oliver, 1993). A thorough review of the topic is provided by Julien *et al.* (2009).

REGULATORY STATUS

(Europe overall): *S. molesta* has been on the EPPO List of Alien Invasive Plants since 2012; prior to that it was on the EPPO Alert List from 2007. In 2016, *S. molesta* was identi?ed as a priority for risk assessment within the requirements of Regulation 1143/2014 (Branquart *et al.*, 2016; Tanner *et al.*, 2017). A subsequent pest risk analysis concluded that *S. molesta* had a high phytosanitary risk to the endangered area (EPPO, 2017) and was added to the EPPO A2 List of pests recommended for regulation. In 2019, *S. molesta* was included on the (EU) list of Union concern (EU Regulation 1143/2014).

In the Netherlands, a Code of conduct agreed to by organizations representing the horticultural trade means that *S. molesta* should be sold with a warning label. This warning label informs customers about the risks associated with plant invasiveness, and provides instructions for ownership designed to reduce the risk of release of the plant to the environment (Verbrugge *et al.*, 2014). In Spain, the species is included in the list of the prohibited species of the Real Decreto 630/2013; http://www.boe.es/boe/dias/2013/08/03/ pdfs/BOE-A-2013-8565.pdf).

In New Zealand, *S. molesta* is listed on the National Plant Pest Accord prohibiting it from sale and commercial propagation and distribution. The species has been included on many other weed lists in New Zealand (see Howell, 2008, for an overview), but was excluded from a consolidated list by Howell (2008) due to its absence from conservation land. In Australia, *S. molesta* is a Weed of National Signi?cance (Australian Weeds Committee, 2016) and is on the national list of Noxious weeds, with some form of noti?cation or control process listed for every state (Australian Weeds Committee, 2016).

Control of the species in South Africa is enabled by the Conservation of Agricultural Resources (CARA) Act 43 of 1983, as amended, in conjunction with the National Environmental Management: Biodiversity (NEMBA) Act 10 of 2004. *Salvinia molesta* was speci?cally de?ned as a Category 1b ‘invader species’ on the NEMBA mandated list of 2014. Category 1b means that the invasive species ‘must be controlled and wherever possible, removed and destroyed. Any form of trade or planting is strictly prohibited’ (http:// www.environment.gov.za). *Salvinia molesta* is included on the Federal Noxious Weeds List (making it illegal in the US to import or transport the plant between states without a permit). State governments listing the species as an invasive species or noxious weed include Arizona, California, Colorado, Florida, Georgia, Louisiana, North and South Carolina, and Texas (http://www.invasivespeciesinfo.gov/ aquatics/salvinia.shtml#cit; McFarland *et al.*, 2004).

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Datasheet history

This datasheet was first published in the EPPO Bulletin in 2017 and is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity' and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

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