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Invasive Species Compendium

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Invasive Species Compendium

Datasheet report for Alternanthera philoxeroides (alligator weed)

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Pictures

Picture	Title	Caption	Copyright
	Leaves and inflorescence	A. philoxeroides is characterized by dark-green waxy leaves, lance-shaped, opposite, 12-14 x 1.5-2.5 cm. Inflorescence white, ball-shaped, papery, 1.5 cm in diameter.	Bill Parsons
	Growth habit	A. philoxeroides is a perennial herb which grows as an emerged, aquatic plant, rooted in the soil or in the substrate below shallow water.	Bill Parsons
	Growth and spread in water	The plant usually roots in a solid substrate and spreads in a tangled mat over the water surface.	Bill Parsons
	Alligator weed infesting river	Excessive growth of A. philoxeroides covers waterways affecting navigation, preventing access, disrupting flow and adversely affecting the aquatic flora and fauna, as in this river at Baton Rouge, Louisiana, USA.	Bill Parsons

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Identity

Preferred Scientific Name

Alternanthera philoxeroides (Mart.) Griseb.

Preferred Common Name

alligator weed

Other Scientific Names

Achyrantes philoxeroides (Mart.)
Achyranthes paludosa Bunbury
Alternanthera philoxerina Suess.
Bucholzia philoxeroides Mart.
Celosia amphibia Salzm. ex Moq.
Mogiphanes philorexoides D. Parodi
Telanthera philoxeroides (Mart.)
Telanthera philoxeroides (Mart.) Moq.

International Common Names

English: alligator grass; pig weed
Spanish: hierba caiman; hierba lagarto; lagunilla; yerba lagarto
Chinese: xi han lian zi cao
Portuguese: erva jacare; periquito-saracura; piriquito

Local Common Names

Argentina: lagunilla
Australia: mukuna-menna; pannankarni
Brazil: erva de jacare
Ecuador: hierba lagarto
India: phackchet
Mexico: hierba caimán; hierba del Caiman
Sri Lanka: kimbul-wenna
Uruguay: raiz colorado
USA: alligatorweed

EPPO code

ALRPH (Alternanthera philoxeroides)

Summary of Invasiveness

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A. philoxeroides is one of the worst weeds in the world because it invades both terrestrial and aquatic habitats. The aquatic form of the plant has the potential to become a serious threat to rivers, waterways, wetlands and irrigation systems. The terrestrial form grows forming dense mats with a massive underground rhizomatous root system (ISSG, 2016). This weed is extremely difficult to control, is able to reproduce from plant fragments and grows in a wide range of climates and habitats, including terrestrial areas. In aquatic habitats it has deleterious effects on other plants and animals, water quality, aesthetics, vector populations, water flow, flooding and sedimentation. In terrestrial situations, it degrades riverbanks, pastures, and agricultural lands producing massive underground lignified root systems penetrating up to 50-60 cm deep. Currently, *A. philoxeroides* is listed as invasive in the United States, Puerto Rico, France, Italy, India, Sri Lanka, China, Taiwan, Indonesia, Myanmar, Singapore, Australia and New Zealand (Weber et al., 2008; Chandra, 2012; Rojas-Sandoval and Acevedo-Rodriguez, 2015; DAISIE, 2016; USDA-ARS, 2016; USDA-NRCS, 2016; Weeds of Australia, 2016). Once established, it behaves as an aggressive invader with the capability to totally disrupt natural aquatic ecosystems, shoreline vegetation and terrestrial and semi-aquatic environments (ISSG, 2016; USDA-NRCS, 2016).

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Caryophyllales
            - Family: Amaranthaceae
              - Genus: Alternanthera
                - Species: Alternanthera philoxeroides

Notes on Taxonomy and Nomenclature

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The family Amaranthaceae includes 174 genera and about 2500 species distributed worldwide especially in warm and dry temperate areas, the subtropics and saline habitats (Stevens, 2012). *Alternanthera* is a diverse genus (80–200 species) and the second largest in the subfamily Gomphrenoideae of Amaranthaceae. The genus is largely restricted to the American tropics and its highest diversity occurs in South America, but many species also occur in the Caribbean, Central America and Mexico (Sanchez del Pino et al., 2012).

There are two biotypes of *A. philoxeroides* in Florida which differ morphologically: broad- and narrow-stemmed forms. Another two biotypes exist in Argentina which are morphologically similar but differ in chromosome number, the wild form being tetraploid (2n=68) and the weedy form being hexaploid (2n=102) (Parsons and Cuthbertson, 1992).

Description

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Decumbent or ascending glabrate aquatic perennials, the simple or branched, often fistulose stems to 100 cm. long. Leaves glabrous or glabrate, lanceolate to narrowly obovate, apically rounded to acute, basally cuneate, rarely denticulate, 2-10 cm. long, 0.5-2 cm. broad; petioles 1-3 mm. long. Inflorescences of terminal and occasionally axillary white glomes, 10-18 mm. long, 10-18 mm. broad, the usually unbranched peduncles 1-5 cm. long. Flowers perfect, bracts and bracteoles subequal, ovate, acuminate, 1-2 mm. long; sepals 5, subequal, oblong, apically acute and occasionally denticulate, neither indurate nor ribbed, 5-6 mm. long, 1.5-2.5 mm. broad; stamens 5, united below into a tube, the pseudostaminodia lacerate and exceeding the anthers; ovary reniform, the style about twice as long as the globose capitate stigma. Fruit an indehiscent reniform utricle 1 mm. long, 1-1.5 mm. broad (Flora of Panama, 2016).

Plant Type

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Aquatic
Biennial
Broadleaved
Herbaceous
Perennial
Succulent
Vegetatively propagated
Vine / climber

Distribution

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A. philoxeroides is native to South America, principally the Parana River region (Julien et al., 1995), from Guyana to Brazil and northern Argentina (USDA-ARS, 2016). It has been introduced into Europe, North and Central America, the Caribbean, tropical Asia, and Oceania (DAISIE, 2016; ISSG, 2016 OEPP/EPPO, 2016; USDA-ARS, 2016).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Bangladesh (/isc/datasheet/108369)	Present		Introduced		Invasive	Islam et al., 2003; Shaheen et al., 2006	
China (/isc/datasheet/108398)	Present		Introduced		Invasive	, ; Julien et al., 1995; Weber et al., 2008	
-Anhui (/isc/datasheet/108667)	Present		Introduced			Julien et al., 1995	
-Beijing (/isc/datasheet/108668)	Present		Introduced		Invasive	Flora of China Editorial Committee, 2016	
-Fujian (/isc/datasheet/108670)	Present		Introduced			Julien et al., 1995; Flora of China Editorial Committee, 2016	
-Guangdong (/isc/datasheet/108671)	Present		Introduced			Julien et al., 1995	
-Guangxi (/isc/datasheet/108673)	Present		Introduced			Julien et al., 1995	
-Guizhou (/isc/datasheet/108674)	Present		Introduced			Julien et al., 1995	
-Hainan (/isc/datasheet/108675)	Present					Guo and Zhou, 2005	
-Hebei (/isc/datasheet/108677)	Present		Introduced		Invasive	Flora of China Editorial Committee, 2016	
-Hong Kong (/isc/datasheet/108678)	Present		Introduced		Invasive	Wu, 2001	
-Hubei (/isc/datasheet/108676)	Present		Introduced			Julien et al., 1995; Flora of China Editorial Committee, 2016	
-Hunan (/isc/datasheet/108681)	Present		Introduced			Julien et al., 1995; Flora of China Editorial Committee, 2016	
-Jiangsu (/isc/datasheet/108683)	Present					Lou et al., 2005; Flora of China Editorial Committee, 2016	
-Jiangxi (/isc/datasheet/108684)	Present		Introduced			Julien et al., 1995; Flora of China Editorial Committee, 2016	
-Shanghai (/isc/datasheet/108690)	Present					Lu et al., 2005	
-Sichuan (/isc/datasheet/108691)	Present					Zhou et al., 2008; Flora of China Editorial Committee, 2016	
-Yunnan (/isc/datasheet/108698)	Present					Zhang et al., 2002	
-Zhejiang (/isc/datasheet/108699)	Present		Introduced			Julien et al., 1995; Flora of China Editorial Committee, 2016	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
India (/isc/datasheet/108459)	Widespread		Introduced		Invasive	Holm et al., 1979; EPPO, 2014	
-Arunachal Pradesh (/isc/datasheet/108722)	Present		Introduced			Julien et al., 1995; Chandra, 2012	
-Assam (/isc/datasheet/108723)	Present		Introduced			Lal and Sah, 1990; Chandra, 2012	
-Bihar (/isc/datasheet/108724)	Present		Introduced			Lal and Sah, 1990	
-Delhi (/isc/datasheet/108727)	Present		Introduced			Lal and Sah, 1990	
-Himachal Pradesh (/isc/datasheet/108733)	Present		Introduced		Invasive	Chandra, 2012	
-Jammu and Kashmir (/isc/datasheet/108736)	Present		Introduced		Invasive	Chandra, 2012	
-Karnataka (/isc/datasheet/108738)	Present		Introduced			Lal and Sah, 1990	
-Kerala (/isc/datasheet/108737)	Present		Introduced			Julien et al., 1995	
-Madhya Pradesh (/isc/datasheet/108743)	Present		Introduced			Sushil and Kamlesh, 2005	
-Maharashtra (/isc/datasheet/108740)	Present					Das and Singh, 2006	
-Manipur (/isc/datasheet/108742)	Present		Introduced			Julien et al., 1995; Chandra, 2012	
-Meghalaya (/isc/datasheet/108741)	Present					Patel et al., 2005; Chandra, 2012	
-Mizoram (/isc/datasheet/108744)	Present		Introduced		Invasive	Chandra, 2012	
-Nagaland (/isc/datasheet/108745)	Present		Introduced		Invasive	Chandra, 2012	
-Sikkim (/isc/datasheet/108750)	Present		Introduced		Invasive	Chandra, 2012	
-Tamil Nadu (/isc/datasheet/108751)	Present		Introduced			Julien et al., 1995	
-Tripura (/isc/datasheet/108752)	Present		Introduced		Invasive	Chandra, 2012	
-Uttar Pradesh (/isc/datasheet/108753)	Restricted distribution		Introduced			Lal and Sah, 1990; Khanna, 2009	
-Uttarakhand (/isc/datasheet/108754)	Present					Chandra, 2012; Pangtey et al., 2012	
-West Bengal (/isc/datasheet/108755)	Present		Introduced			Lal and Sah, 1990; Chandra, 2012	
Indonesia (/isc/datasheet/108455)	Widespread		Introduced		Invasive	Holm et al., 1979; Waterhouse, 1993; EPPO, 2014	
-Java (/isc/datasheet/108714)	Present		Introduced			Julien et al., 1995	
Japan (/isc/datasheet/108467)	Present					Yamamoto and Kusumoto, 2008	
Laos (/isc/datasheet/108481)	Present		Introduced			Waterhouse, 1993	
Myanmar (/isc/datasheet/108503)	Restricted distribution		Introduced			Sankaran and Ramaseshiah, 1974; Waterhouse, 1993	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Nepal (/isc/datasheet/108524)	Present					Paudel and Kaini, 2003; Ranjit and Suwanketnikom, 2005	
Pakistan (/isc/datasheet/108537)	Present		Introduced			OEPP/EPPO, 2016	
Philippines (/isc/datasheet/108535)	Present		Introduced			OEPP/EPPO, 2016	
Singapore (/isc/datasheet/108557)	Present		Introduced		Invasive	Chong et al., 2009	
Sri Lanka (/isc/datasheet/108485)	Widespread		Introduced	1998	Invasive	Bambaradeniya, 2000	
Taiwan (/isc/datasheet/108590)	Widespread					Li et al., 1997; EPPO, 2014	
Thailand (/isc/datasheet/108580)	Widespread		Introduced		Invasive	Sankaran and Ramaseshiah, 1974; Waterhouse, 1993; EPPO, 2014	
Vietnam (/isc/datasheet/108604)	Present		Introduced			Waterhouse, 1993	
North America							
Mexico (/isc/datasheet/108513)	Widespread		Introduced			Holm et al., 1979; EPPO, 2014	
USA (/isc/datasheet/108597)	Restricted distribution					EPPO, 2014	
-Alabama (/isc/datasheet/108796)	Widespread		Introduced			Coulson, 1977; USDA-NRCS, 2016	
-Arkansas (/isc/datasheet/108797)	Restricted distribution		Introduced			Coulson, 1977; USDA-NRCS, 2016	
-California (/isc/datasheet/108799)	Present		Introduced			Coulson, 1977; EPPO, 2014; USDA-NRCS, 2016	
-Florida (/isc/datasheet/108804)	Widespread		Introduced		Invasive	Coulson, 1977	
-Georgia (/isc/datasheet/108805)	Widespread		Introduced			Coulson, 1977	
-Illinois (/isc/datasheet/108809)	Present		Introduced			USDA-NRCS, 2016	
-Kentucky (/isc/datasheet/108812)	Present		Introduced			USDA-NRCS, 2016	
-Louisiana (/isc/datasheet/108813)	Widespread		Introduced			Coulson, 1977	
-Maryland (/isc/datasheet/108815)	Present		Introduced			Thayer and Pfingsten, 2017	
-Mississippi (/isc/datasheet/108820)	Widespread					Coulson, 1977	
-North Carolina (/isc/datasheet/108822)	Widespread		Introduced			Coulson, 1977	
-Oklahoma (/isc/datasheet/108831)	Present		Introduced			USDA-NRCS, 2016	
-South Carolina (/isc/datasheet/108835)	Present		Introduced			Coulson, 1977; USDA-NRCS, 2016	
-Tennessee (/isc/datasheet/108837)	Restricted distribution		Introduced			Coulson, 1977; USDA-NRCS, 2016	
-Texas (/isc/datasheet/108838)	Widespread		Introduced			Coulson, 1977; USDA-NRCS, 2016	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Virginia (/isc/datasheet/108840)	Restricted distribution		Introduced			Coulson, 1977	
Central America and Caribbean							
Honduras (/isc/datasheet/108451)	Widespread		Introduced			Holm et al., 1979; EPPO, 2014	
Puerto Rico (/isc/datasheet/108541)	Widespread					Gangstad, 1977; EPPO, 2014; Rojas-Sandoval and Acevedo-Rodríguez, 2015	
Trinidad and Tobago (/isc/datasheet/108588)	Present		Introduced			Julien et al., 1995	
South America							
Argentina (/isc/datasheet/108359)	Widespread		Native			Julien et al., 1995; EPPO, 2014	
Bolivia (/isc/datasheet/108379)	Present					Julien et al., 1995; USDA-ARS, 2016	
Brazil (/isc/datasheet/108381)	Widespread		Native			Abud, 1985; Julien et al., 1995; EPPO, 2014	
-Acre (/isc/datasheet/108626)	Present		Native			Senna, 2015	
-Alagoas (/isc/datasheet/108627)	Present					Lorenzi, 1982; Senna, 2015	
-Amazonas (/isc/datasheet/108628)	Present		Native			Lorenzi, 1982; Senna, 2015	
-Bahia (/isc/datasheet/108630)	Present					Lorenzi, 1982; Julien et al., 1995; Senna, 2015	
-Ceara (/isc/datasheet/108631)	Present					Lorenzi, 1982; Senna, 2015	
-Espirito Santo (/isc/datasheet/108632)	Present					Lorenzi, 1982; Senna, 2015	
-Fernando de Noronha (/isc/datasheet/108633)	Present					Lorenzi, 1982	
-Goias (/isc/datasheet/108634)	Present					Lorenzi, 1982; Senna, 2015	
-Maranhao (/isc/datasheet/108635)	Present		Native			Senna, 2015	
-Mato Grosso (/isc/datasheet/108638)	Present					Lorenzi, 1982; Julien et al., 1995; Senna, 2015	
-Mato Grosso do Sul (/isc/datasheet/108637)	Present					Lorenzi, 1982; Senna, 2015	
-Minas Gerais (/isc/datasheet/108636)	Present					Lorenzi, 1982; Senna, 2015	
-Para (/isc/datasheet/108639)	Present					Lorenzi, 1982; Senna, 2015	
-Paraiba (/isc/datasheet/108640)	Present		Native			Senna, 2015	
-Parana (/isc/datasheet/108643)	Present		Native			Lorenzi, 1982; Julien et al., 1995; Senna, 2015	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Pernambuco (/isc/datasheet/108641)	Present					Lorenzi, 1982; Senna, 2015	
-Piaui (/isc/datasheet/108642)	Present		Native			Senna, 2015	
-Rio de Janeiro (/isc/datasheet/108644)	Present					Lorenzi, 1982	
-Rio Grande do Sul (/isc/datasheet/108648)	Present					Lorenzi, 1982; Julien et al., 1995; Senna, 2015	
-Rondonia (/isc/datasheet/108646)	Present		Native			Senna, 2015	
-Roraima (/isc/datasheet/108647)	Present		Native			Senna, 2015	
-Santa Catarina (/isc/datasheet/108649)	Present					Lorenzi, 1982; Julien et al., 1995; Senna, 2015	
-Sao Paulo (/isc/datasheet/108651)	Present					Lorenzi, 1982; Julien et al., 1995	
-Sergipe (/isc/datasheet/108650)	Present		Native			Senna, 2015	
-Tocantins (/isc/datasheet/108652)	Present		Native			Senna, 2015	
Colombia (/isc/datasheet/108399)	Widespread					Holm et al., 1979; EPPO, 2014	
French Guiana (/isc/datasheet/108434)	Present					Julien et al., 1995	
Guyana (/isc/datasheet/108448)	Present					Julien et al., 1995	
Paraguay (/isc/datasheet/108544)	Present					Julien et al., 1995	
Peru (/isc/datasheet/108532)	Present		Native			USDA-ARS, 2016	
Suriname (/isc/datasheet/108568)	Widespread					Julien et al., 1995; EPPO, 2014	
Uruguay (/isc/datasheet/108598)	Widespread					Julien et al., 1995; EPPO, 2014	
Venezuela (/isc/datasheet/108601)	Present		Native			Funk et al., 2007	
Europe							
France (/isc/datasheet/108429)	Present					EPPO, 2014; DAISIE, 2016	
Italy (/isc/datasheet/108464)	Present					Garbari and Pedullà, 2001; EPPO, 2014; DAISIE, 2016	
Oceania							
Australia (/isc/datasheet/108362)	Widespread					EPPO, 2014	
-Australian Northern Territory (/isc/datasheet/108619)	Eradicated		Introduced			Gunasekera and Bonila, 2001	
-New South Wales (/isc/datasheet/108620)	Restricted distribution		Introduced		Invasive	Julien et al., 1995; Gunasekera and Bonila, 2001	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Queensland (/isc/datasheet/108621)	Restricted distribution		Introduced		Invasive	Gunasekera and Bonila, 2001	
-South Australia (/isc/datasheet/108622)	Present		Introduced		Invasive	Gunasekera and Bonila, 2001	
-Tasmania (/isc/datasheet/108623)	Present		Introduced		Invasive	Gunasekera and Bonila, 2001	
-Victoria (/isc/datasheet/108624)	Restricted distribution		Introduced		Invasive	Gunasekera and Bonila, 2001	
-Western Australia (/isc/datasheet/108625)	Present		Introduced		Invasive	Gunasekera and Bonila, 2001	
New Zealand (/isc/datasheet/108528)	Widespread		Introduced		Invasive	Aston, 1973; EPPO, 2014	

History of Introduction and Spread

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In the USA, *A. philoxeroides* was probably introduced in contaminated ship ballast water, with the earliest herbarium specimen dating from South Carolina in 1885. In 1894 it arrived in Florida and in 1897 it was collected near Mobile, Alabama. By the early 1900s, it was recognized as a threat, but became a major threat after 1945 when chemical control of water hyacinth became effective and allowed *A. philoxeroides* to flourish (Coulson, 1977; Langeland et al., 2008). Now it is considered one of the worst aquatic weeds invading southern states (USDA-NRCS, 2016).

A. philoxeroides is present in Asia where it is widespread principally across warm temperate regions. In Sri Lanka *A. philoxeroides* was identified in 1998 and by 2004 it reached provinces at elevations > 2500 m (Jayasinghe, 2008). In China it is spreading across Beijing, Fujian, Guangxi, Hebei, Hubei, Hunan, Jiangsu, Jiangxi, Sichuan, Taiwan, and Zhejiang where it is causing serious impacts on aquatic habitats and famous scenic areas (Flora of China Editorial Committee, 2016). In India, *A. philoxeroides* is spreading across Assam, Bihar, West Bengal, Tripura, Manipur, Andhra Pradesh, Karnataka, Maharashtra, Delhi and Punjab. By 2008, *A. philoxeroides* was reported invading Wular Lake, the largest freshwater lake in India (Masoodin and Khan, 2012).

In Australia *A. philoxeroides* arrived during the 1940s, probably in ships' ballast (Julien and Broadbent, 1980). From initial sites at Botany Bay and Newcastle harbour, it had, by 1979, spread to the Lower Hunter River Valley and to near Albury (Julien et al., 1979). It was also found in backyard gardens of some Asian community groups in Australia who grew it as a leafy vegetable by mistake. It has been used since the 1960's and is now found in all Australian states and territories. The State of Victoria has the highest number of backyard plots (more than 800) of alligator weed in Australia (Gunasekera and Adair, 1999).

In New Zealand, it was first recorded in 1906 and now it can be found invading drains, streams, swamps and similar wet habitats across the country (Bassett et al., 2012; OEPP/EPPO, 2016).

In Europe, *A. philoxeroides* was first recorded in 1971 in France. Initially this species was confined to the southwest of France between the middle of the Gironde Estuary and the middle course of the River Garonne. However in the 2000s new populations were found on the Tarn River and in Sorgues (Provence) in 2013. In Italy *A. philoxeroides* was discovered in 2001 near Pisa, Tuscany. Currently, this species can also be found along the Arno River from Signa to Florence, in Lazio, and in Rome along the Tevere River (OEPP/EPPO, 2016).

Risk of Introduction

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The risk of introduction of *A. philoxeroides* is very high. Because this species is able to grow in both aquatic and terrestrial habitats, grows vigorously and spreads from floating fragments, it has a great potential to increase its present distribution into new areas. According to Julien et al. (1995) much of Africa, Asia and southern Europe provide a suitable habitat for this weed.

Liu et al. (2017) modelled the potential for further spread of invasive aquatic weeds following China's South to North Water Diversion project, and predict that *A. philoxeroides* has high potential for northward range expansion in China.

Habitat

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A. philoxeroides grows as a weed in both aquatic and terrestrial habitats, and often grows at the interface between these two environments (OEPP/EPPO, 2016). In natural and semi-natural habitats it is prone to become invasive principally in forests, riverbanks and wetlands. It can be found growing along canals, rivers, swamps, lakes, dams, ditches, and wetlands, being rooted to the ground and emerging above the water surface. However, it can also be found in riparian habitats free-floating in dense mats on the water surface. *A. philoxeroides* is also an important weed of wetter pastures and irrigated crops (ISSG, 2016; USDA-NRCS, 2016; Weeds of Australia, 2016).

Habitat List

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Category	Habitat	Presence	Status
Freshwater	Freshwater	Present, no further details	Harmful (pest or invasive)
	Irrigation channels	Present, no further details	Harmful (pest or invasive)
	Lakes	Principal habitat	Harmful (pest or invasive)
	Lakes	Principal habitat	Natural
	Lakes	Principal habitat	Productive/non-natural
	Ponds	Principal habitat	Harmful (pest or invasive)
	Ponds	Principal habitat	Natural
	Ponds	Principal habitat	Productive/non-natural
	Rivers / streams	Principal habitat	Harmful (pest or invasive)
	Rivers / streams	Principal habitat	Natural
	Rivers / streams	Principal habitat	Productive/non-natural
Littoral	Coastal areas	Present, no further details	Harmful (pest or invasive)
	Coastal areas	Present, no further details	Natural
	Coastal areas	Present, no further details	Productive/non-natural
Terrestrial-managed	Cultivated / agricultural land	Present, no further details	Harmful (pest or invasive)
	Cultivated / agricultural land	Present, no further details	Natural
	Disturbed areas	Present, no further details	Harmful (pest or invasive)
	Disturbed areas	Present, no further details	Natural
	Managed forests, plantations and orchards	Present, no further details	Harmful (pest or invasive)
	Managed forests, plantations and orchards	Present, no further details	Natural
	Protected agriculture (e.g. glasshouse production)	Present, no further details	Harmful (pest or invasive)
	Urban / peri-urban areas	Present, no further details	Harmful (pest or invasive)
	Urban / peri-urban areas	Present, no further details	Natural
	Urban / peri-urban areas	Present, no further details	Productive/non-natural
Terrestrial-natural/semi-natural	Natural forests	Present, no further details	Harmful (pest or invasive)
	Natural forests	Present, no further details	Natural
	Riverbanks	Principal habitat	Harmful (pest or invasive)
	Riverbanks	Principal habitat	Natural

Category	Habitat	Presence	Status
	Riverbanks	Principal habitat	Productive/non-natural
	Wetlands	Principal habitat	Harmful (pest or invasive)
	Wetlands	Principal habitat	Natural
	Wetlands	Principal habitat	Productive/non-natural

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Hosts/Species Affected

A. philoxeroides primarily affects floating aquatic plants and pastures but submerged and emerged aquatic plants are also affected.

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Host Plants and Other Plants Affected

Plant name	Family	Context
Ipomoea batatas (sweet potato) (/isc/datasheet/28783)	Convolvulaceae	Main
Oryza sativa (rice) (/isc/datasheet/37964)	Poaceae	Main
pastures (/isc/datasheet/38982)		Main
Zea mays (maize) (/isc/datasheet/57417)	Poaceae	Main

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Growth Stages

Pre-emergence, Seedling stage, Vegetative growing stage

Biology and Ecology

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Genetics

It has been suggested that the populations of *A. philoxeroides* within and outside its native distribution range are composed of a complex of hybrids. Consequently, the chromosome number for *A. philoxeroides* differs among populations with reports varying from $2n$=66 to $2n$=100 (Xu et al., 1992; Sosa et al., 2008).

Reproductive Biology

A. philoxeroides reproduces both sexually and asexually within its native distribution range, but propagates primarily through vegetative means in its introduced range. In this species, traits associated with sexual reproduction become degraded for sexual dysfunction, with flowers possessing either pistillate stamens or male-sterile anthers. Degradations of sexual characters for loss of sexuality commonly take place in clonal plants; such is the case of *A. philoxeroides* populations spreading mainly by vegetative (clonal) propagules (Zhu et al., 2015).

Physiology and Phenology

A. philoxeroides is a perennial, fast-growing, amphibious herb (ISSG, 2016.) Maximum growth of *A. philoxeroides* occurs during the warmer summer months with growth initiating from parent stock, usually rooting in a solid substrate and spreading in a tangled mat over the water surface. In early winter, emergent stems lose many leaves and become prostrate forming part of the mat that supports the next season's growth. Flowering occurs from mid to late summer (Julien and Broadbent, 1980). The plant does not always set viable seed under natural conditions; but reproduces vegetatively from axillary buds at each node (Julien and Broadbent, 1980).

Activity Patterns

A. philoxeroides grows as an emerged, aquatic plant, rooted in the soil or in the substrate below shallow water. Roots are short and filamentous in water, rising mainly from the nodes. It also grows in terrestrial habitats where its high growth-rates allow it to displace native vegetation and easily become the dominant species. This plant has an amazing ability to grow vigorously forming a massive underground rhizomatous root system that is difficult to control. When growing in terrestrial conditions, this species can survive without any water for several months (Gunasekera and Adair, 2000).

Environmental Requirements

A. philoxeroides prefers to grow at temperatures around 30°C, and growth is suppressed at temperatures below 7°C. However, the species can tolerate mean annual temperatures ranging from 10 to 20°C (OEPP/EPPO, 2016). The photosynthetic optimum for this species occurs between 30°C and 37°C and light saturation at 1000 µmol photons m^{-2} s^{-1} (OEPP/EPPO, 2016), but it can adapt to low light conditions (Weber, 2003). It can tolerate cold winters, but cannot survive prolonged freezing temperatures (Langeland et al., 2008). It has been observed growing in water with pH ranging from 4.8 and 7.7 and it is fairly salt tolerant and can survive in upper tidal beaches and other saline conditions (10-30% that of sea water). *A. philoxeroides* grows well in high-nutrient (eutrophic) conditions, but can survive in areas with low nutrient availability (Weber, 2003; Langeland et al., 2008).

Climate

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Climate	Status	Description	Remark
Af - Tropical rainforest climate	Preferred	> 60mm precipitation per month	
Am - Tropical monsoon climate	Preferred	Tropical monsoon climate (< 60mm precipitation driest month but > (100 - [total annual precipitation(mm}/25]))	
As - Tropical savanna climate with dry summer	Preferred	< 60mm precipitation driest month (in summer) and < (100 - [total annual precipitation{mm}/25])	
Aw - Tropical wet and dry savanna climate	Preferred	< 60mm precipitation driest month (in winter) and < (100 - [total annual precipitation{mm}/25])	
Cs - Warm temperate climate with dry summer	Tolerated	Warm average temp. > 10°C, Cold average temp. > 0°C, dry summers	
Cw - Warm temperate climate with dry winter	Tolerated	Warm temperate climate with dry winter (Warm average temp. > 10°C, Cold average temp. > 0°C, dry winters)	

Air Temperature

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Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	-12	
Mean annual temperature (ºC)	10	20
Mean maximum temperature of hottest month (ºC)	13	25
Mean minimum temperature of coldest month (ºC)	7	15

Rainfall

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Parameter	Lower limit	Upper limit	Description
Dry season duration	3	6	number of consecutive months with <40 mm rainfall
Mean annual rainfall	300	650	mm; lower/upper limits

Rainfall Regime

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Uniform

Soil Tolerances

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Soil drainage

free
impeded
seasonally waterlogged

Soil reaction

acid
alkaline
neutral

Soil texture

heavy
light
medium

Special soil tolerances

infertile
shallow
sodic

Water Tolerances

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Parameter	Minimum Value	Maximum Value	Typical Value	Status	Life Stage	Notes
Water pH (pH)	4.8	7.7		Optimum		
Water temperature (ºC temperature)	10	20	15	Optimum		

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Agasicles hygrophila (/isc/datasheet/3533)	Herbivore				Australia; China; Mississippi; New Zealand; Pacific Islands; Thailand; Florida; Arkansas; North Carolina	
Amynothrips andersoni (/isc/datasheet/5041)	Herbivore				Mississippi; North Carolina; Florida; Arkansas	
Candezea palmerstoni (/isc/datasheet/11154)	Herbivore					
Disonycha argentinensis (/isc/datasheet/19258)	Herbivore					
Junonia lemonias (/isc/datasheet/29283)	Herbivore					
Nanophyes (/isc/datasheet/35697)						
Nimbya alternantherae (/isc/datasheet/110439)	Pathogen			Gilbert et al., 2005		
Psara basalis (/isc/datasheet/44873)	Herbivore	Leaves				
Psara hipponalis (/isc/datasheet/44875)	Herbivore					
Spoladea recurvalis (/isc/datasheet/28245)	Herbivore					
Systena silvestrii (/isc/datasheet/110449)	Herbivore			Cabrera et al., 2007		
Vogtia malloi (/isc/datasheet/56632)	Herbivore				Australia; Mississippi; Florida; Arkansas; North Carolina	

Notes on Natural Enemies

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During South American explorations for biological control agents, over 40 arthropod species were found to feed on *A. philoxeroides* (Coulson, 1977). The flea beetle *Agasicles hygrophila* can cause considerable damage to the aquatic form of *A. philoxeroides* by eating the leaves and boring into the stem, where it pupates. The thrip species *Amymothrips andersoni* produces limited damage to the stands by attacking and deforming the apical leaves. The stem borer *Arcola malloi* (formerly *Vogtia malloi*)) is a small moth that lays its eggs on the apical leaves. The larvae bore into the stem and work their way down the stem, resulting in wilting and drooping of the plant (DiTomaso and Kyser, 2013).

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Means of Movement and Dispersal

Natural Dispersal (Non-Biotic)

A. philoxeroides spreads by seeds and vegetatively by root and stem fragments. However, because seeds are generally not produced in areas outside its native distribution range, most reproduction is vegetative. Fragments are commonly spread downstream by waterways and floods and new plants develop rapidly from any piece of stem or root material containing a node (Langeland et al., 2008; ISSG, 2016; Weeds of Australia, 2016).

Accidental Introduction

A. philoxeroides has been accidentally introduced in the ballast of ships. Stem and root fragments, which have the ability to float, are easily dispersed by floods and water currents. Stem and root fragments can also be dispersed by boats, vehicles, in dumped garden waste, and by animals (ISSG, 2016; Weeds of Australia, 2016). *A. philoxeroides* seed has been found in Europe as a contaminant in bird seed originating from outside the EU, and seedlings have been found contaminating bonsai plants imported from China (OEPP/EPPO, 2016).

Intentional Introduction

A. philoxeroides has been intentionally introduced by humans to be used as an aquarium plant and ornamental aquatic plant (USDA-ARS, 2016).

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Pathway Causes

Cause	Notes	Long Distance	Local	References
Flooding and other natural disasters (/isc/datasheet/109032)	Stem and root fragments	Yes	Yes	Weeds of Australia, 2016
Garden waste disposal (/isc/datasheet/109035)	Stem and root fragments	Yes	Yes	Langeland et al., 2008
Ornamental purposes (/isc/datasheet/109051)	Used as aquarium plant and ornamental aquatic plant	Yes	Yes	USDA-ARS, 2016

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Pathway Vectors

Vector	Notes	Long Distance	Local	References
Clothing, footwear and possessions (/isc/datasheet/108160)		Yes	Yes	
Floating vegetation and debris (/isc/datasheet/109069)	Stem and root fragments	Yes	Yes	Langeland et al., 2008
Land vehicles (/isc/datasheet/109084)	Agricultural and excavation machinery, tyres	Yes	Yes	
Mail (/isc/datasheet/109076)		Yes		
Ship ballast water and sediment (/isc/datasheet/109080)		Yes	Yes	Weeds of Australia, 2016
Soil, sand and gravel (/isc/datasheet/108259)	Mulching materials, top soil	Yes		
Water (/isc/datasheet/109085)	Stem fragments or roots	Yes	Yes	Langeland et al., 2008

Wood Packaging

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Wood Packaging not known to carry the pest in trade/transport
Loose wood packing material
Non-wood
Processed or treated wood
Solid wood packing material with bark
Solid wood packing material without bark

Impact Summary

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Category	Impact
Animal/plant collections	Negative
Animal/plant products	Negative
Biodiversity (generally)	Negative
Crop production	Negative
Cultural/amenity	Negative
Economic/livelihood	Negative
Environment (generally)	Negative
Fisheries / aquaculture	Negative
Forestry production	Negative
Human health	Negative
Livestock production	Negative
Native fauna	Negative
Native flora	Negative
Rare/protected species	Negative
Tourism	Negative
Trade/international relations	Negative
Transport/travel	Negative

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Economic Impact

A. philoxeroides is a problem in 30 countries. It is a serious weed in eight of these and a major weed in the others. It threatens the turf industry in the Sydney basin, Australia, and the vegetable industry in the Hawkesbury Nepean catchment. The plant can be a problem in rice paddies (Waterhouse, 1993) and is seen as a major threat to rice crops in southwestern New South Wales (Weeds of Australia, 2016). It has been estimated that the costs to agriculture in New South Wales could be as high as Aus$250 million per annum if the species was to reach its potential distribution in this state (Weeds of Australia, 2016).

On land, it invades and competes with pastures and this provides a source of further spread. Although it is grazed by cattle in Australia, it is not considered desirable in pastures (Julien and Chan, 1992) and is a declared noxious weed in all mainland states and territories (Parsons and Cuthbertson, 1992) as well as a weed of national significance in Australia (Thorpe, 1999).

A. philoxeroides infestations have been reported to reduce production of rice by 45%, wheat by 36%, maize 19%, sweet potato 63% and lettuce 47% (OEPP/EPPO, 2016). On average vegetable production is reduced by 5-15% (www.weeds.org.au/natsig.htm).

A. philoxeroides mats impede stream flow and lodge against structures thereby promoting sedimentation which contributes to flooding and structural damage. Infestations can disrupt recreational activities including boating, fishing and swimming.

Environmental Impact

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A. philoxeroides is considered to be one of the worst aquatic weeds in the world. The aquatic form of the plant has the potential to become a serious threat to waterways, agricultural lands and the natural environment. The terrestrial form grows into a dense mat with a massive underground rhizomatous root system. This species has the potential to completely disrupt aquatic environments by blanketing the surface of the water impeding light penetration and gaseous exchange with adverse effects on flora and fauna (ISSG, 2016). *A. philoxeroides* also promotes sedimentation and flooding leading to a reduction in water quality (i.e. reduced oxygen levels in the water). When growing on land it also grows forming a dense mat of vegetation with a mass of creeping underground stems and is capable of out-competing all but the most robust plant species. It quickly displaces native plants and can be harmful to the native animals that rely on them (Weeds of Australia, 2016).

Impact on Biodiversity

In China, *A. philoxeroides* has been shown to decrease the stability of the plant community and, over time, permanently displace native species (Guo and Wang, 2009). In India, *A. philoxeroides* is reducing macrophyte species richness by up to 30% when the infestation was high. In New Zealand, an increasing cover of *A. philoxeroides* decreased the cover of native plant species, resulting in loss of native species (Bassett et al., 2012). In a study at different latitudes in China, small-scale invasion of *A. philoxeroides* was associated with higher species diversity, but community diversity was lower when *A. philoxeroides* species cover exceeded 36% (Wu et al., 2016). Zhang et al. (2010) also demonstrate reduced plant species diversity in severely invaded communities.

In Australia, *A. philoxeroides* is already an important environmental weed invading New South Wales, Victoria and Queensland. It is regarded as one of the worst weeds in Australia where it is currently having the greatest impact in New South Wales, where the total infested area is now estimated at 3,950 hectares. *A. philoxeroides* has also been found at several hundred sites in Victoria and is listed among the top 50 most invasive plant species in Queensland (Weeds of Australia, 2016). In New Zealand it is also noted to be harmful to native biodiversity and it is replacing most other herbaceous species on water and dry land. It also causes silt accumulation, obstructs water usage, and causes flooding. Rotting vegetation degrades habitats for native aquatic fauna and flora.

In the United States, *A. philoxeroides* is considered to be one of the worst aquatic weeds and is listed as a noxious weed in 15 states (USDA-NRCS, 2016). In southern states such as Florida and South Carolina it grows forming dense tangled mats that overtop native aquatic plants and out-compete them for sunlight. It eventually replaces desirable native species and can significantly alter the aquatic and riverine ecology of heavily infested areas. This species also invades drains, streams, swamps and similar wet habitats (USDA-NRCS, 2016).

Social Impact

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Thick mats of *A. philoxeroides* prevent access to and use of water, cause health problems by providing habitats for mosquitoes and degrade natural aesthetics. Also, the thick mats of the weed create a dangerous hazard for swimming, boating, rowing and other water sports. Excessive growth of *A. philoxeroides* affects irrigation and fisheries; it also covers waterways affecting navigation, preventing access, disrupting flow and adversely affecting the aquatic flora and fauna (Julien and Chan, 1992). Cultural services can be degraded by the infestation of scenic areas and waterbodies by *A. philoxeroides* (OEPP/EPPO, 2016).

The ability of *A. philoxeroides* to absorb heavy metals is a problem in countries such as Myanmar, Sri Lanka, Australia, and Philippines where it is used as food (Parsons and Cuthbertson, 1992).

Risk and Impact Factors

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Invasiveness

Proved invasive outside its native range
Has a broad native range
Pioneering in disturbed areas
Long lived
Reproduces asexually

Impact outcomes

Negatively impacts human health
Negatively impacts animal health
Negatively impacts livelihoods

Likelihood of entry/control

Highly likely to be transported internationally accidentally
Highly likely to be transported internationally deliberately
Difficult to identify/detect as a commodity contaminant
Difficult to identify/detect in the field

Uses List

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Animal feed, fodder, forage

Fodder/animal feed

General

Ornamental
Pet/aquarium trade

Medicinal, pharmaceutical

Traditional/folklore

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Similarities to Other Species/Conditions

A. philoxeroides is superficially quite similar to *A. sessilis*, but the latter is only an annual species and the clusters of flowers are sessile in the leaf axils, not on peduncles. Members of the genus *Ludwigia* spp. may be confused with *A. philoxeroides* due to a similar growth habit (Flanagan, 1991; Julien and Broadbent, 1980). *A. philoxeroides* has a similar appearance to *Persicaria decipiens* (smartweed) and *Tradescantia albiflora* (wandering jew) in Australia (Gunasekera, 1999). Weeds of Australia (2016) lists differences between *A. philoxeroides* and several native and introduced species of *Alternanthera*. The native Australian joyweeds (e.g. *Alternanthera denticulata* and *Alternanthera nana*) can be easily distinguished from terrestrial *A. philoxeroides* plants by the fact that their whitish flower clusters are stalkless.

The water primroses (*Ludwigia adscendens* and *Ludwigia peploides* subsp. *montevidensis*) often form similar dense mats of vegetation out over the water surface, but can be distinguished by their alternately arranged leaves, larger four-petalled flowers (about 25 mm across) and elongated fruit (Weeds of Australia, 2016).

Prevention and Control

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Prevention

In New Zealand, *A. philoxeroides* is included in the National Pest Plant Accord list, which bans the sale, propagation and distribution of the plant throughout New Zealand. In Australia, it is a prohibited species whose propagation and supply is prohibited, and legislation requires the species to be controlled and/or eradicated. In the USA, the species has varying classifications at federal or state levels (OEPP/EPPO, 2016).

Eradication

In 1992, *A. philoxeroides* was recorded and eradicated from Brisbane and Queensland (Parsons and Cuthbertson, 1992). An infestation in Canberra's Lake Ginninderra was also found and eradicated (Julien et al., 1995).

Control

Mechanical control

Mechanical control methods such as using a cookie cutter, flail chopper, hand removal, harvesting, hand cutter, or rotovation are good for clearing water ways, but unless all fragments of the stems are collected these management practices could exacerbate the problem. Since *A. philoxeroides* reproduces vegetatively, if any fragments move downstream they can develop into another colony ((DiTomaso and Kyser, 2013).

Mechanical harvesting and ploughing are not suitable control methods for *A. philoxeroides* because the weed is able to spread from cut stems and roots (Julien and Broadbent, 1980).

Biological control

A. philoxeroides has been the subject of successful biological control in the USA, Australia, New Zealand and Thailand. There is an extensive biocontrol programme in China. Partial control of the species has been achieved in New Zealand by biocontrol methods (Hayes et al., 2013).

Amynothrips andersoni, a biocontrol agent originally from Argentina, has been introduced into the USA; it is established in Florida, Georgia and South Carolina. It has been released in Alabama, California, Mississippi and Texas, but Julien (1992) could not confirm establishment in these states. Thayer and Pfingsten (2017) report that while biocontrol agents have been successful in managing *A. philoxeroides* in the USA, the effectiveness of *A. andersoni* is questionable as the insect is flightless and rarely seen on wild populations.

Agasicles hygrophila, another biocontrol agent originally from Argentina, has been introduced into other countries. In Australia, it is established and successfully controls *A. philoxeroides* in aquatic habitats. In New Zealand, it destroys most foliage of the weed annually. In Thailand, it has spread around Bangkok and the lower central plain area producing excellent control of *A. philoxeroides*. In the USA, this biocontrol agent is generally successful in controlling the weed in Florida, Louisiana and Texas; it is also well established in South Carolina, Georgia, Alabama and Mississippi (Julien, 1992). Thayer and Pfingsten (2017) say that this beetle along with other introduced insects has provided “exceptional control” of *A. philoxeroides* in the USA, but that the northern spread of the weed is beyond the range of *A. hydrophila*’s ability to overwinter. The beetle is, however, collected annually in St. Johns River in Florida to ship to areas of the country where the biocontrol agent does not overwinter and *A. philoxeroides* persists.

Tests of specificity of *A. hygrophila* in China have confirmed that the beetle cannot complete its life cycle on plants other than *A. philoxeroides* and *Alternanthera sessilis* (Lu et al., 2012; Zhao et al., 2013). Li and Ye (2006) suggest that *Agiscles hygrophila* has been successful in limiting growth of *A. philoxeroides* in water but not on land. Ma et al. (2013)

report that since the first introduction of *A. hygrophila* from Florida to China in 1987, the genetic diversity of the control agent has decreased. It is suggested that genetic diversity should be considered in planning introduction and long-term maintenance of populations.

Arcola malloi (formerly *Vogtia malloi)* is also from Argentina and was introduced into Australia in 1977 where it has become established and spread through the aquatic habitat. It was released unsuccessfully in New Zealand in 1984, and again in 1987; it is now well established and reducing the spread of *A. philoxeroides* at three sites (Julien, 1992). In the USA, it is established in Arkansas, Florida, Louisiana, South Carolina and Texas. In Mississippi, it reduces floating mats by 50-90%, infestations are, however, uneven and may cycle over several years. Thayer and Pfintsten (2017) quote a 1992 publication by Vogt et al. suggesting that the stem borer *A. malloi* has produced more damage to *A. philoxeroides* in the interior regions of the weed's adventive range than has *Agasicles hygrophila* in the southern and coastal regions. This insect is capable of migrating considerable distances and is the most cold tolerant of the insects used for biocontrol of *A. philoxeroides*.

Hymenia recurvalis removed between 25-50% of the leaf material of *A. philoxeroides* in the mid to late summer of 1976/1977, in the Sydney area of Australia. This was of little consequence as it was after most regrowth had occurred (Julien and Broadbent, 1980).

Candezea palmerstoni killed most of the stem tips of *A. philoxeroides* in several areas near Williamstown, New South Wales, Australia, in the summer of 1977/1978; the damage was not widespread and did not occur in succeeding seasons (Julien and Broadbent, 1980).

Three species (*Hymenia recurvalis, Nanophyes* sp. and *Junonia lemonias*), found feeding on *A. philoxeroides* in Thailand, were not sufficiently damaging to be considered useful as biological control agents (Napompeth, 1991).

Research in China has investigated the pathogenicity of fungal agents against *A. philoxeroides*, including *Alternaria alternata* (Zhou et al., 2016). Use of competing plants has also been studied. Cao et al. (2014) found that *Humulus scandens* strongly inhibited growth of *A. philoxeroides*, and suggest that as an annual herb *H. scandens* can then be eliminated by harvesting before its seeds mature.

Chemical control

A. philoxeroides is more resistant to herbicides than other aquatic macrophytes (Julien and Broadbent, 1980). Parsons and Cuthbertson (1992) reported control, but not eradication, of the weed in rice fields with herbicides including bentazone, bifenox, dicamba, fenoprop, pendimethalin, propanil and triclopyr, without causing serious damage to the crop; 2,4-D has only a temporary effect. Bowmer (1992) reported the following two treatments as effective against the weed: one application of dichlobenil followed 9 months later by metsulfuron; and three sprays over 18 months with metsulfuron or a metsulfuron/glyphosate mixture. However, certain treatments cannot be used close to waterbodies where there is the possibility of water being contaminated.

At Griffith, New South Wales, Australia, glyphosate was used on all aquatic areas, metsulfuron on terrestrial areas and dichlobenil in selected areas where terrestrial plants were growing in shallow ponded water (Milvain, 1995). The herbicides, metsulfuron methyl, glyphosate, dichlobenil and a mixture of glyphosate and metsulfuron methyl have been used to control *A. philoxeroides* infestations in Australia. All naturalized sites associated with water were treated with glyphosate at three 2 monthly intervals (Gunasekera and Bonila, 2001). Dugdale et al. (2010) caution that herbicide treatment can leave viable stem fragments which are capable of colonization. Clements et al. (2014) report control of early invasion stages of *A. philoxeroides* in Australia using glyphosate or metsulfuron-methyl, followed by physical removal after initial treatment. Use of herbicides to control *A. philoxeroides* was reviewed by Dugdale and Champion (2012).

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Contributors

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11/11/16 Updated by:

Julissa Rojas-Sandoval, Department of Botany-Smithsonian NMNH, Washington DC, USA

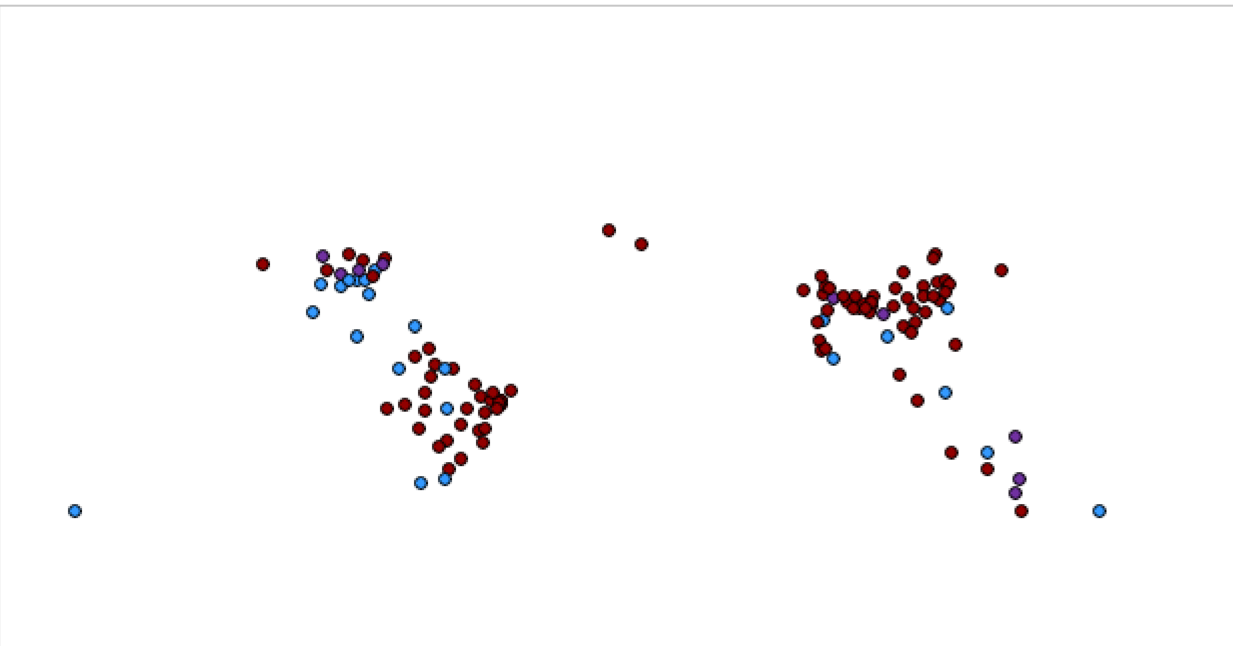
World Map

Analyzed by: Density

Present, no further details

Widespread

Localised



Africa

Asia

Europe

Pacific

North America

Central America

South America

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Coronopus squamatus

Identity

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Preferred Scientific Name

Coronopus squamatus

Local Common Names

Denmark: Almindelig ravnefod
Estonia: lamav teekress
Latvia: Gulscioji varnakoje
Lithuania: zvinaina varnaspeda
Norway: Kr?kekarse
Poland: Wron¢g grzebieniasty
Sweden: Kr?kkrassing

Taxonomic Tree

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Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Dicotyledonae
Order: Capparidales
Family: Brassicaceae
Genus: Coronopus
Species: Coronopus squamatus

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Armenia (/isc/datasheet/108355)	Present					,	
Azerbaijan (/isc/datasheet/108366)	Present					,	
Iraq (/isc/datasheet/108461)	Present					,	
Israel (/isc/datasheet/108457)	Present					,	
Jordan (/isc/datasheet/108466)	Present					,	
Lebanon (/isc/datasheet/108482)	Present					,	
Syria (/isc/datasheet/108572)	Present					,	
Turkey (/isc/datasheet/108587)	Present					,	
Africa							
Algeria (/isc/datasheet/108415)	Present					,	
Egypt (/isc/datasheet/108418)	Present					,	
Libya (/isc/datasheet/108492)	Present					,	
Morocco (/isc/datasheet/108493)	Present					,	
Tunisia (/isc/datasheet/108584)	Present					,	
North America							
USA (/isc/datasheet/108597)	Present					,	
-California (/isc/datasheet/108799)	Present					,	
Europe							
Albania (/isc/datasheet/108354)	Present					,	
Austria (/isc/datasheet/108361)	Present					,	
Belgium (/isc/datasheet/108370)	Present					,	
Bulgaria (/isc/datasheet/108372)	Present					,	
Czech Republic (/isc/datasheet/108409)	Present					,	
Denmark (/isc/datasheet/108412)	Present					,	
Estonia (/isc/datasheet/108417)	Present					,	
Finland (/isc/datasheet/108424)	Present					,	
France (/isc/datasheet/108429)	Present					,	
Germany (/isc/datasheet/108410)	Present					,	
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Hungary (/isc/datasheet/108454)	Present					,	
Ireland (/isc/datasheet/108456)	Present					,	
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Latvia (/isc/datasheet/108491)	Present					,	
Lithuania (/isc/datasheet/108489)	Present					,	
Netherlands (/isc/datasheet/108522)	Present					,	
Norway (/isc/datasheet/108523)	Present					,	
Poland (/isc/datasheet/108538)	Present					,	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Portugal (/isc/datasheet/108542)	Present					,	
Romania (/isc/datasheet/108548)	Present					,	
Russian Federation (/isc/datasheet/108550)	Present					,	
Slovakia (/isc/datasheet/108561)	Present					,	
Spain (/isc/datasheet/108421)	Present					,	
Sweden (/isc/datasheet/108556)	Present					,	
Switzerland (/isc/datasheet/108393)	Present					,	
UK (/isc/datasheet/108431)	Present					,	
Ukraine (/isc/datasheet/108592)	Present					,	

World Map

Analyzed by: Density

Present, no further details

Africa

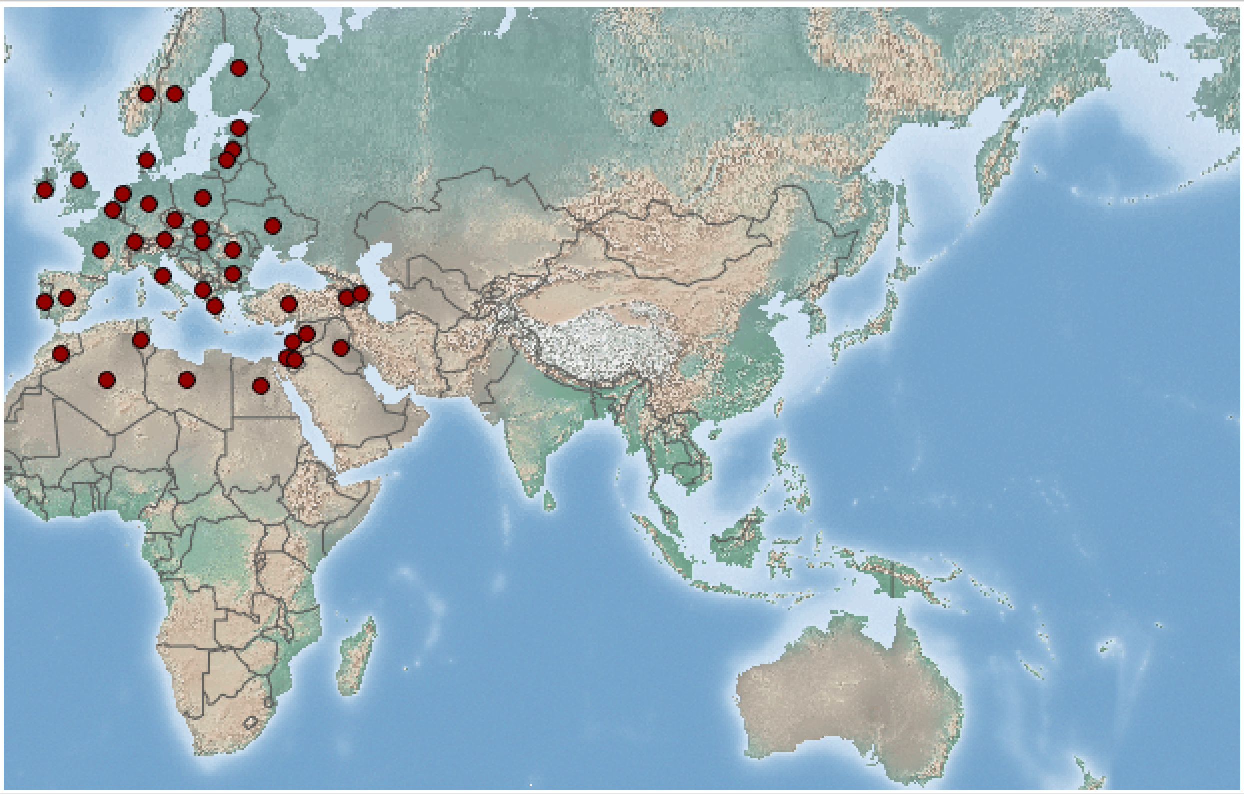
Analyzed by: Density

Present, no further details

Asia

Analyzed by: Density

Present, no further details



Europe

Analyzed by: Density

Present, no further details

Pacific

Analyzed by: Density

Present, no further details

North America

Analyzed by: Density

Present, no further details

Central America

Analyzed by: Density

Present, no further details

South America

Analyzed by: Density

Present, no further details

Date of report: 07 April, 2018

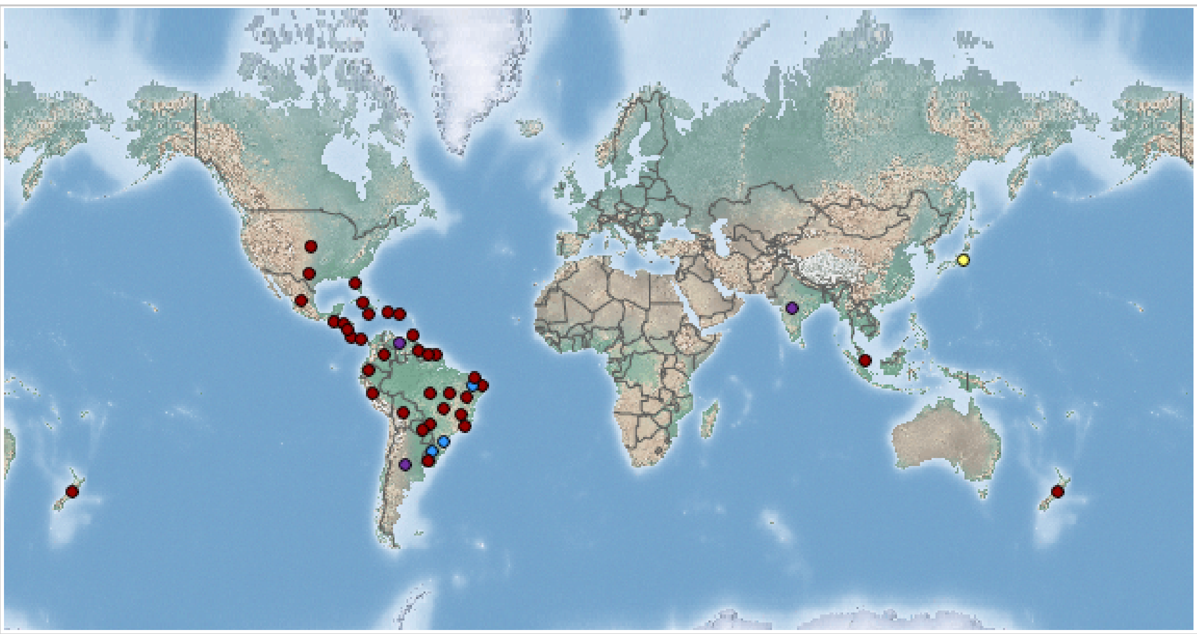
Invasive Species Compendium

Datasheet report for Eichhornia azurea (anchored water hyacinth)

World Map

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread



Africa

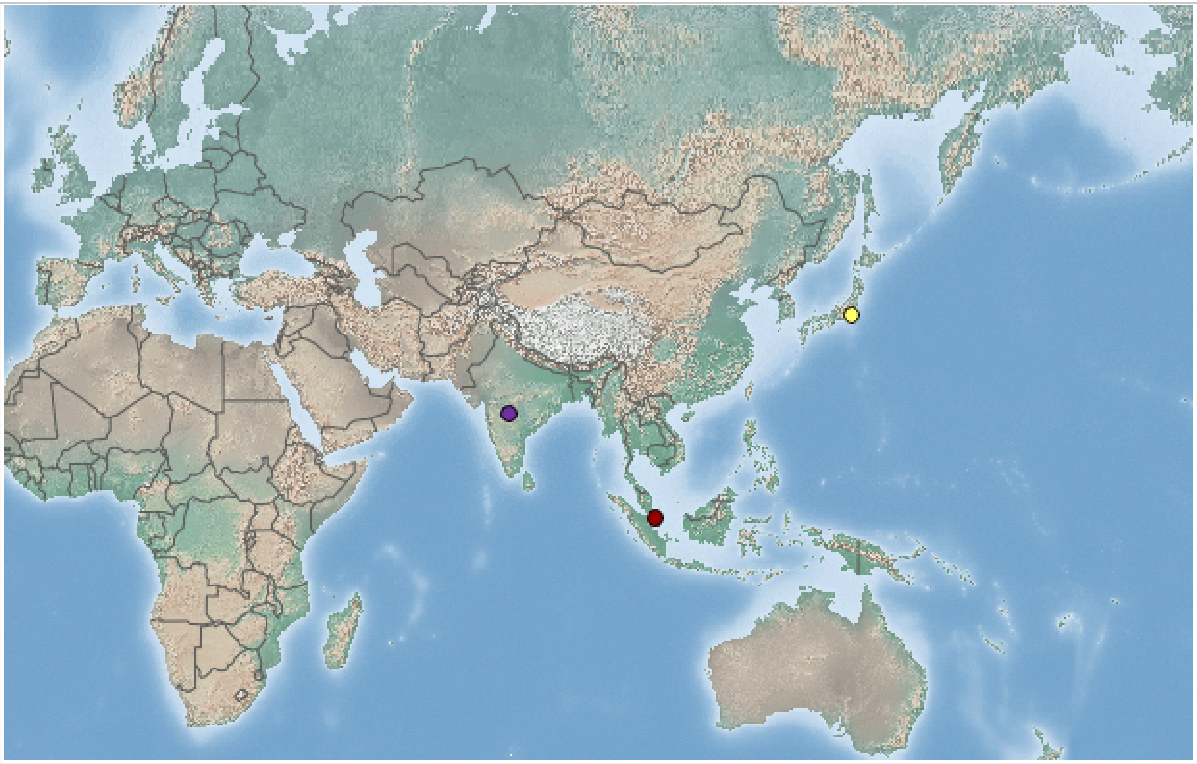
Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread

Asia

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread



Europe

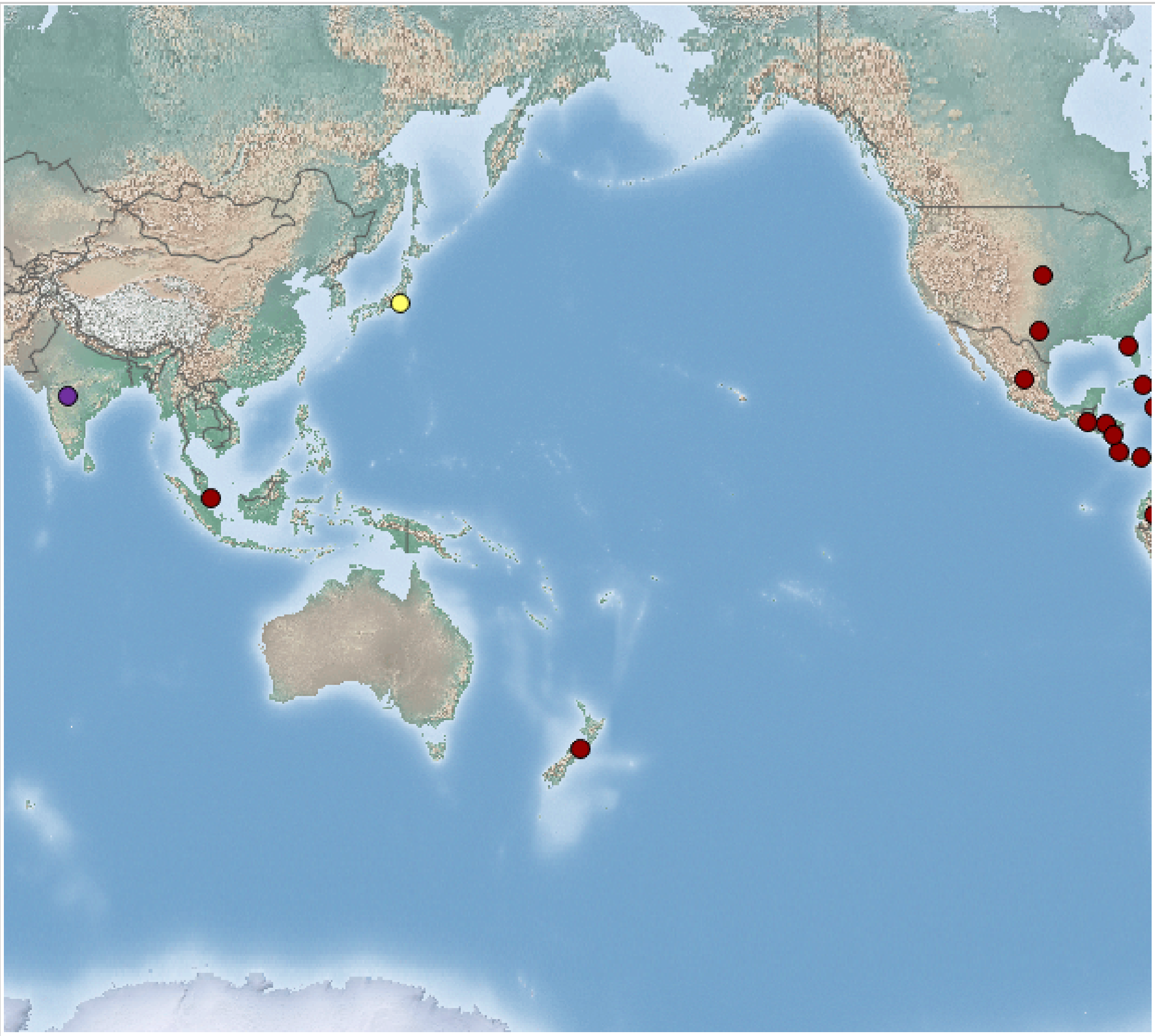
Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread

Pacific

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread



North America

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread

Central America

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread

South America

Analyzed by: Density

Localised	Occasional or few reports
Present, no further details	Widespread

Pictures

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Picture	Title	Caption	Copyright
	Flowering habit	Eichhornia azurea (anchored water hyacinth); flowering habit. Campo Grande, Transpantaneira, Poconé, Mato Grosso, Brazil. June 2016.	©Bernard Dupont/via flickr - CC BY-SA 2.0
	Flowering habit	Eichhornia azurea (anchored water hyacinth); flowering habit. Campo Grande, Transpantaneira, Poconé, Mato Grosso, Brazil. June 2016.	©Bernard Dupont/via flickr - CC BY-SA 2.0
	Habit	Eichhornia azurea (anchored water hyacinth); habit. Campo Grande, Transpantaneira, Poconé, Mato Grosso, Brazil. June 2016.	©Bernard Dupont/via flickr - CC BY-SA 2.0

Identity

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Preferred Scientific Name

Eichhornia azurea (Sw.) Kunth, 1843

Preferred Common Name

anchored water hyacinth

Other Scientific Names

Eichhornia aquatica (Vell.) Schltdl.
Eichhornia azurea var. rhizantha Seub.
Piaropus azureus (Sw.) Raf.
Piaropus tricolor Raf., Fl., Tellur.
Piaropus undulatus Raf., Fl., Tellur.
Pontederia aquatica Vell., Fl. Flumin.
Pontederia azurea Sw.
Pontederia tumida Willd ex Kunth.

International Common Names

English: rooted water hyacinth; saw-petal water hyacinth
Spanish: cola de pato; pico de pato

Local Common Names

Brazil: aguapé; aguapé-de-canudo; aguapé-de-cordao; jacinto d'agua; rainha dos lagos
Cuba: jacinta de agua
Sweden: azurblå vattenhyacint

EPPO code

EICAZ

Summary of Invasiveness

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E. azurea is a rooted perennial aquatic plant with submersed and emersed leaves. Several taxa of this family have spread, as weeds or ornamentals (Barrett, 1978), outside the limits of their native range (Eckenwalder and Barrett, 1986). *Eichhornia crassipes* is the species best known for its invasiveness; it is one of the most troublesome weeds in the world (Gopal, 1987) and is declared a noxious weed in many countries, including in the USA and in two states in Australia. The status of *E. crassipes* (water hyacinth) as a weed has led to the subsequent designation of *E. azurea* and several species of *Eichhornia* as prohibited imports in various countries (USDA-NRCS, 2016; The State of New South Wales, 2009).

E. azurea was introduced into the USA from South America as an aquatic ornamental in the 1980s. It has occasionally escaped into local environments in the USA (Gopal, 1987) but has not become established as a weed there. According to historical records, *E. azurea* has been reported in southern Florida and more recently in Texas (TexasInvasives.org, 2016). It has also been reported in Japan but possibly as a temporary occurrence only (Kadono, 2004).

E. azurea is a weed with a widespread distribution in Brazil, where it often creates large floating mats which obstruct navigation and many other uses of aquatic resources. Reproduction is by seed and vegetatively. Dispersal is by whole plants, by water or by birds.

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Monocotyledonae
          - Order: Pontederiales
            - Family: Pontederiaceae
              - Genus: Eichhornia
                - Species: Eichhornia azurea

Notes on Taxonomy and Nomenclature

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Eichhornia is a small genus in the Pontederiaceae. The species are exclusively palustrial and aquatic herbaceous monocotyledons, native to the New World, predominantly neotropical; only *E. natans* (P. Beauv.) is native to tropical Africa (Eckenwalder and Barrett, 1986; Gopal, 1987; Barrett, 1988). It is important to note that there has been taxonomic confusion within the genus, which comprises between seven (Eckenwalder and Barrett, 1986) and eight species (Barrett, 1978; Cook, 1998). *Eichhornia azurea* was first named as *Pontederia azurea* by Swartz in 1788, and it is a basionym of the current name *E. azurea*, the genus for which was changed by Kunth in 1843 (IPNI, 2009). This name is accepted by Berry et al. (2004) and Walderley et al. (2005). There are no described subspecies or varieties for this species.

Description

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Floating perennial aquatic plant, typically rooted in mud. Plant height up to 100 cm tall. Vegetative stems elongate, developing to and growing at water surface. Flowering stems erect, 8–12 cm, glabrous, distal internode 2–10 cm. Leaves submerged, floating or emergent (or a combination of any two). Sessile leaves submersed, no petiole, alternate on elongate stem. Petiolate leaves emersed; stipule 7–13 cm, apex truncate; petiole never inflated, 11–25 cm; blade round, 7–16 × 2.3–16 cm. Inflorescence a spike or panicle, subtended by 2 reduced, dissimilar leaves. Spikes 7–50-flowered sometimes carrying more than 60 flowers (Gopal, 1987). Flower zygomorphic, spathes obovate, 3–6 cm; peduncle 1.9–15 cm, pubescent with orange hairs. Perianth blue or white, limb lobes obovate, 13–25 mm, margins erose, central distal lobe dark blue at base with yellow distal spot (Haynes, 1988); proximal stamens 15–29 mm, distal 6–20 mm; anthers 1.2–2.3 mm; style 3-lobed. Seeds develop from an anatropous ovule. The fruit contains 10–13-winged seeds (Flora of North America, 2009) 1.5-2.6 mm long, 0.3-0.9 mm wide (Sher, 2009). The roots extend into the substrate, which length varies greatly; 5 cm in the younger portions of the stems but can reach up to 1 m in the older portions (Padial et al., 2009).

Plant Type

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Aquatic
Herbaceous
Perennial
Seed propagated
Vegetatively propagated

Distribution

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E. azurea is a widespread species of Pontederiaceae, largely restricted to the Neotropics (Horn, 1987). It is well distributed in northern Argentina and southern Brazil (Instituto de Botanica Darwinion, 2009). It is also present in Mesoamerica, the Caribbean and northern South America (Missouri Botanical Garden, 2009; USDA-ARS, 2009; USDA-NRCS, 2009; World Checklist of Selected Plant Families, 2009). Liogier and Martorell (1982) cited *E. azurea* as being present in Puerto Rico. It was subsequently listed in various databases as native (USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009) or introduced (USDA-NRCS, 2009). *E. azurea* was excluded as being present in Puerto Rico by Acevedo-Rodríguez and Strong (2005). Axelrod (2011) reports two herbarium specimens collected from Puerto Rico, however these are both *E. crassipes*.

Outside its native range, *E. azurea* has been reported present in the US state of Florida, located in ponds (USDA-NRCS, 2016) and in Texas in a lake and along a slough (TexasInvasive.org, 2016). Outside the New World, it has been observed in Japan but this may be a temporal occurrence (Kadono, 2004). It has also been reported as being introduced into India and Iran (Sher, 2009). Barrett (1978) mentions its introduction into Africa, although no reports of its presence have been made from any countries on that continent. In some cases its presence could be a misidentification.

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
India (/isc/datasheet/108459)	Restricted distribution					EPPO, 2014	
Japan (/isc/datasheet/108467)	Present, few occurrences		Introduced			Kadono, 2004	
Singapore (/isc/datasheet/108557)	Present only in captivity/cultivation		Introduced		Not invasive	National Parks Board, 2016	
North America							
Mexico (/isc/datasheet/108513)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
USA (/isc/datasheet/108597)	Present						Present based on regional distribution.
-Florida (/isc/datasheet/108804)	Present		Introduced			Westbrooks, 1990; USGS, 2005; University of Florida Herbarium, 2009; USDA-NRCS, 2009	
-Indiana (/isc/datasheet/108810)	Unconfirmed record		Introduced	2000	Not invasive	USGS, 2005	Southern Indiana, located in 5 sites in unspecified pond
-Texas (/isc/datasheet/108838)	Present		Introduced		Invasive	Kartesz, 2016; TexasInvasives.org, 2016	
Central America and Caribbean							
Costa Rica (/isc/datasheet/108402)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Cuba (/isc/datasheet/108405)	Present		Introduced		Invasive	World Checklist of Selected Plant Families, 2009; Oviedo Prieto et al., 2012	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Dominican Republic (/isc/datasheet/108414)	Present		Native			Missouri Botanical Garden, 2009; World Checklist of Selected Plant Families, 2009	
Guatemala (/isc/datasheet/108445)	Present		Native			USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Honduras (/isc/datasheet/108451)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009	
Jamaica (/isc/datasheet/108465)	Present		Native			USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Nicaragua (/isc/datasheet/108521)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Panama (/isc/datasheet/108530)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Puerto Rico (/isc/datasheet/108541)	Present		Native			Acevedo-Rodríguez and Strong, 2005; USGS, 2005; USDA-ARS, 2009; USDA-NRCS, 2009; World Checklist of Selected Plant Families, 2009	
Trinidad and Tobago (/isc/datasheet/108588)	Present		Native			World Checklist of Selected Plant Families, 2009	
South America							
Argentina (/isc/datasheet/108359)	Restricted distribution		Native			Instituto Botanica Darwinion de, 2009; Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009; EPPO, 2014	
Bolivia (/isc/datasheet/108379)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Brazil (/isc/datasheet/108381)	Present		Native			Lorenzi, 1982; Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
-Bahia (/isc/datasheet/108630)	Present		Native			Lorenzi, 1982	
-Goias (/isc/datasheet/108634)	Present		Native			Lorenzi, 1982	
-Mato Grosso (/isc/datasheet/108638)	Present		Native			Lorenzi, 1982	
-Mato Grosso do Sul (/isc/datasheet/108637)	Widespread		Native			Instituto Botanica Darwinion de, 2009	
-Minas Gerais (/isc/datasheet/108636)	Present		Native			Lorenzi, 1982	
-Para (/isc/datasheet/108639)	Present		Native			Lorenzi, 1982	
-Parana (/isc/datasheet/108643)	Widespread		Native			Instituto Botanica Darwinion de, 2009	
-Rio de Janeiro (/isc/datasheet/108644)	Present		Native			Lorenzi, 1982	
-Rio Grande do Sul (/isc/datasheet/108648)	Widespread		Native			Instituto Botanica Darwinion de, 2009	
-Santa Catarina (/isc/datasheet/108649)	Widespread		Native			Instituto Botanica Darwinion de, 2009	
-Sao Paulo (/isc/datasheet/108651)	Present		Native			Lorenzi, 1982	
-Tocantins (/isc/datasheet/108652)	Present		Native			Lorenzi, 1982	
Colombia (/isc/datasheet/108399)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Ecuador (/isc/datasheet/108416)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009	
French Guiana (/isc/datasheet/108434)	Present		Native			CIRAD, 2008; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Guyana (/isc/datasheet/108448)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Paraguay (/isc/datasheet/108544)	Present		Native			Instituto Botanica Darwinion de, 2009; Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Peru (/isc/datasheet/108532)	Present		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009	
Suriname (/isc/datasheet/108568)	Present		Native			USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009	
Uruguay (/isc/datasheet/108598)	Present		Native			Instituto Botanica Darwinion de, 2009; Missouri Botanical Garden, 2009; World Checklist of Selected Plant Families, 2009	
Venezuela (/isc/datasheet/108601)	Restricted distribution		Native			Missouri Botanical Garden, 2009; USDA-ARS, 2009; World Checklist of Selected Plant Families, 2009; EPPO, 2014	
Oceania							
New Zealand (/isc/datasheet/108528)	Present only under cover/indoors		Introduced		Not invasive	Champion and Clayton, 2001	Present in the aquarium trade, but not currently offered for sale

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History of Introduction and Spread

E. azurea was reported in Texas (Shinners, 1962), but this record was based on a misidentified specimen that was actually *E. crassipes* (Flora of North America, 2009). More recent reports in 2013 and 2014 of *E. azurea* in Texas, one in a lake and one along a slough, have been verified (TexasInvasives.org, 2016). In 1987, it was found in several locations in Florida (Westbrooks, 1990); the report specifically noted a population growing in a residential estate pool in Palm Beach that was then eradicated in 1988. Another collection from Columbia County in Florida was also eradicated (Flora of North America, 2009). Currently, *E. azurea* is present at one site in Florida (University of Florida Herbarium, 2009) where all of the plants are located in ponds. It is present in the aquarium / pond plant trade in New Zealand, but it is not currently offered for sale (Champion and Clayton, 2001).

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Introductions

Introduced to	Introduced from	Year	Reason	Introduced by	Established in wild through		References	Notes
					Natural reproduction	Continuous restocking		
Florida	South America	1987	Ornamental purposes (pathway cause) (/isc/datasheet/109051)				Gopal (1987)	

Risk of Introduction

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E. azurea can be introduced intentionally as an ornamental plant, and it is offered for sale in the USA by aquarium or water-garden dealerships; it is also advertised on commercial websites (Stratford and Steve, 2001) and can be obtained by mail-order from aquatic plant nurseries (Schmitz et al., 1998). It could also be introduced as seed contaminant (USDA-ARS, 2009). The traits of this species would limit its ability to spread widely and, while it may become a problem on a local scale, doubt has been expressed about its potential to become a weed (S Barrett, personal communication, 2008 in Julien, 2008).

E. azurea has been declared a federal noxious weed by the USA government (USDA-APHIS, 2006), and declared an aquatic noxious weed in parts of the USA. Class A noxious weed: Alabama, Vermont. Prohibited noxious weed: Arizona, Arkansas, Indiana, Oklahoma. Quarantined: California, Oregon. Prohibited aquatic plant, Class 1: Florida. Prohibited: Massachusetts. Class A noxious weed: North Carolina. Invasive aquatic plant pest: South Carolina. Noxious weed: Texas (USDA-ARS, 2009; USDA-NRCS, 2009; Indiana Invasive Species Council, 2013).

In Australia, *E. azurea* is declared as follows: New South Wales: noxious weed (Class 1) (The State of New South Wales, 2009). Queensland: pest plant (Class 1) (The State of Queensland, 2009). It is included on noxious plant lists in South Africa (Global Compendium of Weeds, 2007). It has also failed risk assessments for the management of potential weeds in the ornamental trade in New Zealand (Champion and Clayton, 2001), where *E. azurea*'sseeds are Regulated Weed Seeds and prohibited from all consignments (MAF Bisosecurity, 2009). Further introductions into New Zealand are therefore unlikely.

Habitat

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E. azurea is a large, long-lived, mat-forming perennial which most commonly occurs in permanent water bodies. Predominant in mud along rivers, lakes, marshes, canals, the channel between rivers and lakes and in the littoral zone of lakes (Barrett, 1988). It prefers open and slow-moving water environments.

E. azurea is found in the neotropical zone of South America from sea level to 1000 m (Instituto de Botanica Darwinion, 2009). It is the most common species of emergent macrophytes in tropical areas subjected to flooding (Howard-Williams, 1985), being the predominant species in wetlands and lakes associated with flood plains (Pinto et al., 1999; Nunes, 2003) which are generally shallow (depths are usually lower than 1.5 m) (Padial et al., 2009). *E. azurea* together with *E. crassipes* has been found near the coast in a river delta in Brazil (Tavares et al., 2005); the two have also been found together in reservoirs (Brazil) (Martins et al., 2008; Pitelli et al., 2008).

Habitat List

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Category	Habitat	Presence	Status
Freshwater	Irrigation channels	Present, no further details	
	Lakes	Secondary/tolerated habitat	Natural
	Ponds	Present, no further details	
	Reservoirs	Secondary/tolerated habitat	Harmful (pest or invasive)
	Reservoirs	Secondary/tolerated habitat	Natural
	Rivers / streams	Secondary/tolerated habitat	Natural
Terrestrial-natural/semi-natural	Riverbanks	Principal habitat	Natural
	Wetlands	Principal habitat	Natural

Biology and Ecology

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Genetics

E. azurea is 2n=32, the same as *E. crassipes*, which is usually 2n=32 (Cook, 1998).

Reproductive Biology

E. azurea is pollinated by a variety of insects depending on the flower form. Tristylous flowers of *E. azurea* are almost exclusively visited by one bee species, *Ancyloscelis gigas* (Anthophoridae). The latter's proboscis morphology make this bee species narrowly adapted (Alves dos Santos and Wittmann, 2000). The absence of the specialized pollinator may cause the breakdown of the tristylous system (Barrett, 1979; 1988; Alves dos Santos, 2002). The breeding system of *E. azurea* has been described as heteromorphic self-incompatible in the Amazon, southern Brazil and northern Argentina (Barrett, 1978; Alves dos Santos and Wittmann, 2000; Bianchi et al., 2000). In addition, there are populations with semi-homostylous floral morphs (breakdown of tristyly) in southeastern Brazil (Barrett, 1978; Alves dos Santos, 2002). Under natural conditions in Brazil's Pantanal wetlands, the species is a partially self- and heteromorphic compatible system (Cunha and Fischer, 2009). Alves dos Santos (1999) reports that non-tristylous flowers are pollinated by long-tongued bees and butterflies and Cunha and Fisher (2009) report observing honeybees, *Trigona* sp. bees, butterflies, hemipterans and dipterans visiting flowers in the southern Pantanal of Brazil.

Self- and illegitimate pollinations produced significantly less fruit and seed than legitimate pollinations in all 3 style morphs (Bianchi et al., 2000; Alves dos Santos, 2002). It flowers from June to October in its native range (Hederson and Cilliers, 2002; Flora of North America, 2009); in its southern area of distribution it starts flowering in May; and in the northern area it finishes in November. Flowers of *E. azurea* open for just one day. At the end of flowering, the inflorescence bends down and sinks into the water, where the capsules and seeds develop (Alves dos Santos, 2002). Vegetative reproduction occurs by fragmentation and sprouting of the robustly branching stems (Barrett, 1978).

Physiology and Phenology

E. azurea is characterized by great morphological plasticity and its ability to adapt to different growth conditions, and overall by its secondary submerged roots, which change morphologically depending on the water nutrient concentrations, particularly phosphorus (e.g., Gopal, 1987; Camargo and Esteves, 1996). Other traits increase linearly with water depth and with water clarity (Milne et al., 2006). Water is the most significant source of nutrients (Nogueira et al., 1996) and the plant size is proportional to the level of available nutrients (Pott and Pott, 2004). The biomass of roots in *E. azurea* is 83.62 g/m^2 and of leaves is 154.47 g/m^2, the total biomass of 237.09 is higher than that of *E. crassipes* (Sanchez-Botero et al., 2003); biomasses of up to 900 g DW/m^2 can be reached (Bini, 1996). It demonstrates a low leaf area index, a long time interval for the emergence of new leaves, a long leaf life-span and a low capacity for branching (Ikusima and Gentil, 1993).

In its native range, *E. azurea* grows all year round. It is dominant in relatively deep water owing to its potential for great elongation of its main stem. The oldest ramets of *E. azurea* occur anchored at the shoreline, and the most recent grow in the direction of the limnetic zone (Nogueira et al., 1996); it forms floating vegetation banks that extend themselves for some metres from the coastal region, as well at the lowest-lying sites, and only dies off during the driest years. If dry conditions occur in sequence, it does not return rapidly (Heckman, 1998). Long-term droughts cause massive *E. azurea* death leading to detritus accumulation in the margin of several lagoons, where decomposition occurs and concentrations of the detritus are significantly affected by flooding regimes (Padial and Thomaz, 2006). *E. azurea* has a good absorption capacity for copper and iron and can be used to identify metal contamination in the study area (Laybauer and Ortiz, 1999).

Associations

The high abundance of *E. azurea* has been coupled with either abundant free-floating plants (usually *Salvinia* spp., *E. crassipes* or *Pistia stratiotes*) or emergents such as aquatic grasses, or *Polygonum* spp. (Murphy et al., 2003). It is the most characteristic species in the Pantanal wetlands (Pott and Pott, 2004) together with *Pontederia lanceolata,* and both species block the spread of *E. crassipes*' drift (Heckman, 1998).

In its natural habitats, *E. azurea* presents higher invertebrate species richness than other floating plants (Poi de Neiff and Neiff, 2006; Silva and Henry, 2013). *E. azurea* provides a high level of structural heterogeneity due to its submerged roots (Dibble and Thomaz, 2006) providing an important biotope for fishes (Agostinho et al., 2007; Padial et al., 2009), many invertebrates (Lima et al., 2003; Monkolski et al., 2005) and mainly insects (Raizer and Amaral, 2001; Moretti, 2003; De Melo et al., 2004; Fulan and Henry, 2007; Higuti et al., 2007); it is also the preferred substratum for molluscs (Pfeifer and Pitoni, 2003). It is noted that *E. azurea* has associated dark septate fungi and arbuscular mycorrhizal fungi (de Marins, 2009).

Environmental Requirements

Nutrient enrichment is observed to aid in the establishment and spread in reservoirs (Bini et al., 2005).

Climate

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Climate	Status	Description	Remark
Af - Tropical rainforest climate	Tolerated	> 60mm precipitation per month	
Am - Tropical monsoon climate	Preferred	Tropical monsoon climate (< 60mm precipitation driest month but > (100 - [total annual precipitation(mm}/25]))	
Aw - Tropical wet and dry savanna climate	Preferred	< 60mm precipitation driest month (in winter) and < (100 - [total annual precipitation{mm}/25])	
Cf - Warm temperate climate, wet all year	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, wet all year	

Latitude/Altitude Ranges

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Latitude North (°N)	Latitude South (°S)	Altitude Lower (m)	Altitude Upper (m)
20	30		

Air Temperature

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Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	0	
Mean annual temperature (ºC)	24	30
Mean maximum temperature of hottest month (ºC)	27	32
Mean minimum temperature of coldest month (ºC)	13	21

Rainfall

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Parameter	Lower limit	Upper limit	Description
Mean annual rainfall	800	2500	mm; lower/upper limits

Rainfall Regime

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Bimodal
Uniform

Soil Tolerances

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Soil drainage

- seasonally waterlogged

Water Tolerances

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Parameter	Minimum Value	Maximum Value	Typical Value	Status	Life Stage	Notes
Alkalinity (mg/l of Calcium Carbonate)			500	Optimum		(mEq/l). Upper Rio Parana, southern Brazil
Conductivity (µmhos/cm)			132.0-181.9	Optimum		(mS/cm). Upper Rio Parana, southern Brazil
Depth (m b.s.l.)			0.54-1.28	Optimum		Upper Rio Parana, southern Brazil
Water pH (pH)				Optimum		Neutral. Upper Rio Parana, southern Brazil

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Cornops aquaticum (/isc/datasheet/16184)	Herbivore	Whole plant	not specific	Silva et al., 2010		
Drosophila aguape (/isc/datasheet/109192)	Herbivore	Inflorescence		Val and Marques, 1996		
Orthogalumna terebrantis (/isc/datasheet/38080)	Herbivore	Leaves	not specific	Center et al., 2002	North America, Australia, Asia, Africa	Eichhornia crassipes, E. azurea, Pontederia cordata, Reussia subovata
Thrypticus sp. (/isc/datasheet/53715)	Herbivore	Whole plant		Cordo et al., 2000		

Notes on Natural Enemies

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E. azurea has a specific host herbivore of the genus *Thrypticus* (Diptera: Dolichopodidae) (Cordo et al., 2000) and *Drosophila aguape* is associated with flowers (Val and Marques, 1996) although the effect of its damage to the demography of *E. crassipes* is unknown. Other specific and non-specific herbivores of *E. azurea* are listed in Poi de Neiff and Casco (2003) and Center et al. (2002). *Cornops aquaticum* is a grasshopper that feeds on *E. azurea*, *E. crassipes* and *Pontederia cordata* and has been investigated as a potential biocontrol agent of *E. crassipes* (Silva et al., 2010). *E. azurea* has a specific pathogen - the galls found in the rhizomes induced by a new species of cecidomyiid (Cecidomyiidae: Diptera) and larval development cause enlargement of the infected area and a small change of natural colour in the rhizome (Pelaez-Rodriguez et al., 2003).The marsh deer (*Blastocerus dichotomus*) and the capybara (*Hydrochoerus hydrochaeris*) feed on *E. azurea* (Heckman, 1998).

Means of Movement and Dispersal

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Natural Dispersal (Non-Biotic)

Reproduction is both by seed and vegetative propagation, and the propagules can be carried out by the drift from the upper stream to downstream (Bini et al., 2005). Vegetative reproduction is not as extensive as in *E. crassipes* (EPPO, 2008).

Vector Transmission (Biotic)

The seeds may be carried by birds (Barrett, 1988).

Accidental Introduction

It could be introduced as a seed contaminant (USDA-ARS, 2009) in shipments (University of Florida Herbarium, 2009).

Intentional Introduction

E. azurea can be introduced intentionally as an ornamental plant; it is offered for sale in the USA by aquarium or water garden dealerships; it is also advertised on commercial websites (Stratford and Steve, 2001) and can be obtained by mail-order from aquatic plant nurseries (Schmitz et al., 1998).

Pathway Causes

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Cause	Notes	Long Distance	Local	References
Internet sales (/isc/datasheet/109044)		Yes		Schmitz et al., 1998
Ornamental purposes (/isc/datasheet/109051)		Yes		Gopal, 1987
Pet trade (/isc/datasheet/109054)		Yes		Stratford and Steve, 2001

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Mail (/isc/datasheet/109076)		Yes		Schmitz et al., 1998

Plant Trade

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Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Growing medium accompanying plants	seeds			Pest or symptoms usually invisible

Impact Summary

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Category	Impact
Cultural/amenity	Negative
Economic/livelihood	Negative

Economic Impact

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E. azurea is one the most problematic species in the reservoirs in Brazil in sub-tropical and tropical regions (Carauta et al., 1991; Fernández et al., 1993) in particular because these environments are frequently subject to eutrophication, which may enhance the growth of free-floating nuisance species (Thomaz and Bini, 1998). This affects the multiple utilization of the water body, including fish production, irrigation, transportation and hydroelectric production (Martins et al., 2003), causing damage to turbines and necessitating expensive cleaning processes (Pitelli, 2000; Pitelli et al., 2008). In its native range, it has been reported in Cuba as agricultural weed (Acuna, 1974 cited in Global Compendium of Weeds, 2007) and it can be found invading channels of the polder in French Guyana (CIRAD, 2008). However, there is insufficient information with which to evaluate these impacts.

Environmental Impact

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Impact on Habitats

E. azurea has the potential to form thick mats over the water surface, shading out native vegetation and altering water chemistry (Martins et al., 2003).

Social Impact

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E. azurea is often considered a nuisance species in many Brazilian reservoirs with impacts on tourism, and recreation, navigation and fishing activities (Pitelli, 2000; Pitelli et al., 2008).

Risk and Impact Factors

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Invasiveness

Invasive in its native range
Reproduces asexually

Likelihood of entry/control

Highly likely to be transported internationally accidentally
Highly likely to be transported internationally deliberately
Highly likely to be transported internationally illegally
Difficult to identify/detect as a commodity contaminant

Uses

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Economic Value

E. azurea is only slightly palatable and is digested with difficulty (Henry-Silva and Camargo, 2000).

Environmental Services

In its natural habitats, *E. azurea* presents higher invertebrate richness than other species of floating plants (Poi de Neiff and Neiff, 2006). It is eaten by capybara, pigs, and other herbivores and creates habitat for fish, insect larvae, and snails among other organisms (Dahroug et al., 2016).

Uses List

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General

Botanical garden/zoo
Pet/aquarium trade
Research model

Ornamental

Propagation material

Similarities to Other Species/Conditions

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E. azurea and *E. crassipes* are superficially similar in appearance and are confused with one another in botanical collections and in systematic literature (Barrett, 1978). *E. azurea* can be distinguished from other *Eichhornia* by its elongate, fan-like submersed leaves and long floating stems with large obovate, erect leaves with slender petioles and secondary submerged roots (coming from stem nodes). The petiole of the emergent leaf is never swollen. Flowers are similar to floating water hyacinth but are often less robust and more blue in colour. The inner petals have a fringed margin. *E. crassipes* can float freely, unlike its congener *E. azurea,* which must root to the substrate and is therefore confined to shallow ponds and the edges of lakes and rivers (Barrett, 1989; Q-Bank, 2016).

Prevention and Control

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Prevention

Anchored water hyacinth is not known to be invasive out of its native range, so prevention of its establishment is the best form of control. In New Zealand, for example, *E. azurea*'s seeds are Regulated Weed Seeds; this means that they are prohibited and that all consignments must be managed according to the phytosanitary requirements specified in the specific schedules for entry the MAF Biosecurity protocol (MAF Bisosecurity, 2009). The aquatic weed risk assessment model used to manage potential weeds in the ornamental trade in New Zealand produced a high-risk result for *E. azurea* (Champion and Clayton, 2001). The introduction of *E. azurea* into New Zealand is therefore unlikely.

Rapid response

The US Southern Regional Forest Service (USDA Forest Service Southern Regional, 2008) recognizes *E. azurea* as posing a severe potential threat to southern forests and grassland ecosystems. *E. azurea* is therefore included in the early detection watch list of non-native invasive species of southern forest and grassland ecosystems.

Public awareness

Texas (USA) has declared possession of *E. azurea* to be illegal; penalties range from $200 to $2,000 for the possession of individual plants (Texas Parks and Wildlife Department**,** 2009). Queensland in Australia has declared it a serious offence to introduce, keep or supply a Class 1 pest, imposing fines of up to $60,000 (The State of Queensland, 2009).

Eradication

E. azurea was eradicated in various locations in Florida in 1988 (Flora of North America, 2009). The methods used to remove the plants are unknown.

Throughout New South Wales in Australia, *E. azurea* is a Class 1 noxious weed which must be eradicated and the land kept free of the plant. As a notifiable weed, all outbreaks must be reported to the local council(The State of New South Wales, 2009). *E. azurea* has been declared a Class 1 pest plant in Queensland (The State of Queensland, 2009), which means that it is subject to eradication by the state. Landowners must take reasonable steps to keep their land free of Class 1 pests.

Control

Cultural control and sanitary measures

E. azurea could be controlled in the same ways as *E. crassipes.* Chemical and mechanical removal of this species is often ineffective and too expensive; biological control agents have been used with limited success. The most effective control method remains the control of excessive nutrients and prevention of the spread of this species.

Physical/mechanical control

Control programmes and/or the management of aquatic macrophytes at local scales (generally in the reservoir main body) will rarely be successful due to continuous colonization by propagules originating in upper tributary segments, where aquatic vegetation is uncontrolled. Thus, despite evident difficulties, aquatic vegetation management should be undertaken at the regional scale (Bini et al., 2005).

Biological control

There are no reports of any biological control methods using host-specific herbivores or parasites. Carauta et al. (1991) suggests the use of grazing as a method of control, using fishes, birds and, in particular, mammals (capybaras) to control *E. azurea* in Brazil's reservoirs.

Chemical control

There are several herbicides available for the control of *E. crassipes* e.g.2,4-D and glyphosate, which are only effective on small populations - but none are currently registered for *E. azurea*.

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Gaps in Knowledge/Research Needs

A great deal is known about the biology of *E. crassipes* but this is not the case for *E. azurea*. Further work is needed, particularly with regard to the potential risk zone of the species, and on the best way to manage the control of the species in the event that it becomes invasive.

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25/11/09 Original text by:

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Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Eichhornia crassipes (water hyacinth)

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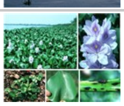
Pictures

Picture	Title	Caption	Copyright
	Flowers	Each flower has a perianth tube 1.5 cm long, expanding into six mauve or purple lobes up to 4 cm long. The main lobe has a bright-yellow, diamond-shaped patch surrounded by deeper purple.	©Colin Wilson
	Leaves	Leaves consist of petiole (often swollen, 2-5 cm thick) and blade (roughly round, ovoid or kidney-shaped, up to 15 cm across).	©Colin Wilson
	Growth habit	Once the inflorescence is fully emerged from the leaf sheath, flowers all open together, starting at night, completing the process in the morning and withering by the next night.	©Colin Wilson
	Growth habit	Extremely large populations of inter-connected shoots can develop very rapidly.	©Colin Wilson
	Habit	Water hyacinth flowering - note presence of Salvinia auriculata in lower part of image.	©A.R. Pittaway
	Infestation of waterway	Water hyacinth growing in Manila harbour, Philippines.	Bill Parsons
	Colour photographs	Clockwise from top right: flowers; stems showing symptoms of attack by Neochetina eichhorniae; leaf showing characteristic feeding scars from N. eichhorniae; young plant; lake infested with water hyacinth.	©Chris Parker/Bristol, UK

Identity

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Preferred Scientific Name

Eichhornia crassipes (Mart.) Solms 1883

Preferred Common Name

water hyacinth

Other Scientific Names

Eichhornia cordifolia Gandoger 1920
Eichhornia crassicaulis Schlect. 1862
Eichhornia speciosa Kunth 1843
Heteranthera formosa Miq. 1843
Piaropus crassipes (Mart.) Raf. 1837
Piaropus mesomelas Raf. 1837
Pontederia crassicaulis Schlect. 1862
Pontederia crassipes Mart. 1823
Pontederia elongata Balf. 1855

International Common Names

English: floating water hyacinth; lilac devil; Nile lily; pickerelweed; water orchid; water violet
Spanish: aguapey (Argentina); cola de pato; hierba jicotea; lagunero (Nicaragua); lechuguilla; lila de agua; lila de caño; pontederia azul (Mexico); reina del agua; taruya (Nicaragua)
French: bofinace; héliotrope; jacinthe d'eau
Portuguese: jacinto aquatico

Local Common Names

Antigua and Barbuda: water violet
Argentina: aquapey; camalotes; jacinto de agua
Bangladesh: kachuripana
Brazil: aguape de flor roxa; aguape puru-a; baronesa; dama del lago; jacinta d'agua; murumurii
Cambodia: kamplauk
Chile: jiro de agua; violeta de agua
Colombia: buchon; lirio de agua; tarulla
Congo: kongo ya sika
Costa Rica: lirio de agua
Cuba: boniatillo de agua; flor de agua; hierba de jicotea; jacinto de agua; lirio acauático; malangueta
Czechoslovakia (former): tokozelka; vodin hyacint
Denmark: vanhyazint
Dominican Republic: lila de agua
Egypt: bisnidh; habba; halassandi/halassant; war-el-nil; zanim; zoqqeym et-tani
El Salvador: halsa; lechugo; lechugo de concha
Fiji: babadabeniga; bekabekairaga; jalkhumbe
Former USSR: wampee
France: eichhornie
Germany: wasserhyazinthe
Guatemala: lirio acuatico; ninfa

India: akasa thamarai; German pana; jalkhumbi; kachuripana; kajor pati; kolavazha; kulavali; neithamarai; pisachi thanana; sokh-samundar; tagoi; vilayati pana
Indonesia: bengai gondo; bengok; bia bia; eceng; eceng gondok; eceng padi; gendot; ilung ilung; mampau/mampoh; nappong; sekar bopong; wewehan
Israel: yakinton hamaim
Italy: giacinto d'acqua
Jamaica: water lily
Japan: hotei-aoi; torin; uchikusa; weinchan
Lesser Antilles: glaïeul bleu
Madagascar: tetezanalika; tsikafokafona
Malaysia: bunga jamban; keladi bunting; kemeling telur
Mauritius: hoteiaoi
Mexico: jacinto acuatico; lirio acuatico
Myanmar: beda-bin; ye-padauk
Netherlands: waterhyacint
Nicaragua: lirio de agua
Pakistan: gulbakauli; kalali
Peru: camalote; lirio de agua
Philippines: water lily
Puerto Rico: flor de agua
South Africa: Florida devil; lilac devil; waterhiasint
Spain: lirio de agua
Sri Lanka: diya kehel; diya manel; habara/habarala; sabara; yapura
Suriname: badawaro; moessiri; oponopa-joelire
Taiwan: putailien
Thailand: paktopjava; sawah; top-chawa
Turkey: su sümbülü
Uruguay: aguape/aguape-puru
USA: river raft
Venezuela: bora; lagunera
Vietnam: luc-binh

EPPO code

EICCR (Eichhornia crassipes)

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Summary of Invasiveness

E. crassipes, a native of South America, is a major freshwater weed in most of the frost-free regions of the world and is generally regarded as the most troublesome aquatic plant (Holm et al., 1997). It has been widely planted as a water ornamental around the world because of its striking flowers. Wherever it has encountered suitable environmental conditions it has spread with phenomenal rapidity to form vast monotypic stands in lakes, rivers and rice paddy fields. Then it adversely affects human activities (fishing, water transport) and biodiversity. It is impossible to eradicate, and often only an integrated management strategy, inclusive of biological control, can provide a long-term solution to this pest.

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Monocotyledonae
          - Order: Pontederiales
            - Family: Pontederiaceae
              - Genus: Eichhornia
                - Species: Eichhornia crassipes

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Notes on Taxonomy and Nomenclature

Although almost certainly collected as early as 1801 in Colombia, the species was first described in 1824 and given the name *Pontederia crassipes* by C.F.P. von Martius from specimens collected in Brazil. Kunth in 1843 split the genus and created *Eichhornia* to cover species with trilocular ovary and numerous ovules. He ignored the epithet '*crassipes*' and used the name *Eichhornia speciosa* Kunth. He also ignored Rafinesque's revision of 1836 in which the genus had been given the name *Piaropus*. A number of other combinations were applied by different authors in the nineteenth century, but finally, in 1883, H. Solms-Laubach established the combination *Eichhornia crassipes* (Mart.) Solms by which the species is now universally known. This ignores the priority of the name *Piaropus* on the basis that *Eichhornia* had been in use since 1843 and was regarded as a nomen conservatum (after Gopal, 1987).

In early years there was considerable confusion with the closely related *Eichhornia azurea* (Swartz) Kunth, which had been collected and described as *Pontederia azurea* Sw. somewhat earlier in 1797. The distribution of this species overlaps with that of *Eichhornia crassipes* in South and Central America. *Eichhornia azurea* differs in having finely toothed petals, a more elongated main stem (not spreading by stolons) and distichous leaves lacking swollen petioles. Even now there is confusion between the two species in some areas, resulting from excessive reliance on the petiole character and an assumption that a lack of swollen petioles means it must be *Eichhornia azurea*.

Six other species of *Eichhornia* have been described, mainly from South and Central America but including *Eichhornia natans* (P. Beauv.) Solms. which is restricted to Africa. All are relatively rare and of little or no economic importance. Confusion with *Eichhornia natans* is unlikely as leaves of the latter rarely exceed 4 cm long and flowers are less than 2 cm across.

Description

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The initial leaves of seedling *E. crassipes* are elongated and strap-like, but soon develop the familiar spathulate form and, under suitable unshaded conditions, swollen petioles which ensure that, once dislodged, the seedlings will float from the mud into open water. The plant is very variable in size, seedlings having leaves that are only a few centimetres across or high, whereas mature plants with good nutrient supply may reach 1 m in height. Plants in an uncrowded situation tend to have short, spreading petioles with pronounced swelling, while in a dense stand they are taller, more erect and with little or no swelling of the petioles.

The plant system consists of individual shoots/crowns each with up to ten expanded leaves arranged spirally (3/8 phyllotaxy) and separated by very short internodes. As individual shoots develop, the older leaves die off leaving a stub of leafless dead shoot projecting downwards. This may eventually cause the whole shoot to sink and die.

Leaves consist of petiole (often swollen, 2-5 cm thick) and blade (roughly round, ovoid or kidney-shaped, up to 15 cm across). The base of the petiole and any subsequent leaf is enclosed in a stipule up to 6 cm long.

Roots develop at the base of each leaf and form a dense mass: usually 20-60 cm long, though they can extend to 300 cm. The ratio of root to shoot depends on the nutrient conditions, and in low nutrient conditions they may account for over 60% of the total plant weight. They are white when formed in total darkness but often purplish under field conditions, especially in conditions of low nutrients.

Periodically, axillary buds develop as stolons, growing horizontally for 10-50 cm before establishing daughter plants. Extremely large populations of inter-connected shoots can develop very rapidly, though the connecting stolons eventually die.

The inflorescence is a spike which develops from the apical meristem, but tends to appear lateral owing to the immediate development of an axillary bud as a 'renewal' or 'continuation' shoot. Each spike, up to 50 cm high, is subtended at the base by two bracts and has 8-15 sessile flowers (rarely 4-35). Each flower has a perianth tube 1.5 cm long, expanding into six mauve or purple lobes up to 4 cm long. The main lobe has a bright-yellow, diamond-shaped patch surrounded by deeper purple. Once the inflorescence is fully emerged from the leaf sheath, flowers all open together, starting at night, completing the process in the morning and withering by the next night when the peduncle starts to bend down. Each capsule may contain up to 450 small seeds, each about 1 x 3 mm.

The flowers are tristylous. They have six stamens and one style, arranged in three possible configurations (floral trimorphism) - with short style (and medium and long stamens), medium style (short and long stamens) or long style (short and medium stamens). The medium style form is genetically dominant and is by far the commonest form in almost all infested areas. The short-styled form is only known from South America, whereas the long-styled form is found commonly in South America, more rarely in South-East Asia and very rarely in Africa. Only in Sri Lanka is the long-styled the commonest form. Some other tristylous species show incompatibility between the different forms but *E. crassipes* does not. Hence pollination (mainly by wind) can result in good seed set, though in some populations there may be a higher degree of self-incompatibility.

Plant Type

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Aquatic
Herbaceous
Perennial
Seed propagated
Vegetatively propagated

Distribution

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E. crassipes originated in tropical South America, but is now naturalized in Africa, Australia, India and many other countries.

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Bangladesh (/isc/datasheet/108369)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Bhutan (/isc/datasheet/108383)	Restricted distribution		Introduced			Parker, 1992	
Brunei Darussalam (/isc/datasheet/108378)	Present		Introduced			Waterhouse, 1993; EPPO, 2014	
Cambodia (/isc/datasheet/108472)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
China (/isc/datasheet/108398)	Widespread		Introduced	1901	Invasive	Jianqing et al., 2000; Xie et al., 2001; EPPO, 2014	
-Fujian (/isc/datasheet/108670)	Widespread		Introduced		Invasive	Ding et al., 2001; EPPO, 2014	
-Guangdong (/isc/datasheet/108671)	Widespread		Introduced		Invasive	Ding et al., 2001; EPPO, 2014	
-Guizhou (/isc/datasheet/108674)	Present					EPPO, 2014	
-Hong Kong (/isc/datasheet/108678)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Jiangsu (/isc/datasheet/108683)	Present		Introduced			Dai and Zhang, 1988	
-Yunnan (/isc/datasheet/108698)	Widespread		Introduced		Invasive	Ding et al., 2001; Xie et al., 2001; EPPO, 2014	
-Zhejiang (/isc/datasheet/108699)	Widespread		Introduced		Invasive	Ding et al., 2001; EPPO, 2014	
India (/isc/datasheet/108459)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Andhra Pradesh (/isc/datasheet/108721)	Widespread		Introduced		Invasive	Gopal, 1987	
-Arunachal Pradesh (/isc/datasheet/108722)	Widespread		Introduced		Invasive	Gopal, 1987	
-Assam (/isc/datasheet/108723)	Widespread		Introduced		Invasive	Gopal, 1987	
-Bihar (/isc/datasheet/108724)	Widespread		Introduced		Invasive	Gopal, 1987	
-Delhi (/isc/datasheet/108727)	Widespread		Introduced		Invasive	Gopal, 1987	
-Goa (/isc/datasheet/108731)	Widespread		Introduced		Invasive	Gopal, 1987	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Gujarat (/isc/datasheet/108732)	Widespread		Introduced		Invasive	Gopal, 1987	
-Haryana (/isc/datasheet/108734)	Widespread		Introduced		Invasive	Gopal, 1987	
-Himachal Pradesh (/isc/datasheet/108733)	Widespread		Introduced		Invasive	Gopal, 1987	
-Indian Punjab (/isc/datasheet/108748)	Widespread		Introduced		Invasive	Gopal, 1987	
-Karnataka (/isc/datasheet/108738)	Widespread		Introduced		Invasive	Gopal, 1987	
-Kerala (/isc/datasheet/108737)	Widespread		Introduced		Invasive	Gopal, 1987	
-Madhya Pradesh (/isc/datasheet/108743)	Widespread		Introduced		Invasive	Gopal, 1987	
-Maharashtra (/isc/datasheet/108740)	Widespread		Introduced		Invasive	Gopal, 1987	
-Manipur (/isc/datasheet/108742)	Widespread		Introduced		Invasive	Gopal, 1987	
-Nagaland (/isc/datasheet/108745)	Widespread		Introduced		Invasive	Gopal, 1987	
-Odisha (/isc/datasheet/108746)	Widespread		Introduced		Invasive	Gopal, 1987	
-Rajasthan (/isc/datasheet/108749)	Restricted distribution		Introduced			Gopal, 1987	
-Tamil Nadu (/isc/datasheet/108751)	Widespread		Introduced		Invasive	Gopal, 1987	
-Tripura (/isc/datasheet/108752)	Widespread		Introduced		Invasive	Gopal, 1987	
-Uttar Pradesh (/isc/datasheet/108753)	Widespread		Introduced		Invasive	Gopal, 1987	
-West Bengal (/isc/datasheet/108755)	Widespread		Introduced		Invasive	Gopal, 1987	
Indonesia (/isc/datasheet/108455)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Irian Jaya (/isc/datasheet/108713)	Widespread		Introduced		Invasive	Gopal, 1987	
-Java (/isc/datasheet/108714)	Widespread		Introduced	1894	Invasive	Gopal, 1987	
-Kalimantan (/isc/datasheet/108715)	Widespread		Introduced		Invasive	Gopal, 1987	
-Moluccas (/isc/datasheet/108716)	Widespread		Introduced		Invasive	Gopal, 1987	
-Sulawesi (/isc/datasheet/108718)	Widespread		Introduced		Invasive	Gopal, 1987	
-Sumatra (/isc/datasheet/108719)	Present		Introduced			Gopal, 1987	
Israel (/isc/datasheet/108457)	Present, few occurrences				Invasive	EPPO, 2014	
Japan (/isc/datasheet/108467)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Honshu (/isc/datasheet/108761)	Widespread		Introduced		Invasive	Gopal, 1987	
-Kyushu (/isc/datasheet/108762)	Widespread		Introduced		Invasive	Gopal, 1987	
-Shikoku (/isc/datasheet/108764)	Widespread		Introduced		Invasive	Gopal, 1987	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Jordan (/isc/datasheet/108466)	Present					EPPO, 2014	
Korea, DPR (/isc/datasheet/108476)	Present		Introduced			Dostalek et al., 1989	
Korea, Republic of (/isc/datasheet/108477)	Widespread		Introduced		Invasive	Gopal, 1987	
Laos (/isc/datasheet/108481)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Lebanon (/isc/datasheet/108482)	Present					EPPO, 2014	
Malaysia (/isc/datasheet/108514)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Peninsular Malaysia (/isc/datasheet/108765)	Widespread		Introduced		Invasive	Gopal, 1987	
-Sabah (/isc/datasheet/108766)	Widespread		Introduced		Invasive	Gopal, 1987	
-Sarawak (/isc/datasheet/108767)	Widespread		Introduced		Invasive	Gopal, 1987	
Maldives (/isc/datasheet/108511)	Present		Introduced		Invasive	Pallewatta et al., 2003; EPPO, 2014	
Myanmar (/isc/datasheet/108503)	Present		Introduced			Gopal, 1987; EPPO, 2014	
Pakistan (/isc/datasheet/108537)	Restricted distribution		Introduced			Gopal, 1987; Imran et al., 2013	
Philippines (/isc/datasheet/108535)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Singapore (/isc/datasheet/108557)	Widespread		Introduced	1903	Invasive	Gopal, 1987; EPPO, 2014	
Sri Lanka (/isc/datasheet/108485)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Syria (/isc/datasheet/108572)	Present					EPPO, 2014	
Taiwan (/isc/datasheet/108590)	Present		Introduced		Invasive	Ding et al., 2001; EPPO, 2014	
Thailand (/isc/datasheet/108580)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Turkey (/isc/datasheet/108587)	Present					Uremis et al., 2014	
Vietnam (/isc/datasheet/108604)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Africa							
Angola (/isc/datasheet/108357)	Restricted distribution		Introduced			Gopal, 1987	
Benin (/isc/datasheet/108375)	Restricted distribution		Introduced			van Thielen, 1993; EPPO, 2014	
Botswana (/isc/datasheet/108385)	Present		Introduced			Gopal, 1987	
Burkina Faso (/isc/datasheet/108371)	Present					EPPO, 2014	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Burundi (/isc/datasheet/108374)	Present		Introduced		Invasive	Moorhouse et al., 2001; EPPO, 2014	
Cameroon (/isc/datasheet/108397)	Present					EPPO, 2014	
Central African Republic (/isc/datasheet/108391)	Restricted distribution		Introduced			Gopal, 1987	
Congo (/isc/datasheet/108392)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Congo Democratic Republic (/isc/datasheet/108615)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Côte d'Ivoire (/isc/datasheet/108394)	Restricted distribution		Introduced			Harley, 1993; EPPO, 2014	
Egypt (/isc/datasheet/108418)	Widespread		Introduced		Invasive	Fayad et al., 2001; EPPO, 2014	
Equatorial Guinea (/isc/datasheet/108442)	Present					EPPO, 2014	
Ethiopia (/isc/datasheet/108422)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Gabon (/isc/datasheet/108430)	Present					EPPO, 2014	
Ghana (/isc/datasheet/108436)	Restricted distribution		Introduced			de Graft-Johnson, 1993; EPPO, 2014	
Guinea (/isc/datasheet/108440)	Present					EPPO, 2014	
Guinea-Bissau (/isc/datasheet/108447)	Present					EPPO, 2014	
Kenya (/isc/datasheet/108470)	Widespread		Introduced	1989	Invasive	Owiti, 1990; Mailu, 2001; IPPC-Secretariat, 2005; EPPO, 2014	
Liberia (/isc/datasheet/108487)	Present					EPPO, 2014	
Madagascar (/isc/datasheet/108498)	Widespread		Introduced		Invasive	Binggeli, 2003; EPPO, 2014	
Malawi (/isc/datasheet/108512)	Widespread		Introduced	1960s	Invasive	Harley, 1993; Phiri et al., 2001; EPPO, 2014	
Mali (/isc/datasheet/108502)	Restricted distribution		Introduced			Lomer, 1995	
Mauritius (/isc/datasheet/108510)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Morocco (/isc/datasheet/108493)	Present					EPPO, 2014	
Mozambique (/isc/datasheet/108515)	Restricted distribution		Introduced			Gopal, 1987; EPPO, 2014	
Niger (/isc/datasheet/108518)	Restricted distribution		Introduced			Akinyemiju, 1987; Lomer, 1995	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Nigeria (/isc/datasheet/108520)	Restricted distribution		Introduced		Invasive	Akinyemiju, 1987; EPPO, 2014	
Réunion (/isc/datasheet/108546)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Rodriguez Island (/isc/datasheet/108547)	Present		Introduced			Royal Botanic Gardens Kew, 2012	
Rwanda (/isc/datasheet/108551)	Widespread		Introduced		Invasive	Harley, 1993; EPPO, 2014	
Senegal (/isc/datasheet/108564)	Restricted distribution		Introduced			Gopal, 1987; EPPO, 2014	
Seychelles (/isc/datasheet/108554)	Present		Introduced			Royal Botanic Gardens Kew, 2012	
Sierra Leone (/isc/datasheet/108562)	Present					EPPO, 2014	
South Africa (/isc/datasheet/108613)	Widespread		Introduced		Invasive	Jones, 2001; EPPO, 2014	
Sudan (/isc/datasheet/108555)	Widespread		Introduced	1957	Invasive	Gay, 1960; Gopal, 1987; EPPO, 2014	
Swaziland (/isc/datasheet/108573)	Present					EPPO, 2014	
Tanzania (/isc/datasheet/108591)	Widespread		Introduced		Invasive	Mallya et al., 2001; EPPO, 2014	
-Zanzibar (/isc/datasheet/108793)	Restricted distribution		Introduced			Gopal, 1987	
Togo (/isc/datasheet/108579)	Present					EPPO, 2014	
Uganda (/isc/datasheet/108594)	Widespread		Introduced		Invasive	Hill, 1999; Mailu, 2001; EPPO, 2014	
Zambia (/isc/datasheet/108614)	Widespread		Introduced		Invasive	Bennett, 1972; Hill, 1997; EPPO, 2014	
Zimbabwe (/isc/datasheet/108616)	Widespread		Introduced		Invasive	Chikwenhere, 2001; EPPO, 2014	
North America							
Bermuda (/isc/datasheet/108377)	Widespread		Introduced		Invasive	Gopal, 1987; Kairo et al., 2003; EPPO, 2014	
Canada							
-Ontario (/isc/datasheet/108661)	Present					Adebayo et al., 2011	
Mexico (/isc/datasheet/108513)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
USA (/isc/datasheet/108597)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Alabama (/isc/datasheet/108796)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Arizona (/isc/datasheet/108798)	Present					EPPO, 2014	
-Arkansas (/isc/datasheet/108797)	Present		Introduced			Center et al., 2002; EPPO, 2014	
-California (/isc/datasheet/108799)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Colorado (/isc/datasheet/108800)	Present					EPPO, 2014	
-Connecticut (/isc/datasheet/108801)	Present		Introduced			USDA-NRCS, 2013	
-Delaware (/isc/datasheet/108803)	Present					EPPO, 2014	
-Florida (/isc/datasheet/108804)	Widespread		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Georgia (/isc/datasheet/108805)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Hawaii (/isc/datasheet/108806)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Illinois (/isc/datasheet/108809)	Present					EPPO, 2014	
-Kentucky (/isc/datasheet/108812)	Present					EPPO, 2014	
-Louisiana (/isc/datasheet/108813)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Maryland (/isc/datasheet/108815)	Present					EPPO, 2014	
-Mississippi (/isc/datasheet/108820)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Missouri (/isc/datasheet/108819)	Present					EPPO, 2014	
-New Jersey (/isc/datasheet/108826)	Present					EPPO, 2014	
-New York (/isc/datasheet/108829)	Present					EPPO, 2014	
-North Carolina (/isc/datasheet/108822)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Oregon (/isc/datasheet/108832)	Present					EPPO, 2014	
-South Carolina (/isc/datasheet/108835)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Tennessee (/isc/datasheet/108837)	Present					EPPO, 2014	
-Texas (/isc/datasheet/108838)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Virginia (/isc/datasheet/108840)	Present					EPPO, 2014	
-Washington (/isc/datasheet/108842)	Present					EPPO, 2014	
Central America and Caribbean							
Antigua and Barbuda (/isc/datasheet/108352)	Present		Introduced			Acevedo-Rodríguez and Strong, 2012	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Aruba (/isc/datasheet/108363)	Present		Introduced			Royal Botanic Gardens Kew, 2012	
Bahamas (/isc/datasheet/108382)	Present		Introduced		Invasive	Gopal, 1987; Kairo et al., 2003; EPPO, 2014	
Barbados (/isc/datasheet/108368)	Present		Introduced			Gopal, 1987	
Belize (/isc/datasheet/108387)	Present					Gopal, 1987	
Costa Rica (/isc/datasheet/108402)	Present					Gopal, 1987; EPPO, 2014	
Cuba (/isc/datasheet/108405)	Widespread		Introduced		Invasive	Gopal, 1987; Oviedo Prieto et al., 2012; EPPO, 2014	
Dominica (/isc/datasheet/108413)	Present		Introduced			Acevedo-Rodríguez and Strong, 2012	
Dominican Republic (/isc/datasheet/108414)	Widespread				Invasive	Gopal, 1987; Kairo et al., 2003; EPPO, 2014	
El Salvador (/isc/datasheet/108571)	Present					Gopal, 1987	
Guadeloupe (/isc/datasheet/108441)	Present		Introduced			Acevedo-Rodríguez and Strong, 2012	
Guatemala (/isc/datasheet/108445)	Present					Gopal, 1987; EPPO, 2014	
Haiti (/isc/datasheet/108453)	Present		Introduced			Gopal, 1987; EPPO, 2014	
Honduras (/isc/datasheet/108451)	Present					Gopal, 1987; EPPO, 2014	
Jamaica (/isc/datasheet/108465)	Widespread		Introduced		Invasive	Gopal, 1987; Kairo et al., 2003; EPPO, 2014	
Martinique (/isc/datasheet/108506)	Present		Introduced			Acevedo-Rodríguez and Strong, 2012	
Nicaragua (/isc/datasheet/108521)	Present					Gopal, 1987; EPPO, 2014	
Panama (/isc/datasheet/108530)	Widespread					Gopal, 1987; EPPO, 2014	
Puerto Rico (/isc/datasheet/108541)	Widespread		Introduced		Invasive	Gopal, 1987; Kairo et al., 2003; EPPO, 2014	
Saint Lucia (/isc/datasheet/108483)	Present		Introduced			Graveson, 2012	Naturalized
Saint Vincent and the Grenadines (/isc/datasheet/108600)	Present		Introduced			Gopal, 1987	
Trinidad and Tobago (/isc/datasheet/108588)	Present		Introduced			Gopal, 1987	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
United States Virgin Islands (/isc/datasheet/108603)	Present		Introduced			Acevedo-Rodríguez and Strong, 2012	
South America							
Argentina (/isc/datasheet/108359)	Restricted distribution					Gopal, 1987	
Bolivia (/isc/datasheet/108379)	Restricted distribution					Gopal, 1987	
Brazil (/isc/datasheet/108381)	Widespread		Native			Gopal, 1987; EPPO, 2014	
-Acre (/isc/datasheet/108626)	Present		Native			Lorenzi, 1982	
-Alagoas (/isc/datasheet/108627)	Present		Native			Lorenzi, 1982	
-Amapa (/isc/datasheet/108629)	Present		Native			Gopal, 1987	
-Amazonas (/isc/datasheet/108628)	Present		Native			Gopal, 1987	
-Bahia (/isc/datasheet/108630)	Present		Native			Lorenzi, 1982	
-Ceara (/isc/datasheet/108631)	Present		Native			Lorenzi, 1982	
-Espirito Santo (/isc/datasheet/108632)	Present		Native			Lorenzi, 1982	
-Goias (/isc/datasheet/108634)	Present		Native			Lorenzi, 1982	
-Maranhao (/isc/datasheet/108635)	Present		Native			Gopal, 1987	
-Mato Grosso (/isc/datasheet/108638)	Present		Native			Gopal, 1987	
-Mato Grosso do Sul (/isc/datasheet/108637)	Present		Native			Lorenzi, 1982	
-Minas Gerais (/isc/datasheet/108636)	Present		Native			Gopal, 1987	
-Para (/isc/datasheet/108639)	Present		Native			Gopal, 1987	
-Paraiba (/isc/datasheet/108640)	Present		Native			Lorenzi, 1982	
-Parana (/isc/datasheet/108643)	Present		Native			Gopal, 1987	
-Pernambuco (/isc/datasheet/108641)	Present		Native			Gopal, 1987	
-Piaui (/isc/datasheet/108642)	Present		Native			Gopal, 1987	
-Rio de Janeiro (/isc/datasheet/108644)	Present		Native			Gopal, 1987	
-Rio Grande do Norte (/isc/datasheet/108645)	Present		Native			Lorenzi, 1982	
-Rio Grande do Sul (/isc/datasheet/108648)	Present		Native			Gopal, 1987	
-Rondonia (/isc/datasheet/108646)	Present		Native			Gopal, 1987	
-Roraima (/isc/datasheet/108647)	Present		Native			Lorenzi, 1982	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Santa Catarina (/isc/datasheet/108649)	Present		Native			Gopal, 1987	
-Sao Paulo (/isc/datasheet/108651)	Present		Native			Gopal, 1987	
-Sergipe (/isc/datasheet/108650)	Present		Native			Lorenzi, 1982	
Chile (/isc/datasheet/108396)	Restricted distribution					Gopal, 1987; EPPO, 2014	
Colombia (/isc/datasheet/108399)	Widespread		Native		Invasive	Gopal, 1987; PIER, 2013; EPPO, 2014	
Ecuador (/isc/datasheet/108416)	Restricted distribution					Gopal, 1987; EPPO, 2014	
Guyana (/isc/datasheet/108448)	Widespread					Gopal, 1987	
Paraguay (/isc/datasheet/108544)	Present					Gopal, 1987	
Peru (/isc/datasheet/108532)	Restricted distribution					Gopal, 1987; EPPO, 2014	
Suriname (/isc/datasheet/108568)	Restricted distribution					Gopal, 1987	
Uruguay (/isc/datasheet/108598)	Present					Gopal, 1987	
Venezuela (/isc/datasheet/108601)	Present					Gopal, 1987; EPPO, 2014	
Europe							
Belgium (/isc/datasheet/108370)	Introduced, not established		Introduced			DAISIE, 2013	
Czech Republic (/isc/datasheet/108409)	Restricted distribution		Introduced		Not invasive	Pysek et al., 2002	
France (/isc/datasheet/108429)	Restricted distribution		Introduced		Not invasive	Georges and Pax, 2002; EPPO, 2014	
-Corsica (/isc/datasheet/108704)	Transient: actionable, under eradication					DAISIE, 2013; EPPO, 2014	
Hungary (/isc/datasheet/108454)	Introduced, not established		Introduced			DAISIE, 2013	
Italy (/isc/datasheet/108464)	Present		Introduced			DAISIE, 2013; EPPO, 2014	
-Sardinia (/isc/datasheet/108758)	Present, few occurrences					EPPO, 2014	
-Sicily (/isc/datasheet/108757)	Introduced, not established		Introduced			DAISIE, 2013	
Portugal (/isc/datasheet/108542)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Azores (/isc/datasheet/108776)	Present		Introduced			DAISIE, 2013	
Romania (/isc/datasheet/108548)	Present		Introduced			DAISIE, 2013	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Russian Federation (/isc/datasheet/108550)	Absent, formerly present					EPPO, 2014	
-Central Russia (/isc/datasheet/108782)	Absent, formerly present					EPPO, 2014	
Spain (/isc/datasheet/108421)	Present					EPPO, 2014	
Oceania							
American Samoa (/isc/datasheet/108360)	Present		Introduced		Invasive	PIER, 2013; EPPO, 2014	
Australia (/isc/datasheet/108362)	Restricted distribution		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
-Australian Northern Territory (/isc/datasheet/108619)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
-New South Wales (/isc/datasheet/108620)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
-Queensland (/isc/datasheet/108621)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
-South Australia (/isc/datasheet/108622)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
-Victoria (/isc/datasheet/108624)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
-Western Australia (/isc/datasheet/108625)	Restricted distribution		Introduced		Invasive	Gopal, 1987	
Cook Islands (/isc/datasheet/108395)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Fiji (/isc/datasheet/108425)	Widespread		Introduced	1905	Invasive	Parham, 1958; EPPO, 2014	
French Polynesia (/isc/datasheet/108533)	Present					PIER, 2013; EPPO, 2014	
Guam (/isc/datasheet/108446)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
Marshall Islands (/isc/datasheet/108499)	Present					EPPO, 2014	
Micronesia, Federated states of (/isc/datasheet/108427)	Present					EPPO, 2014	
Nauru (/isc/datasheet/108526)	Present		Introduced		Invasive	PIER, 2013; EPPO, 2014	
New Caledonia (/isc/datasheet/108517)	Present		Introduced		Invasive	PIER, 2013; EPPO, 2014	
New Zealand (/isc/datasheet/108528)	Restricted distribution		Introduced			Gopal, 1987; EPPO, 2014	
Northern Mariana Islands (/isc/datasheet/108505)	Present					EPPO, 2014	
Palau (/isc/datasheet/108543)	Present					EPPO, 2014	
Papua New Guinea (/isc/datasheet/108534)	Widespread		Introduced		Invasive	Schmedding, 1995; EPPO, 2014	
Samoa (/isc/datasheet/108608)	Restricted distribution		Introduced		Invasive	Space and Flynn, 2000; EPPO, 2014	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Solomon Islands (/isc/datasheet/108553)	Present		Introduced		Invasive	Gopal, 1987; EPPO, 2014	
US Minor Outlying Islands (/isc/datasheet/108596)	Present					EPPO, 2014	
Vanuatu (/isc/datasheet/108605)	Present		Introduced		Invasive	PIER, 2013; EPPO, 2014	

History of Introduction and Spread

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The origin of *E. crassipes* is almost certainly the Amazon basin of Brazil (Barrett and Forno, 1982), and the natural distribution prior to 1800 is not thought to have extended beyond South America. Although it may not be strictly native in Central America it had certainly spread to many countries of Central America and the Caribbean by the end of the nineteenth century. It was first introduced to the USA (Louisiana) in 1884, when the plant was distributed to participants in the New Orleans Cotton Exposition and apparently became a problem thereafter (Julien, 2001), and further to Florida in 1890.

Because of its striking flowers, it was deliberately introduced into botanic gardens in many other countries, from which it inevitably spread as a weed. Some dates of introduction indicated by Gopal (1987) include: Australia, Egypt and Japan all about 1890; Indonesia, 1894; India, 1896; China, 1902 (1901 according to Xie Yan et al., 2001); Singapore, 1903; Sri Lanka, 1904; South Africa, 1910; the Philippines, 1912; Myanmar, 1913. It was probably introduced to Madagascar around, or shortly after, 1900 as an ornamental and was first recorded in 1920 (Binggeli, 2003).

The early introduction and spread of the plant to South-East Asia has been outlined by Burkill (1935). It was brought from an unknown location to Java in 1894, to Tonkin in 1902, and in about 1902 it reached southern China. A person noted the species in Hong Kong, admired its beauty and took the plant to Sri Lanka. A Chinese resident in Singapore imported it from Hong Kong to his garden and the plant was subsequently brought into the Botanic Gardens. Then local Chinese villagers took the plant to their homes and successfully fed it to their pigs and it became generally adopted for this purpose.

Within South-East Asia, there has been extensive spread throughout Malaysia, Indonesia, the Philippines, Vietnam, Thailand, Cambodia and Laos; also through southern provinces of China and Japan. *E. crassipes* was first reported from Papua New Guinea in 1962.

In recent years, introduction (deliberate and otherwise) has been especially serious in Africa, with troublesome infestations developing in the Congo river from about 1950, the Sigi and Pangani rivers (Tanzania) from 1955, 1959 respectively (Ivens, 1989), the upper Nile from about 1956, Senegal from about 1960 (all cited in Gopal, 1987). It was first recorded in Sudan in 1957 and is thought to have been introduced that year or shortly before. It started to spread rapidly up the Nile's tributaries thanks to steamer traffic (Gay, 1960). It was recorded along the Shire river (Malawi) from 1968 (Harley, 1993), Nigeria from 1982 (Akinyemiju, 1987), Ghana from 1984 (de Graft-Johnson, 1993), Benin from 1985 (van Thielen, 1993), Lake Kyoga (Uganda) from 1988, Lake Naivasha (Kenya) from 1989 (Owiti, 1990), and Lake Victoria from 1989 (Twongo, 1993). Although *E. crassipes* was present in Uganda before 1987 in the (relatively) lower reaches of the White Nile (Gopal, 1987), it was only noticed in Lake Kyoga by 1988 (Twongo, 1993). Occurrence in the Niger river in Mali and Niger has now also been confirmed (Lomer, 1995).

Once introduced to favourable habitats, especially open waters, *E. crassipes* may spread very rapidly and can form dense monotypic mats. In the 1950s, within 3 years of its first sighting, it had spread 1600 km along the Congo River (Holm et al., 1969). On Lake Victoria the species-spread in the early 1990s was just as dramatic but by the end of the decade the population had crashed (Mailu, 2001). In Madagascar, the potential threat to the freshwater bodies of the island was recognised in the 1920s following the introduction of the species as an ornamental. However, the advice to eradicate the plant was not heeded and by the late 20th century it became a major pest (Binggeli, 2003).

Risk of Introduction

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From the early part of the twentieth century *E. crassipes* has been identified as a troublesome plant and declared a noxious weed. For instance, in Fiji it was proclaimed a noxious plant, it was one of the first plants to be recognised as a noxious weed in January 1923 and growing it in a lily pond was made illegal (Parham, 1958). *E. crassipes* is also listed as a noxious weed in other countries, including Australia and South Africa. Even the movement of plant material may be prohibited within countries such as Australia (Parsons and Cuthbertson, 1992). There may also be regulations requiring the destruction of *E. crassipes* wherever it is found. However, enforcement is difficult and uneven. The lack of effective regulatory control has been responsible for most of the world's worst infestations of *E. crassipes*. The current ease with which plants, including *E. crassipes*, are available from the internet threatens efforts to prevent the sale and spread of weedy species to countries blacklisting them.

Habitat

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E. crassipes is a floating weed of tropical and sub-tropical freshwater lakes and rivers, especially those enriched with plant nutrients. It may also be a weed in flooded rice.

Habitat List

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Category	Habitat	Presence	Status
Freshwater	Freshwater	Present, no further details	Harmful (pest or invasive)
Terrestrial-managed	Cultivated / agricultural land	Present, no further details	Harmful (pest or invasive)

Host Plants and Other Plants Affected

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Plant name	Family	Context
Oryza sativa (rice) (/isc/datasheet/37964)	Poaceae	Main

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Biology and Ecology

Genetics

The chromosome number is 2n = 32 (Darlington and Wylie, 1955).

Physiology and Phenology

The growth of *E. crassipes* is extremely rapid and the plant may double its population size in 6 to 18 days.

E. crassipes leaves show anatomical characteristics of C3 plants but the photosynthetic process shows some characteristics of the more productive C4 plants, especially in showing no light saturation up to high light levels. This makes it a highly efficient plant and relative growth rates have been recorded of 1.012 to 1.077. Other studies suggest it is capable of increasing in biomass by up to 12% per day. The time required to double in number or biomass is variously reported to be from 6 to 15 days. Productivity can also be expressed in terms of 100-500 g fresh weight/m^2 per day, 1000-5000 kg/ha per day or 400-1700 t/ha per year. The total biomass or 'standing crop' can be as much as 42 kg/m^2 or 420 t fresh weight/ha. As the dry weight is normally about 5-7% of fresh weight, this represents about 2.5 kg dry weight/m^2 or 25 t dry matter/ha (Gopal, 1987). As would be expected, the foliage is very dense with one study in Florida finding leaf area index values of 7.8 and 5.8, comparable with many of the most productive terrestrial ecosystems (Knipling et al., 1970).

Flowering is seasonal in some countries but not obviously so in others. There is apparently little or no response to photoperiod but considerable evidence that flowering may be induced by nutrient shortages.

Reproductive Biology

The flowers of *E. crassipes* are tristylous, but unlike some other tristylous species, there is no incompatibility between the different forms. Hence pollination (mainly by wind) can result in good seed set, though in some populations there may be a higher degree of self-incompatibility.

E. crassipes propagates vegetatively and by seed. After flowering, the peduncle is deflexed and the capsules mature and seeds are eventually released below water. The seeds are capable of germinating immediately but may remain dormant for many years. Germination is encouraged by aerobic conditions and alternating temperatures; large populations of seedlings may become established on exposed mud at the edges of water bodies when water levels fall. Seedlings are rooted in mud initially but become free-floating as a result of wave action or rising water levels. From an early stage, the axillary buds of the older leaves of the seedling are capable of developing into stolons, which grow horizontally and develop daughter plants. Such vegetative spread can occur indefinitely and very large populations are produced in this way without any sexual reproduction.

Environmental Requirements

Optimum temperature for growth of *E. crassipes* is 25-30°C. Growth ceases when water temperature is above 40°C or below 10°C, but short periods at freezing may be tolerated.

E. crassipes is very responsive to nutrients (especially nitrogen and phosphorus) and high growth rates are always associated with eutrophic, nutrient-rich conditions. Growth rate was greater by a factor of eight where total nutrient content was 52 mg/l, compared with 8 mg/l (Lugo et al., 1979). The growth rate is proportional to the percentage concentration of nitrogen in the leaves (Aoyama and Nishizaki, 1993) and there is a hyperbolic relationship between the growth rate and the nutrient concentration in the water. The mean percentage nitrogen (dry weight) of the second youngest leaves in the field has been determined at between 1 and 5% (Center and Wright, 1991; M Purcell, unpublished data; MH Julien, unpublished data; Lorber et al., 1984). The percentage phosphorus is slightly lower - ranging from 0.2 to 1.0% (cited in Lorber et al., 1984). The percentage nitrogen varies between plant parts and decreases exponentially as leaves age (Center and Wright, 1991).

Optimum pH is between 6 and 8 and extremes of pH (below 4.5 or above 10) can be damaging. Calcium concentration is important, with an observed threshold of 5 mg/l, below which growth ceases.

E. crassipes will tolerate only low levels of salinity; one-quarter strength sea water is lethal (Muramoto et al., 1991) and the problem in coastal lagoons depends on the growth of the weed in the fresh water of the rivers that flow into the lagoon.

Associations

E. crassipes is often associated with other water weeds such as *Pistia stratiotes, Myriophyllum aquaticum* and *Azolla filiculoides*. However, it tends to be the dominant species unless some form of biological control has been initiated (Chikwenhere, 2001).

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Air Temperature

Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	0	

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Soil Tolerances

Soil reaction

acid
alkaline
neutral

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Water Tolerances

Parameter	Minimum Value	Maximum Value	Typical Value	Status	Life Stage	Notes
Salinity (part per thousand)	0	6		Optimum		
Salinity (part per thousand)		8		Harmful		
Water pH (pH)	6	8		Optimum		
Water temperature (ºC temperature)	10	25		Optimum		
Water temperature (ºC temperature)	5			Harmful		

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Acremonium zonatum (/isc/datasheet/2987)	Pathogen					
Alternaria alternata (/isc/datasheet/4480)	Pathogen					
Alternaria eichhorniae (/isc/datasheet/4501)	Pathogen	Leaves				
Argyractis subornata (/isc/datasheet/6890)	Herbivore	Roots				
Bellura densa (/isc/datasheet/8889)	Herbivore	Leaves/Stems				
Cercospera rodmanii (/isc/datasheet/11899)	Pathogen					
Cercospora piaropi (/isc/datasheet/12261)	Pathogen	Leaves/Stems				
Cercospora rodmanii (/isc/datasheet/12271)	Pathogen	Leaves/Seeds				
Cochliobolus lunatus (/isc/datasheet/14690)	Pathogen					
Cochliobolus sativus (/isc/datasheet/14694)	Pathogen					
Cochliobolus spicifer (/isc/datasheet/14696)	Pathogen					
Cornops aquaticum (/isc/datasheet/16184)	Herbivore	Leaves				
Ctenopharyngodon idella (/isc/datasheet/16772)	Herbivore					
Eccritotarsus catarinensis (/isc/datasheet/20346)	Herbivore	Leaves				
Flechtmannia eichhorniae (/isc/datasheet/24223)	Herbivore	Whole plant				
Fulica americana (/isc/datasheet/24575)	Herbivore					
Fusarium chlamydosporum (/isc/datasheet/24645)	Pathogen					
Gesonula punctifrons (/isc/datasheet/25132)	Herbivore	Leaves				
Gibberella intricans (/isc/datasheet/25162)	Pathogen					
Gibberella zeae (/isc/datasheet/25167)	Pathogen					
Haematonectria haematococca (/isc/datasheet/24697)	Pathogen					
Marisa cornuarietis (/isc/datasheet/32526)	Predator					
Megamelus sp. (/isc/datasheet/33760)	Herbivore					

Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Myrothecium roridum (/isc/datasheet/35576)	Pathogen	Leaves			Malaysia	
Neochetina bruchi (/isc/datasheet/35785)	Herbivore	Growing point/Leaves/Stems			Africa; Benin; India; New South Wales; Queensland; Papua New Guinea; Zimbabwe	
Neochetina eichhorniae (/isc/datasheet/35786)	Herbivore	Growing point/Leaves/Stems			Africa; Benin; India; Malaysia; Pacific Islands; Queensland; South Africa; Sri Lanka; Texas; Thailand; New South Wales; Papua New Guinea; Indonesia; Zimbabwe	
Niphograpta albiguttalis (/isc/datasheet/48268)	Herbivore	Growing point/Leaves/Stems			Africa; Queensland; New South Wales	
Orthogalumna terebrantis (/isc/datasheet/38080)	Herbivore	Leaves			India	
Penicillium oxalicum (/isc/datasheet/39583)	Pathogen					
Phoma sorghina (/isc/datasheet/40442)	Pathogen					
Thanatephorus cucumeris (/isc/datasheet/47203)	Pathogen	Larvae				
Thrypticus sp. (/isc/datasheet/53715)	Herbivore	Stems				
Trichechus manatus (/isc/datasheet/54724)	Herbivore	Whole plant				
Uredo eichhorniae (/isc/datasheet/55750)	Pathogen					
Xubida infusellus (/isc/datasheet/2679)	Herbivore	Leaves/Stems				

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Notes on Natural Enemies

Almost 100 different insect species and a comparable number of pathogens have been recorded as attacking *E. crassipes* (refer to Gopal, 1987). Most of these are restricted to the areas of the New World from which the weed originates. In Africa and Asia, the weed is normally quite healthy, though sporadically attacked and sometimes moderately damaged by sundry local organisms. A few species of insects and fungi have been developed for use as biological control agents, with varying success (see Control).

The more important natural enemies in South America are listed, including those that have been used as biological control agents, or studied as potential biological control agents, and also some organisms that have been reported as causing significant damage in some of the countries where *E. crassipes* has been introduced (see Waterhouse (1987), Julien and Griffiths, (1998) and Hill et al. (1999) for details).

Means of Movement and Dispersal

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Natural Dispersal (Non-Biotic)

Wind will readily move the plant and the upright leaves act as sails in lakes and canals. Along rivers, water flow is the prime mover of vegetative material but strong winds may sometimes blow the plant upstream.

Vector Transmission (Biotic)

Seeds are thought to be transported over long distances by birds (e.g. waterfowl and shore birds) and if coated in mud they may cling to both mammals and birds (Holm et al., 1969; Batcher, 2000).

Accidental Introduction

New infestations may arise via unintentional human transportation such as canoes, boats and probably even charcoal transport as sacks used in the process are, in some parts of Africa, plugged with the plant.

Intentional Introduction

The high ornamental value of the plant still makes it liable to intentional introductions, especially as the species is up for sale on the internet.

Impact Summary

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Category	Impact
Animal/plant collections	None
Animal/plant products	None
Biodiversity (generally)	Negative
Crop production	Negative
Environment (generally)	Negative
Fisheries / aquaculture	Negative
Forestry production	None
Human health	Negative
Livestock production	Positive
Native fauna	Negative
Native flora	Negative
Rare/protected species	Negative
Tourism	Negative
Trade/international relations	None
Transport/travel	Negative

Economic Impact

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As a result of its rapid growth and large biomass, *E. crassipes* has a range of detrimental effects, which include:

- Physical interference with water transport, communication and access. Gopal (1987) refers to serious interference with navigation in southern USA, South Africa, southeast Asia, Australia, Congo and Sudan. Annual costs of control or removal have, in the past, amounted to millions of dollars on the Panama Canal, on the Nile in Sudan, on the Congo and have been as much as $35 million in southern USA. Costs of controlling water hyacinth in Malaysia have been estimated at M$ 10 million per year (Mahomed et al., 1992), while Harley et al. (1996) quoting this figure, state that present actual costs are believed to be much higher. In recent years, the operation of Port Bell, Uganda, on Lake Victoria has been seriously threatened and costs have involved $1 million for a mechanical harvester, as well as the loss of trade at times when the port was completely blocked (Hill, 1999). Infestations are also increasing in Ethiopia, creating a range of problems including restricted access (Aweke, 1994). Harley et al. (1996) refer to 'devastating effects' on socio-economic structure and on the environment in the lower flood plain of the Sepik river in Papua New Guinea resulting from problems of access to subsistence gardens, hunting and fishing areas, and markets. The same authors refer to the recent increase in water hyacinth infestations in West Africa which are resulting in serious disruption of the socio-economic structure, food supply and health of several million people. In Nigeria, Alimi and Akinyemiju (1991) showed that costs of fuel and repairs to boats on infested waterways was approximately three times that on uninfested waterways. The problem has also been increasing recently in Mali (Dembele et al., 2000). Economic losses also result from interference with recreational uses of water bodies (for example, Gopal, 1987; Aweke, 1994; Cilliers et al., 1996).

- Interference with fishing. This effect is most acute for small-scale fishing communities. Apart from the problems of access to fishing grounds and interference with the spreading or retrieval of nets or with landing their catch, there can be serious effects on fish stocks and fish breeding. Although a sparse cover of water hyacinth may not reduce fish and may even be used to advantage in some fishing techniques (Gopal, 1987), a dense infestation can lead to de-oxygenation and kill-off fish or reduce fish stocks. Gopal (1987) refers to heavy losses of fish production in the Congo, Nile and other rivers and in Pakistan and to losses amounting to 45 million kg in West Bengal, India in the 1950s and reductions of 70% in fish production in the USA as a result of a cover of only 25%, presumably due to reduction of phosphorus levels and phytoplankton. The shallow water of lake edges can be especially important spawning areas for fish and a dense cover of water hyacinth can interfere severely with fish breeding. Hill (1999) refers to this phenomenon on Lake Victoria where the estimated 10,000 ha of the weed includes an almost continuous fringe along the shoreline extending to at least 10 m. Labrada (1996) quotes fuel costs increased by a factor of 2-3 and fish catches down 50-75% on parts of Lake Victoria. Fishermen affected by another relatively new infestation, in the Shire river in Malawi, report reduced catches which are not confirmed by the locally available statistics but there is no doubt fishermen are being troubled by a reduced range of fish species, loss of nets and impeded access (Terry, 1996).

- Risks of mechanical damage to hydro-electric installations and other structures such as bridges. Expensive barriers or mechanical harvesters may be needed to minimize these risks, for example, to the Owen Falls Dam on Lake Victoria (Hill, 1999). Elsewhere, there are similar concerns in South Africa (Harley et al., 1996), Brazil (Pitelli, 2000), New Zealand (Clayton, 2000) and Ethiopia (Aweke, 1994).

- Reduced irrigation flow can indirectly cause crop loss but there can also be direct interference and competition from water hyacinth where it occurs in flooded rice. Such losses have been estimated at many million dollars in West Bengal, India and as significant in many other countries including Sri Lanka, Bangladesh, Burma, Malaysia, Indonesia, Thailand, Philippines, Japan and Portugal (Gopal, 1987).

Nang'alelwa (2008) summarizes the socioeconomic effects in the Victoria Falls World Heritage site in Zambia. Major impacts include effects on the generation of hydro electric power, tourism development, native biodiversity, fish catches and human health. Other recorded impacts are reduced quality and quantity of water for domestic use, restricted navigation of waterways and the threat posed to vital infrastructure.

Environmental Impact

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Once it proliferates in a water body, *E. crassipes* dramatically alters the ecosystem and often results in environmental degradation and a reduction in bio-diversity. A number of authors note that in many water bodies and wetland areas, the encroachment of water hyacinth has reduced or eliminated natural vegetation (Terry, 1996; Kumar and Rohatgi, 1999). The plant may negatively impact some native species of invertebrates, fish, birds and plants. For example, in Madagascar, many parts of the Alaotra Lake, a site of biological importance, have been reported as covered with carpets of *E. crassipes* that are detrimental to a number of species, such as the duck *Thalassornis leuconotus* (Binggeli, 2003).

Other environmental impacts include:

- Restricting water flow in rivers, irrigation and drainage channels, thus reducing irrigation water and/or leading to greater risk of flooding. Gopal (1987) refers to water flow being reduced by 40-95% in irrigation channels, sometimes leading to flooding in Malaysia and Guyana.

- Excess evapotranspiration, causing wastage of water that would otherwise be used for irrigation, drinking, fisheries, etc. Rates of loss have been reported up to 13 times that from a free water surface, with an average of 2.5 times the loss (Gopal, 1987). In India, the loss of water of the mats of *E. crassipes* was 7.8 times greater that of open water thus resulting in massive wastage of water especially in dry regions (Vasudevan and Jain, 1991). However, it has recently been claimed that these figures have been grossly exaggerated by inadequate experimental technique (Allen et al., 1997).

- When mats decompose dissolved oxygen levels are reduced and sedimentation increases.

The effects of *E. crassipes* on physicochemical characteristics of water in Lake Naivasha, Kenya, are described by Mironga et al. (2012). Impacts include greater levels of free carbon dioxide, lower pH and lower levels of dissolved oxygen in infested areas than in open water. A similar study in Badagry Creek and Ologe Lagoon, Lagos, Nigeria (Ndimele, 2012) found effects on salinity, conductivity, total hardness and total dissolved solids. It is suggested that while there are negative impacts on water quality, the ability of *E. crassipes* to passively absorb heavy metals and nutrients can be put into good use.

Social Impact

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E. crassipes may reduce water quality in various ways and encourage mosquitoes, snails and other organisms associated with human illnesses, including malaria, schistosomiasis, encephalitis, filariasis and cholera (Gopal, 1987). Harley et al. (1996) comment that people in Papua New Guinea have died through a combination of reduced nutrition, degraded water, increased disease vectors and generally reduced health, directly related to the degrading effect of water hyacinth on the environment. Dense mats greatly hinder boating by fishermen and may prevent fishing altogether, thus denying the locals their main source of protein and sometimes forcing people to relocate. In extreme cases of competition between *E. crassipes* and rice crops, fields have been abandoned. In the Lake Victoria Basin, the main negative social impact were identified by interviewees as an increase in certain diseases, difficulties associated with clean water availability and migration of communities (Mailu, 2001).

Risk and Impact Factors

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Invasiveness

Invasive in its native range
Proved invasive outside its native range

Likelihood of entry/control

Highly likely to be transported internationally deliberately
Difficult to identify/detect as a commodity contaminant

Uses

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E. crassipes can be utilized in various ways (for instance for East Africa see Lindsey and Hirt, 1999). Although not generally suitable as an animal feed, small amounts can be fed to pigs and buffaloes, but in China during the 1950s-1970s, when fodder was scarce, it was widely used as an animal feed (Ding Jianqing et al., 2001). It can be used as a mulch, for making compost, fuel bricks, paper or board, for generating methane biogas, and for removing nutrients and toxic chemicals from water. Recent work on composting includes Montoya et al. (2013) who found that a large-scale composting system using water hyacinth as a primary feedstock reached high enough temperatures to inactivate seeds and other propagules, and thus that the plant can be composted without the potential danger of spread.

Its very high growth rate and ability to withstand various types of pollution are proving of interest for the treatment of polluted water but there remains the problem of disposal of the harvested (polluted) material (Aoyama et al., 1986; Ayade, 1998). Yan et al. (2012) tested *E. crassipes* for removal of pollutants in Lake Caohai, China, and found that the plant could not only remove phosphorus in the water, but also remove the soluble phosphorus in the sediment of Lake Caohai, Ndimele and Ndimele (2013) suggest that the species absorbs petroleum hydrocarbon and can be used for phytoremediation of crude oil-polluted aquatic ecosystems.

Potentially, water hyacinth could be very important in sewage and waste water treatment. Its fast growth rate and high absorption of nutrients and heavy metals could make it a cheap and largely environmentally benign form of decontamination (Hill et al., 1999; Zhu et al., 1999). However, the biggest use made of water hyacinth is probably as an ornamental in temperate regions (Cohen, 1993).

Work on utilization includes use as an organic manure in Bangladesh (Nasima et al., 1997); as a compost to suppress nematodes in India (Verma et al., 1997); for water purification (Ayade, 1998); for biogas production (Rodriguez et al., 1997; Sarkar and Banergee, 2013)); for feeding buffaloes in India (Mitra et al., 1997); and as a mulch to suppress weeds in Indonesia (Lamid and Wahab, 1996). Masto et al. (2013) explored the conversion of *E. crassipes* to biochar for improvement of soil quality. There are many recent studies on utilizing *E. crassipes* for bioenergy. Hussain et al. (2013) converted *E. crassipes* biomass into liquid hydrocarbon fuel using catalytic pyrolysis. Bergier et al. (2012) suggest that biomass from water hyacinth in the Panatanal of South America could be managed for production of biofuels. Sudhakar et al. (2013) assess bioelectricity production using water hyacinth biomass. Anaerobic co-digestion with poultry litter for biogas production is considered by Patil et al. (2013), while Zhang et al. (2013) report on hydrothermal liquefaction. Biogas production from water hyacinth polluting water bodies in Nigeria is studied by Adeleye et al. (2013).

Uses List

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Animal feed, fodder, forage

Fodder/animal feed

Environmental

Soil improvement

Fuels

Biofuels

General

Ornamental

Detection and Inspection

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Detection of mature floating *E. crassipes* plants is all too simple but where control methods have been used to eliminate these, there is a need to watch for seedling plants at the edges of the water body.

Similarities to Other Species/Conditions

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Apart from the possible confusion with other species of *Eichhornia*, notably *E. azurea* in Central and South America (see Taxonomy and Nomenclature), some other species in Pontederiaceae could perhaps be confused with *E. crassipes*. These include the rice weed *Monochoria vaginalis* which is common throughout South-East Asia. This is superficially similar, with a spike of showy purple flowers, but these are smaller, radially symmetrical and the petals are free. Leaf shape can be somewhat similar but petioles are not swollen. Some species of *Pontederia* can occur as aquatic weeds in North America but these have a unilocular ovary and flowers are two-lipped, each lip with three lobes. Several species of *Heteranthera* occur as weeds in the Americas and Africa but these have only three stamens. All these related species are rooted weeds, not floating aquatics like *E. crassipes*.

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Prevention and Control

Cultural Control

Although the exact nutrient threshold below which *E. crassipes* will not flourish is not yet clear, it is certain that its vigour is directly related to available levels of nitrogen and phosphorus. Wherever possible, nutrient levels in the water body should be reduced or controlled: for example, by processing sewage or other nutrient-rich water, or by diverting it away from critical areas In South Africa, Coetzee and Hill (2012) suggest that the first step in any control programme should be to reduce the nutrient status of the water body, as a meta-analysis of studies that investigated the combined effect of P and nitrogen (N) water nutrient concentration and control agent herbivory showed that water nutrient status was more important than herbivory in water hyacinth growth.

Mechanical Control

Where *E. crassipes* is causing the most acute problems (e.g. impeding access for fishermen, or threatening to block harbours or damage hydro-electric installations), an effective solution may be the use of floating booms or fixed barriers to prevent movement into the critical areas. Booms may also be used to try and prevent movement of the weed down rivers, though their success will depend on their design (complicated by the need to maintain navigability along the river), the mass of material involved and the capacity to clear the booms by physical removal of weed.

Physical removal or destruction of the infestation may be achieved on a small scale by manual removal. On the larger scale, machinery is needed, either shore-based, or mounted on boats. Where possible, on smaller water bodies, reliance should be placed on unspecialized shore-based equipment (e.g. drag-lines, excavators, moving-belt elevators etc.), the weed being pushed to the shore by suitably modified boats. For larger water bodies, special boats may be needed with suitable harvesting equipment, together with a means of crushing the weed or otherwise reducing the volume of water. Where the water body is sufficiently large and deep for the weed to be returned to the water after crushing, without risk of decomposition causing deoxygenation, the use of such equipment may be economic. If the weed has to be transported to the land for unloading, the running costs become much greater and such methods may not be economic.

Julien (2008) reviews biological aspects of *E. crassipes* related to management, and suggest that containment and eradication from a catchment may only be accomplished if the invasion is very young, small, isolated and accessible, and if the short-term resource commitment is high. Jyoti and Garima (2013) present methods of control including manual pulling and harvesting.

Chemical Control

2,4-D has been widely used for control of *E. crassipes*. Best results are achieved under conditions of rapid growth, high temperature and high humidity, when most plants of any age will be killed and sink within 2-4 weeks. Under less favourable conditions, some plants may regrow and require repeat treatment. In any case re-treatment is almost inevitably required after a few months as a result of re-infestation from incompletely sprayed plants, re-invasion from outside the sprayed area, or regrowth by seedlings.

Glyphosate has been tested and used for control of *E. crassipes*. It is much more expensive than 2,4-D but has possible advantages over 2,4-D in not causing taint of drinking water and in causing a slower kill of the weed, apparently reducing the risks of deoxygenation during decomposition (Findlay and Jones, 1996).

Other herbicides that have been used include the contact herbicides paraquat and diquat, but these have high mammalian toxicity and should not normally be used. Diquat use is described by Pitelli et al. (2011), who suggest that night application is more effective than day spraying. Aminotriazol [amitrole], ametryn and terbutryn can each be effective alone, but have been most often used in mixture with 2,4-D. Wersal and Madsen (2010) evaluated the use of penoxsulam, which gave effective control which was not improved by applying in combination with diquat.

New herbicides in the imidazolinone and sulfonylurea groups have been shown to have high activity on *E. crassipes*, but have not yet been adequately tested. These and other possibilities have been summarized by Price (1993).

Herbicides have rarely been used with complete success, owing to the need for repeated treatment over a long period, requiring dedicated management and organization. Apart from the problems of limited success, the use of 2,4-D and other herbicides can be unsatisfactory in several other respects. Ester formulations of 2,4-D can be highly toxic to aquatic organisms as well as creating a vapour drift problem. While the direct toxicity to aquatic organisms of 2,4-D amine salt formulations and the other listed compounds is largely negligible at the concentrations reached in the water, there can be devastating stress caused by deoxygenation as the weed dies and decomposes. Other problems include those of taint of drinking water by 2,4-D, and, for any herbicide that is used, damage by spray-drift onto non-target crops and other plant life adjacent to sprayed areas.

Biological Control

Seven arthropods and three fungi have been developed and released for the biocontrol of *E. crassipes* (Harley, 1990; Julien and Griffiths, 1998). The arthropods are the curculionids *Neochetina bruchi* and *Neochetina eichhorniae*, the pyralids *Xubida infusellus* and *Niphograpta albiguttalis*, the noctuid *Bellura densa*, the mirid *Eccritotarsus catariensis*, and the galumnid mite *Orthogalumna terebrantis*. The fungi are all hyphomycetes: *Acremonium zonatum*, *Cercospora piaropi* and *Cercospora rodmanii*. Additionally, there has been work on the development of the fungus *Alternaria eichhorniae* as a mycoherbicide (Aneja, 1996; Shabana, 1997). *Acremonium zonatum*, *Cercospora piaropi*, *Myrothecium roridum*, and *Rhizoctonia solani* are viewed as suitable bioherbicides (Charudattan, 2001). In Africa, an international programme has been established to develop a mycoherbicide for the control of the weed, using fungal isolates that have been found in Africa (Bateman, 2001). Karim Dagno et al. (2012) review the current status of development of mycoherbicides against *E. crassipes*, but report that biological, technological and commercial constraints have hindered progress. Oil emulsions are recognized as a way to increase both efficiency of application and efficacy of biocontrol agents

The two *Neochetina* weevils have together given excellent results in the USA, Argentina, India, Australia and Sudan, acting apparently in a complementary fashion. Infestations of *E. crassipes* have been reduced by 80-90% or more. In Uganda, the two weevils have greatly reduced the problem on Lake Kyoga, and are beginning to take effect on Lake Victoria (Hill, 1999). In Papua New Guinea, *N. eichhorniae* is reported to be giving 'permanent control' in some areas (Orapa and Atip, 1996). More recently, Orapa and Julien (2001) reported that although control had been achieved in some areas, such as the Sepik River and Waigani Lake, the full impact of biological control by the *Neochetina* weevils on water hyacinth in PNG is not known.

Some successful control programmes have been recorded in Mexico (Panduro and Domunguez, 1998), Benin, South Africa, Zimbabwe and Malawi. Control takes from 2 to 10 years depending on the location and the environmental conditions, but in some locations (including the countries mentioned) the weevils do not appear able to control the weed.

Adult weevils feed on the leaf and petiole surfaces, preferentially on the youngest leaves (Center, 1985). They make distinctive, almost square, feeding scars. This may cause significant loss of functional leaf surface and also may allow entry of pathogens, with the potential in extreme situations for removing over 50% of the laminar area (Van and Center, 1994). However, the most significant damage is caused by the larval stages. Eggs are laid in the petioles. Upon hatching, the larvae burrow down the petiole into the crown of the plant where they can cause major damage (Patnaik et al., 1988). The weevils pupate underwater in the roots. Under certain circumstances the adults can migrate through flight (Buckingham and Passoa, 1984). This damage to the petiole often results in complete collapse of the leaf and eventually in loss of buoyancy so that the whole plant sinks. Each of the two *Neochetina* species has small but distinct differences in biology, ecology and feeding habits, which result in additive, complementary effects. *N. bruchi* are slightly smaller weevils and develop faster but in many locations including Florida, USA, and Benin, *N. eichhorniae* is the species most commonly encountered in the field. The developmental time is much shorter in the tropics with *N. eichhorniae* taking 80 days to develop from egg to adult in Florida and about 50 days in West Africa.

The moth *Niphograpta albiguttalis* is believed to have contributed to the successes in Sudan and the USA. Oke et al. (2012) report that this moth did not successfully establish when released in Benin or Ghana, but that without recorded release of the moth in Nigeria the larvae were found damaging water hyacinth in the infested waterways of Badagry, Ejirin and Epe in Lagos State and Iwopin in Ogun State. The larval instars found were damaging only water hyacinth with bulbous petioles. The other organisms listed above have rarely been effective on their own, but the fungi are often observed to increase the damage caused by insects or by the mite *Orthogalumna terebrantis*; this has been observed in South Africa.

Chemical control (e.g. using 2,4-D) may be necessary as an extreme measure, for the rapid destruction of large masses of weed which are seriously impeding access or navigation. All the larvae of *Neochetina* spp. and many adults on the sprayed plants are likely to be lost as a result of complete kill of the weed. This should be considered in deciding the areas to be treated, in addition to the possible problems from deoxygenation when the weed is decomposing. Where *Neochetina* spp. are being introduced, any herbicide treatment should of course be kept well away from the introduction points. Low doses of 2,4-D, which damage but do not kill the weed are believed to encourage insect attack and will thus be beneficial in the longer term (Haag and Habeck, 1991). Other evidence suggesting that herbicides are not necessarily detrimental to *Neochetina* spp. is provided by, for example, Findlay and Jones (1996) and Center et al. (1999). Herbicides are also known to encourage certain fungi. Hence chemical and biological control are not necessarily incompatible.

Biological control programmes can readily involve local community groups. In Australia, CSIRO has harnessed the resources of the school system via the formation of the Double Helix Science Club as part of a sponsored initiative to promote science in schools. In 1995, this club released the biocontrol agent *Neochetina bruchi* (Briese and McLaren, 1997).

A new agent, *Cornops aquaticum*, is being tested for specificity in South Africa (Oberholzer and Hill, 2001). Coetzee et al. (2011) review biological control efforts in South Africa, but suggest that long-term management of alien aquatic plants in South Africa relies on the prevention of new introductions of aquatic plant species that could replace those that have been controlled, and, more importantly, on a reduction in nutrient levels in South Africa's aquatic ecosystems.

Sacco et al. (2013) evaluate the potential of the planthopper *Taosa logula*, native to South America, for control of *E. crassipes*. Tests showed that individual growth and biomass production of water hyacinth was reduced due to the effect of the insect feeding above five nymphs per cage. The number of new plants produced by clonal reproduction was only significantly different above 15 nymphs per cage. These results suggest that this planthopper could be an effective agent for the biological control of *E. crasssipes*.

Integrated Control

Although it is hoped that biological control will eventually be capable of achieving the necessary level of control of *E. crassipes*, there is likely to be scope for the integration of physical and chemical methods with biological methods on a local basis, to help speed the achievement of control. The possible approaches include:

- control of nutrient levels.

- use of booms to control movement of the weed.

- exploitation of variable water levels.

- manual removal of the weed from shores and small channels.

- mechanical removal or destruction by land-based or floating equipment.

- use of biological control agents.

- careful use of herbicide to kill or weaken the weed.

- utilization of the weed.

An example of a well integrated control approach (in Mexico) is provided by Gutierrez et al. (1996). In South Africa, biological control with five arthropod species and fungal pathogens attempted since the mid-1970s has had limited success and it has been suggested that additional control agents may be required as well as implementing site-specific integrated management plans (Hill and Cilliers, 1999). Due to the weed's recent rapid increase in the species' abundance and distribution in Africa and elsewhere, international co-operation has been promoted in order to effectively combat the plant (Julien et al., 1996). Lu et al. (2007) suggest that in China the currently dominant biological control-centered view should be broadened to a sustainability science-based management framework that explicitly incorporates principles from landscape ecology and Integrated Pest Management.

Control of Nutrient Levels

The reduction of nutrient pollution of water bodies, wherever it is at all feasible, should be a high-priority approach. Redistribution of excess nutrient, as an alternative to its prevention, should be considered in some situations.

Removal

Where infestations occur in relatively narrow rivers, the removal by manual or land-based machinery is often feasible and, although such removal is expensive, the cost may be at least partly offset by utilization (see below). In larger water bodies, the weed should, wherever possible, be pushed to the shore for harvesting by land-based methods, but floating equipment may be appropriate in some situations.

Utilization

A range of uses for water hyacinth have been proposed and studied (see Uses) none can be regarded as suitable for large-scale use and at the same time provide a satisfactory means of control. However, some of the uses can be exploited on a small scale, especially in conjunction with manual or mechanical harvesting, to recoup some costs and help to make the procedures more economic. Some of these can help to cover some of the costs of control but in almost no case does the usefulness outweigh the economic problems caused by the weed. The possibilities of incorporating utilization into an integrated system of control are reviewed in detail by Gopal (1987).

Each water body should be considered separately; an ideal combination of measures should be devised for each water body, depending on many factors and in close consultation with all users of the water.

Gopal (1987) ends his book with the warning that 'The interests of mankind can only be safeguarded by seeking effective control of water hyacinth and not by its utilization'.

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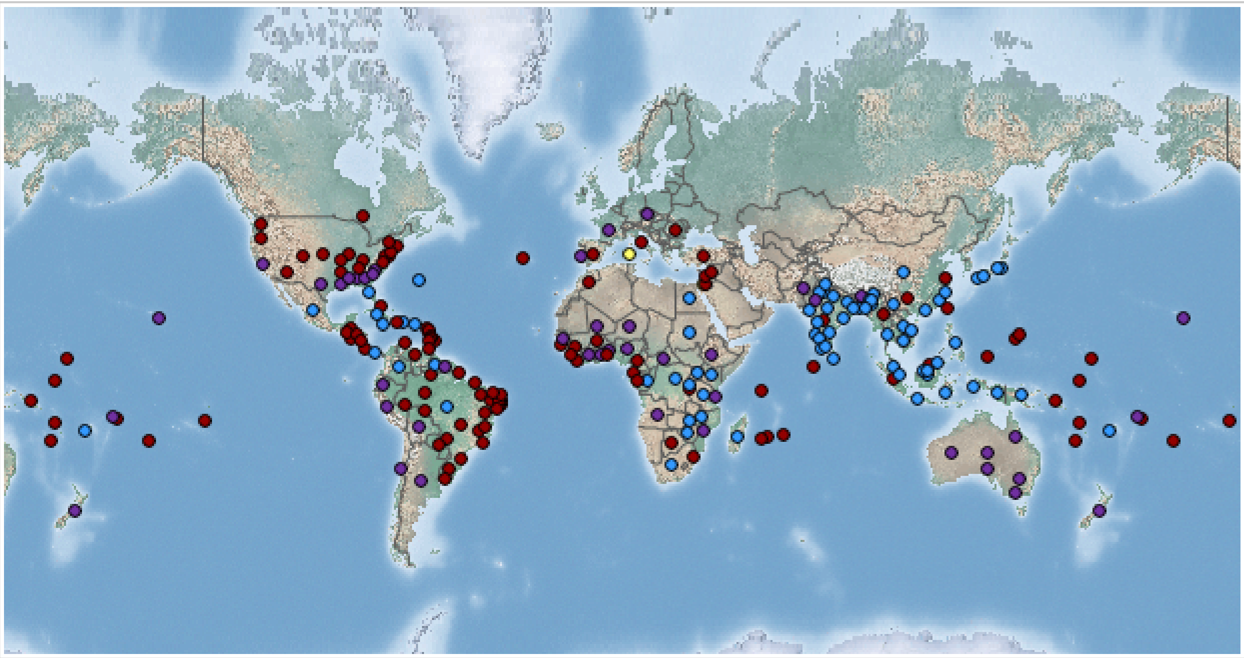
World Map

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports
Present	



Africa

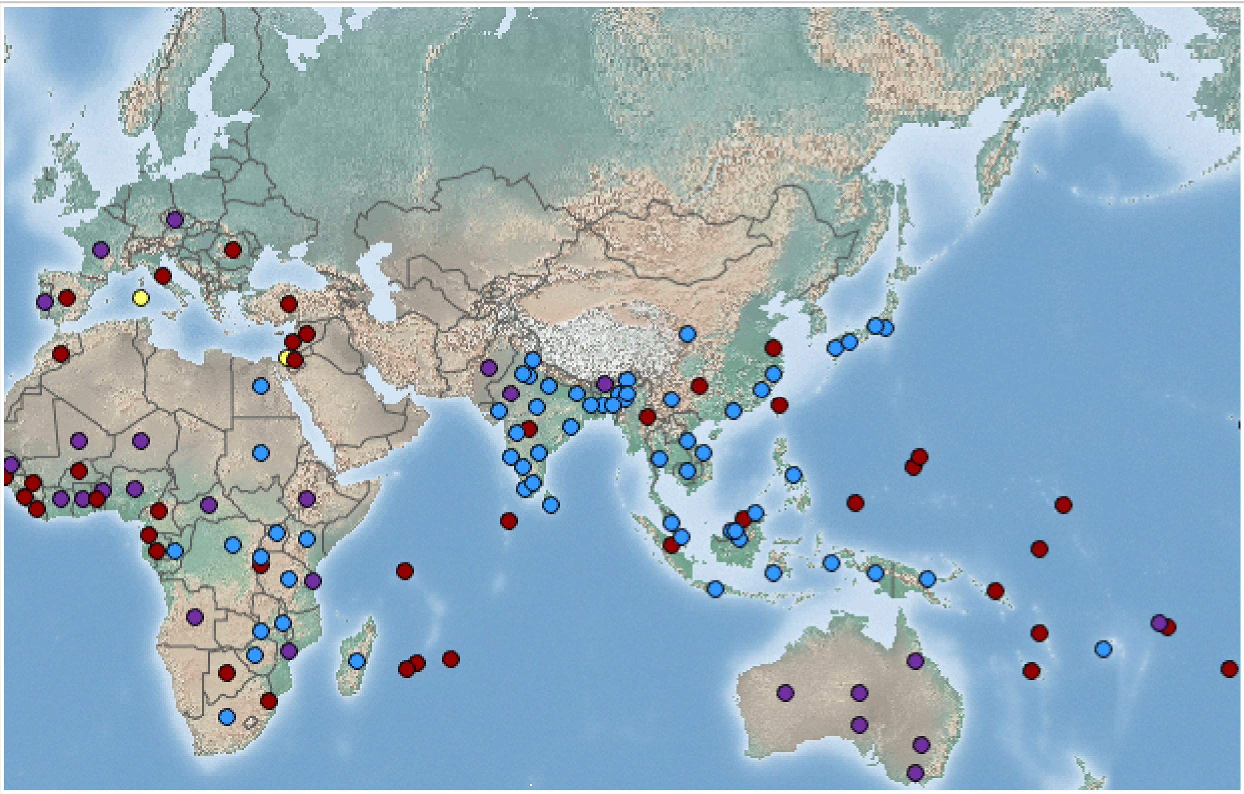
Analyzed by: Density

Present	Localised
Present, no further details	Widespread
Occasional or few reports	

Asia

Analyzed by: Density

Present	Localised
Present, no further details	Widespread
Occasional or few reports	



Europe

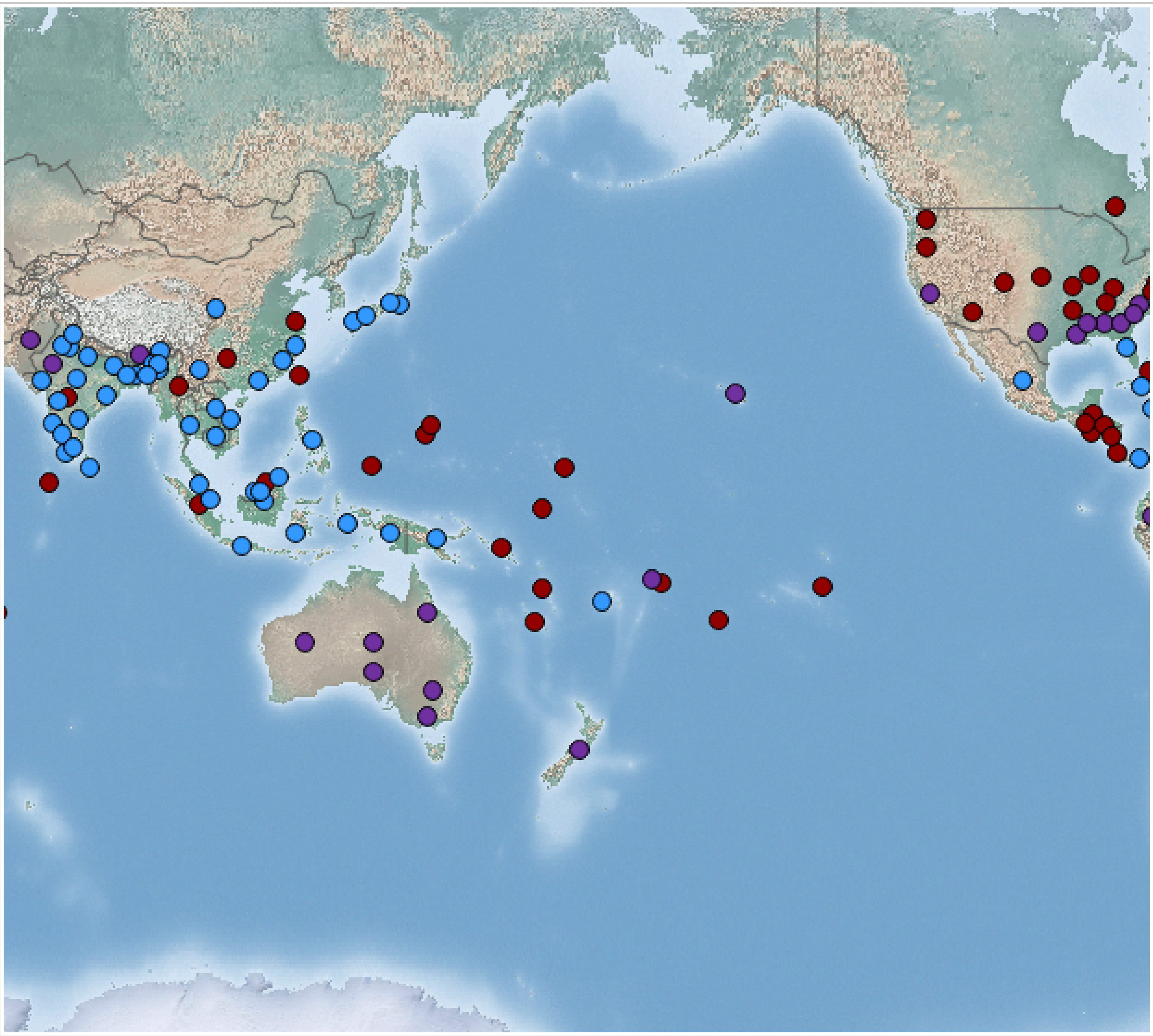
Analyzed by: Density

Present	Localised
Present, no further details	Widespread
Occasional or few reports	

Pacific

Analyzed by: Density

Present	Localised
Present, no further details	Widespread
Occasional or few reports	



North America

Analyzed by: Density

Present

Central America

Analyzed by: Density

Present

South America

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Ipomoea triloba (three-lobe morning glory)

Pictures

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Picture	Title	Caption	Copyright
	I. triloba	I. triloba is a herbaceous, annual twining vine with milky sap, simple leaves and pink to pale-purple funnel-shaped flowers. Leaves 2-12 cm long and 2-10 cm broad.	Ross Lubigan/IRRI
	I. triloba - line drawing	a1, Flower, from above; a2, flower, side view; b, corolla, opened; c, pistil; d, capsule with stalk and persistent calyx, crowned by style base, and cross-section of the stalk; e1-2, seed, two views.	SEAMEO-BIOTROP

Identity

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Preferred Scientific Name

Ipomoea triloba L.

Preferred Common Name

three-lobe morning glory

International Common Names

English: aiea morning glory; caapi; caapi-doux; little bell; morning glory; wild potato; wild slip
Spanish: aguialdo rosado; campanilla; campanilla rosado; churristate; pink aguinaldo

Local Common Names

Cuba: bouiato marrullero
Germany: dreilappige; trichterwinde
Japan: hoshiasagao

EPPO code

IPOTR (Ipomoea triloba)

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Solanales
            - Family: Convolvulaceae
              - Genus: Ipomoea
                - Species: Ipomoea triloba

Notes on Taxonomy and Nomenclature

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I. triloba is an annual member of the 'I. batatas complex' which contains 12 species, including sweet potatoes [I. batatas] (Austin, 1978).

Description

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I. triloba is a herbaceous, annual twining vine with milky sap, simple leaves and pink to pale-purple funnel-shaped flowers.

Stems prostrate and twining, usually much branched, 1-3 m long, glabrous or sometimes sparsely pubescent, more densely pubescent on the nodes.

Leaves simple, alternate, petiolate; leaf blades broadly ovate to orbicular, 2-12 cm long and 2-10 cm broad, bases cordate; leaf margins entire, coarsely dentate, or deeply 3-5 lobed.

Inflorescences axillary, with dense several-flowered cymes, occasionally 1-flowered; peduncles 1-10 cm long, stout, angular, glabrous, minutely verruculose toward the apex.

Flowers mostly pink to pale-purple (sometimes white, especially in West Africa (Heine, 1963)), often with darker centre and pale mid-petal areas; pedicel 3-10 mm, firm, angular, thickened at apex, glabrous; sepals 5, free, 6-10 mm long, with 3-5 large, raised central veins, corolla funnel-shaped, 1.8-2 cm long, 1.8-2.5 cm across, glabrous, strongly narrowed at the base, the limb with 5 short, obtuse, mucronulate lobes; stamens 5, attached to the inside of the corolla tube; anthers and filaments white, mostly included, very rarely longer than the corolla tube, filaments densely hairy at base, sparsely covered with curved hairs in lower half; ovary globose, pilose, with a white nectary.

Fruit a subglobose, bristly pubescent, thin-walled capsule, 5-6 mm long and in diameter, 2-celled, 4-valved; seeds usually 4 per capsule, subglobose, 2.5-3.2 mm long, dark-brown.

(After Austin, 1978.)

Distribution

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I. triloba was originally a native of tropical America, but is now pantropical.

The map is based on published country records: I. triloba specimens have also been collected from Guatemala (R Westbrooks, Animal and Plant Health Inspection Service, USDA, North Carolina, USA, personal communication, 1995), the Lesser Antilles (Adams et al., 1972), Polynesia and Micronesia (Gunn and Ritchie, 1982).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Cambodia (/isc/datasheet/108472)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
China (/isc/datasheet/108398)	Present						Present based on regional distribution.
-Jiangxi (/isc/datasheet/108684)	Present					Zeng et al., 2013	
India (/isc/datasheet/108459)	Present					Gunn and Ritchie, 1982; Deva and Naithani, 1990	
Indonesia (/isc/datasheet/108455)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
-Java (/isc/datasheet/108714)	Present					van, 1965	
Iran (/isc/datasheet/108462)	Present					Pahlevani and Sajedi, 2011	
Israel (/isc/datasheet/108457)	Present					Joel and Liston, 1986	
Laos (/isc/datasheet/108481)	Present					Gunn and Ritchie, 1982	
Myanmar (/isc/datasheet/108503)	Present					Waterhouse, 1993	
Nepal (/isc/datasheet/108524)	Restricted distribution					Gunn and Ritchie, 1982; EPPO, 2014	
Pakistan (/isc/datasheet/108537)	Present					Gunn and Ritchie, 1982	
Philippines (/isc/datasheet/108535)	Restricted distribution					Holm et al., 1979; Moody, 1986; Pamplona, 1988; EPPO, 2014	
Sri Lanka (/isc/datasheet/108485)	Present					,	
Thailand (/isc/datasheet/108580)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
Africa							
Côte d'Ivoire (/isc/datasheet/108394)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
Senegal (/isc/datasheet/108564)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
South Africa (/isc/datasheet/108613)	Present					Gunn and Ritchie, 1982	
North America							

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Mexico (/isc/datasheet/108513)	Present					Austin, 1978	
USA (/isc/datasheet/108597)	Widespread					EPPO, 2014	
-Arizona (/isc/datasheet/108798)	Present					Kearney and Peebles, 1951	
-Florida (/isc/datasheet/108804)	Present					Westbrooks and Eplee, 1989	
-Hawaii (/isc/datasheet/108806)	Present					, ; EPPO, 2014	
Central America and Caribbean							
Bahamas (/isc/datasheet/108382)	Present					,	
Belize (/isc/datasheet/108387)	Present					Austin, 1978	
Cayman Islands (/isc/datasheet/108479)	Present					Adams et al., 1972	
Costa Rica (/isc/datasheet/108402)	Restricted distribution					Ordetx, 1949; EPPO, 2014	
Cuba (/isc/datasheet/108405)	Restricted distribution					Ordetx, 1949; EPPO, 2014	
Dominica (/isc/datasheet/108413)	Present					Austin, 1978	
Dominican Republic (/isc/datasheet/108414)	Present					Austin, 1978	
El Salvador (/isc/datasheet/108571)	Present					Ordetx, 1949	
Haiti (/isc/datasheet/108453)	Present					Austin, 1978	
Honduras (/isc/datasheet/108451)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
Jamaica (/isc/datasheet/108465)	Restricted distribution					Adams et al., 1972; EPPO, 2014	
Nicaragua (/isc/datasheet/108521)	Present					Gunn and Ritchie, 1982	
Panama (/isc/datasheet/108530)	Present					Ordetx, 1949	
Puerto Rico (/isc/datasheet/108541)	Restricted distribution					Adams et al., 1972; EPPO, 2014	
Trinidad and Tobago (/isc/datasheet/108588)	Present					Adams et al., 1972	
South America							
Argentina (/isc/datasheet/108359)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
Bolivia (/isc/datasheet/108379)	Present					Gunn and Ritchie, 1982	
Colombia (/isc/datasheet/108399)	Restricted distribution					Holm et al., 1979; Hallman, 1984; EPPO, 2014	
Ecuador (/isc/datasheet/108416)	Restricted distribution					Holm et al., 1979; EPPO, 2014	
Venezuela (/isc/datasheet/108601)	Present					Gunn and Ritchie, 1982	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Oceania							
Australia (/isc/datasheet/108362)	Restricted distribution					Auld and Medd, 1992; EPPO, 2014	
Guam (/isc/datasheet/108446)	Present					Gunn and Ritchie, 1982	
Papua New Guinea (/isc/datasheet/108534)	Restricted distribution					Gunn and Ritchie, 1982; EPPO, 2014	

Risk of Introduction

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Seeds of I. triloba have been detected as a contaminant of sesame seeds originating from China, El Salvador and Guatemala (R Westbrooks, Animal and Plant Health Inspection Service, USDA, North Carolina, USA, personal communication, 1995). I. triloba has also been intercepted as a contaminant of various types of imported spices and as a 'hitch-hiker' in cars at the USA-Mexican border (Westbrooks, 1989).

Habitat

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I. triloba is known to occur in various habitats, including cultivated fields (e.g., cotton, citrus groves), sandy ground and grassy swamp margins, on hedges, and in thickets, from low to middle elevations (Ordetx, 1949; Haselwood and Motter, 1966; Adams et al., 1972). In Queensland, Australia, it occurs as a weed of sugarcane and tropical pastures (Auld and Medd, 1992). In Java, it has been observed in brushwoods, living fences, sugarcane fields, roadsides, fields, and waste places (van Ooststroom, 1965).

Host Plants and Other Plants Affected

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Plant name	Family	Context
Citrus (/isc/datasheet/13436)	Rutaceae	Main
Glycine max (soyabean) (/isc/datasheet/25400)	Fabaceae	Other
Gossypium (cotton) (/isc/datasheet/25791)	Malvaceae	Main
Ipomoea batatas (sweet potato) (/isc/datasheet/28783)	Convolvulaceae	Other
Saccharum officinarum (sugarcane) (/isc/datasheet/48160)	Poaceae	Main
Sesamum indicum (sesame) (/isc/datasheet/49489)	Pedaliaceae	Main
Solanum lycopersicum (tomato) (/isc/datasheet/31837)	Solanaceae	Main
Sorghum bicolor (sorghum) (/isc/datasheet/50633)	Poaceae	Main
Zea mays (maize) (/isc/datasheet/57417)	Poaceae	Main

Biology and Ecology

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I. triloba is a twining annual herb that reproduces by seeds (Haselwood and Motter, 1966). Studies in the Philippines indicated that distinct patterns of emergence under natural conditions are related to rainfall patterns (Janiya and Moody, 1987).

In the Philippines, nicking the seed coat with a blade was the most effective dormancy-breaking treatment studied. Sand scarification was effective but damaged the seed. A 40-80% saturation level in the soil favoured germination (Gacutan, 1979).

I. triloba is considered to be an important plant in honey production in Cuba and other Central American countries (Ordetx, 1949).

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Agrius cingulatus (/isc/datasheet/26945)	Herbivore					

Notes on Natural Enemies

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The phytophagous arthropods (and their natural enemies) in an agroecosystem in the warm region of central Tolima, Colombia were investigated from November 1976 until May 1979. This project found that Agrius cingulatus showed some promise for biological control of I. triloba. On several occasions, this sphingid completely defoliated the weed in soyabean crops without damaging the crop. Larvae placed on soyabean leaves in the laboratory died without feeding (Hallman, 1979).

Impact

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I. triloba is considered a serious weed in Australia and the Philippines; a principal weed in Cuba, Hawaii, and Honduras; and a common weed in Argentina, Jamaica, and Indonesia (Holm et al., 1979). Like other 'morning-glories', it competes with crop plants for nutrients and water. Due to its twining nature, it also fouls mechanical harvesters. It has been noted as one of three morning-glory weeds of cotton fields in Arizona, USA (G Yatskievych, University of Arizona, personal communication, 1981).

In Java, I. triloba is a weed of brushwoods, living fences, sugarcane fields, roadsides, fields and waste places (van Ooststroom, 1965). A nematode assessment survey of the vegetable-growing areas of Barangay Sicsican in Talavera, Neuva, Ecija, Philippines found that I. triloba and several other weeds serve as alternative hosts for root-knot nematodes (Meloidogyne javanica and M. incognita). Such alternative hosts play an important role in the nematodes' ability to survive and persist during the rice season before the vegetable season (Mamari and Alberto, 1989).

In the Philippines, I. triloba is one of the main weeds of monoculture maize (Pamplona, 1988), one of the most common weeds in intercropped maize, sorghum, sunflowers, coconuts, tomatoes, and sesame (Moody, 1986), and has been listed there as one of 21 common weeds of cotton (Paller and Lijauco, 1981).

In one study, varying densities of I. triloba were maintained in monocultures of soyabeans or maize and maize-soyabean intercrops. Weed density did not normally have a significant effect on insect pest populations, but the presence of I. triloba tended to increase damage by insects in soyabeans and to act as a pest attractant in maize (Mercado et al., 1980).

I. triloba was first reported in Israel in 1986 as a weed in cotton (Joel and Liston, 1986).

Studies in the Solomon Islands showed that I. triloba and two other species are alternative hosts for witches' broom disease of sweet potatoes (Jackson and Zettler, 1983).

Uses List

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Genetic importance

Related to

Human food and beverage

Honey/honey flora

Detection and Inspection

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To avoid further worldwide spread, shipments of seeds and spices from infested countries should be closely examined for the presence of seeds of I. triloba. Devitalized [killed] seed samples should be provided to plant regulatory inspectors to increase the effectiveness of the inspection. To avoid losses and costs of control, field surveys should be conducted to permit early detection and eradication of this noxious weed before it becomes firmly established.

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Similarities to Other Species/Conditions

According to Austin (1978), most floristic studies of the New World have failed to recognize the difference between I. triloba and I. batatas (sweet potatoes). Characteristics that separate these two species include corolla length [1.8-2 cm for I. triloba versus 3-5(7) cm], nectary colour (white versus yellow to yellow-orange), number of seeds/fruit (four versus usually less than four), and a lack of sweet potato tubers.

Another species that is similar to I. triloba is I. x grandifolia. According to Austin (1978), these species may be separated by sepal shape (oblong to narrowly elliptic-oblong for I. triloba versus lanceolate to ovate-lanceolate), sepal length [6-8(10) mm versus 8-11 mm], capsule size (5-6 mm long and in diameter versus 6-7 mm in diameter, capsule pubescence (pilose versus hirsute), and seed size (2.5-3.2 mm long versus 3.5-4 mm long).

I. triloba and I. lacunosa (which is spread in birdseed and millet) may be separated on the basis of flower colour (pink to purple for I. triloba versus white), sepal size [6-8(10) mm long versus (8)11-14 mm long], sepal shape (more or less oblong versus lanceolate), capsule size (5-6 mm long and in diameter versus 10-15 mm in diameter), and seed size (2.5-3.2 mm long versus 5-6 mm long) (Austin, 1978).

I. triloba and a rather common form of the hybrid I. x leucantha (parent species I. lacunosa and I. trichocarpa) may be separated on the basis of sepal shape (more or less oblong for I. triloba versus lanceolate), sepal length [6-8(10) mm versus (8)10-14 mm], capsule size (5-6 mm long and in diameter versus 7-8 mm in diameter), and seed size (2.5-3.2 mm long versus 3.2-4.5 mm long) (Austin, 1978).

Prevention and Control

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Chemical, Cultural and Sanitary Methods

Coconuts
Research in the Philippines showed that I. triloba was controlled in coconut nurseries with the use of paraquat or by hand weeding at intervals of 1-2 months (Abad and Juan, 1981).

Maize
Field studies to evaluate different herbicides and herbicide combinations in the Philippines showed that pendimethalin alone failed to control I. triloba in maize cv. Pioneer 6181 (Jover et al., 1982). Madrid and Manimtim (1978a) found that atrazine provided good control of broad-leaved weeds, including I. triloba; however, oxyfluorfen provided good control for I. triloba but killed the maize.

Sugarcane and Sorghum
Research by the Hawaiian Sugar Planters' Association indicated that metsulfuron provided good control of I. triloba (Santo, 1989). In another Hawaiian study, conducted during the first 4-6 months of sugarcane growth until the canopy closed, atrazine was found to give excellent control of several broadleaved weeds, including I. triloba (Olney, 1971).

Field trials in sugarcane and sorghum in New South Wales and Queensland (Australia) during 1982-86, showed that I. triloba was moderately susceptible to fluroxypyr, but was controlled with a tank mixture of fluroxypyr and 2,4-D (Webb and Feez, 1987).

Hondrade (1981) found that pendimethalin was ineffective in controlling I. triloba in sugarcane.

In field trials in the Burdekin District of Queensland, 2,4-D and MCPA applied to sugarcane at hilling up gave good control of I. triloba, I. plebeia and I. purpurea, and provided an economical and reliable alternative to aerial spraying. The major Burdekin cane cultivars, Q96 and Q80, could be treated without risk of damage. 2,4-D was the least expensive of the treatments (on the basis of the cost of chemical). Extensive commercial spraying showed that 2,4,5,-T [superseded] could be used to maintain satisfactory weed control, but that higher rates were needed where Cucumis metuliferus or Passiflora subpeltata were also present (Anonymous, 1980).

Mungbeans and Soyabeans
In the Philippines, oxyfluorfen was effective in inhibiting the germination of I. triloba in mungbeans and soyabeans when applied 2 days after planting. Emergence of I. triloba was observed at lower rates, but the seedlings died 2 weeks after treatment (Fabro and Robles, 1982).

In another Philippine study, oxadiazon applied pre-emergence in soyabeans gave excellent control of I. triloba. In another trial, however, oxadiazon controlled I. triloba but severely injured the crop. Combination pre-emergence and post-emergence directed applications of bentazone also provided control (Madrid and Manimtim, 1978b).

Tomatoes and Cabbages
Rice straw, rice hulls and sawdust mulches reduced populations of I. triloba in tomatoes by 50% at 30 days after transplanting. However, the weed eventually penetrated the mulches and grew out of control. In transplanted cabbage, mulching also cut populations of I. triloba in half during the wet season of 1977 in the Philippines (Paller et al., 1979).

Miscellaneous
Pre-emergence application of bromacil was effective in controlling I. triloba in a variety of tropical crops in the Philippines (Mendoza, 1979). In another Philippine study, bentazone applied post-emergence or as a directed spray

controlled I. triloba at the 2-3 leaf stage. However, yields were less than with hand weeding and weed control was not season long (Robles et al., 1979).

Biological Control

The phytophagous arthropods (and their natural enemies) in an agroecosystem in the warm region of central Tolima, Colombia were investigated from November 1976 until May 1979. This project found that Agrius cingulatus showed some promise for biological control of I. triloba. On several occasions, this sphingid completely defoliated the weed in soyabean crops without damaging the crop. Larvae placed on soyabean leaves in the laboratory died without feeding (Hallman, 1979).

Regulatory Control

I. triloba is listed as a Federal Noxious Weed in the USA. Introduction is permitted there only by permit from the Animal and Plant Health Inspection Service, USDA.

Preliminary studies indicate that a 0.35% solution of caustic soda (NaOH) in hot water at 92°C is sufficient to kill seeds of I. triloba that contaminate shipments of sesame (caustic soda is used to de-hull or decorticate raw sesame seeds). Preliminary studies also indicate that dry heat (hot air) temperatures of 130°C will kill seeds of I. triloba (R Westbrooks, Animal and Plant Health Inspection Service, USDA, North Carolina, USA, personal communication, 1995).

Regulatory strategies to prevent the world movement and further establishment of exotic pest plants such as I. triloba include foreign prevention (production of weed-free commodities for export to uninfested countries); exclusion (detection and mitigation of weed contaminants in imported products at ports of entry); detection, containments and eradication of incipient infestations, and cost-effective control of widespread species (Westbrooks, 1991).

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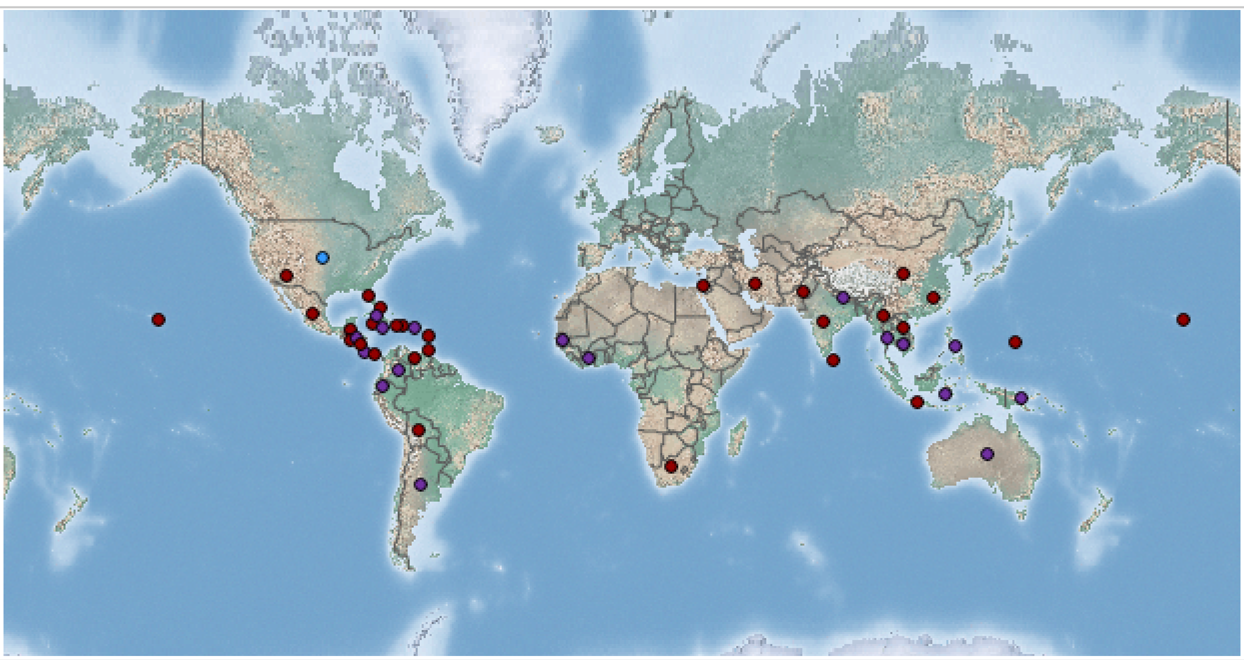
World Map

Analyzed by: Density

Localised	Present, no further details
Widespread	



Africa

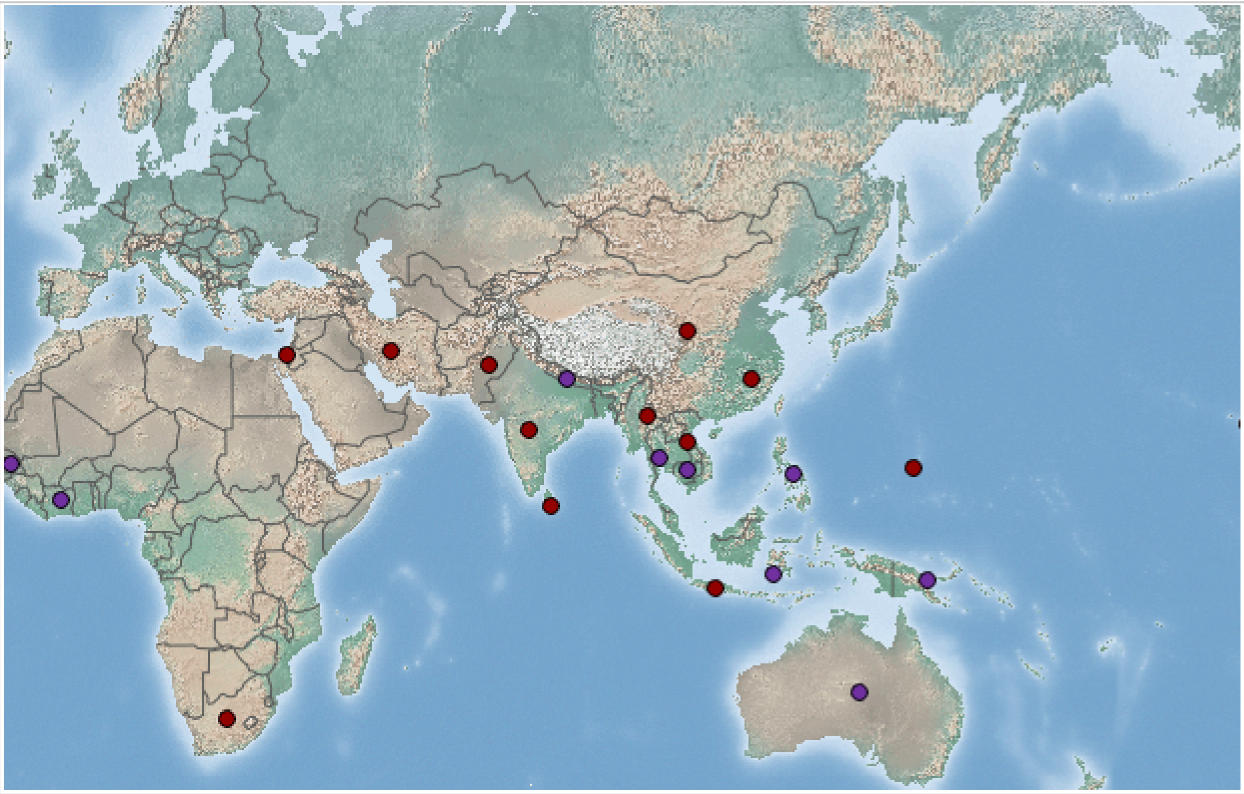
Analyzed by: Density

- Localised
- Present, no further details
- Widespread

Asia

Analyzed by: Density

Localised	Present, no further details
Widespread	



Europe

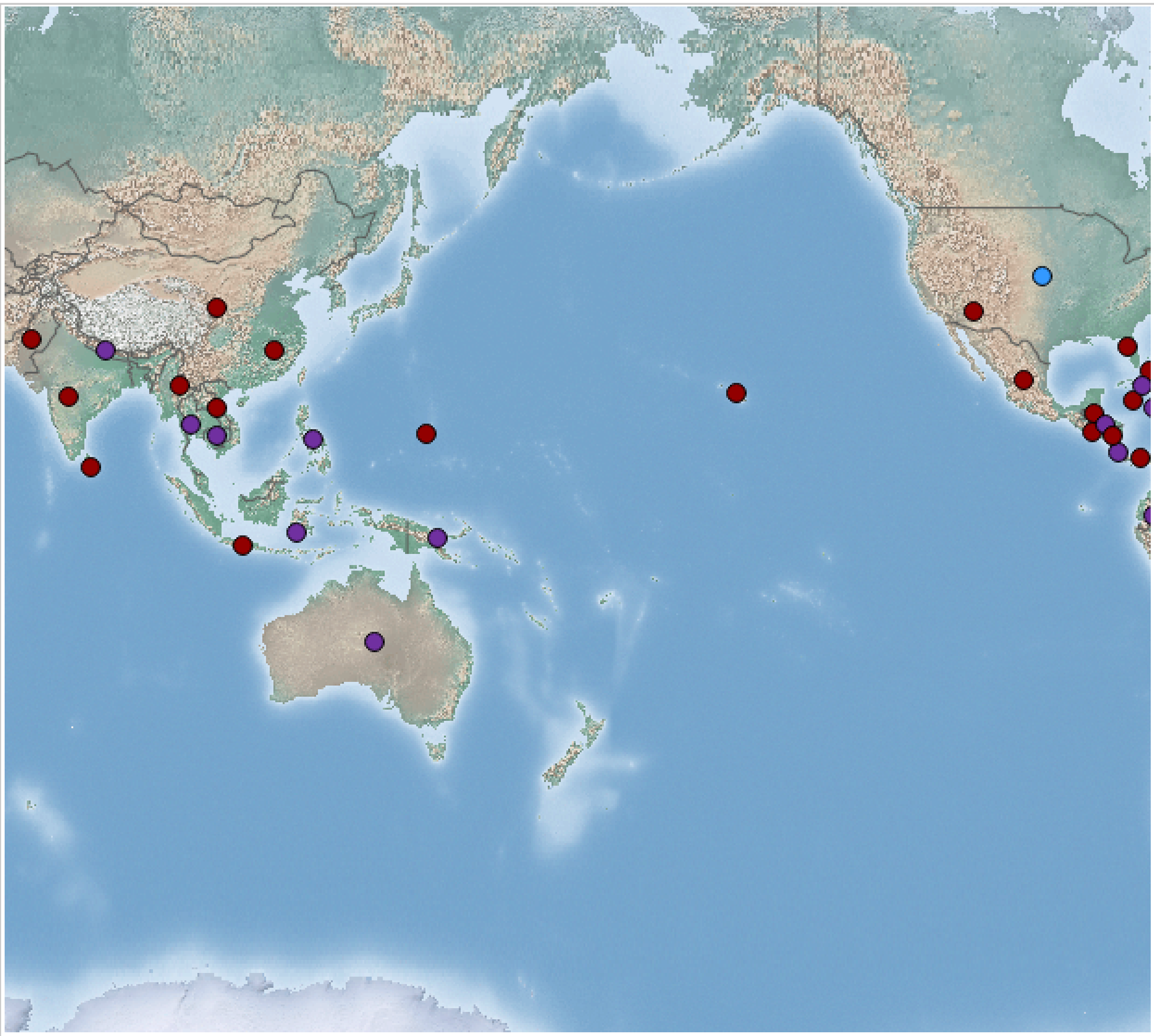
Analyzed by: Density

Localised	Present, no further details
Widespread	

Pacific

Analyzed by: Density

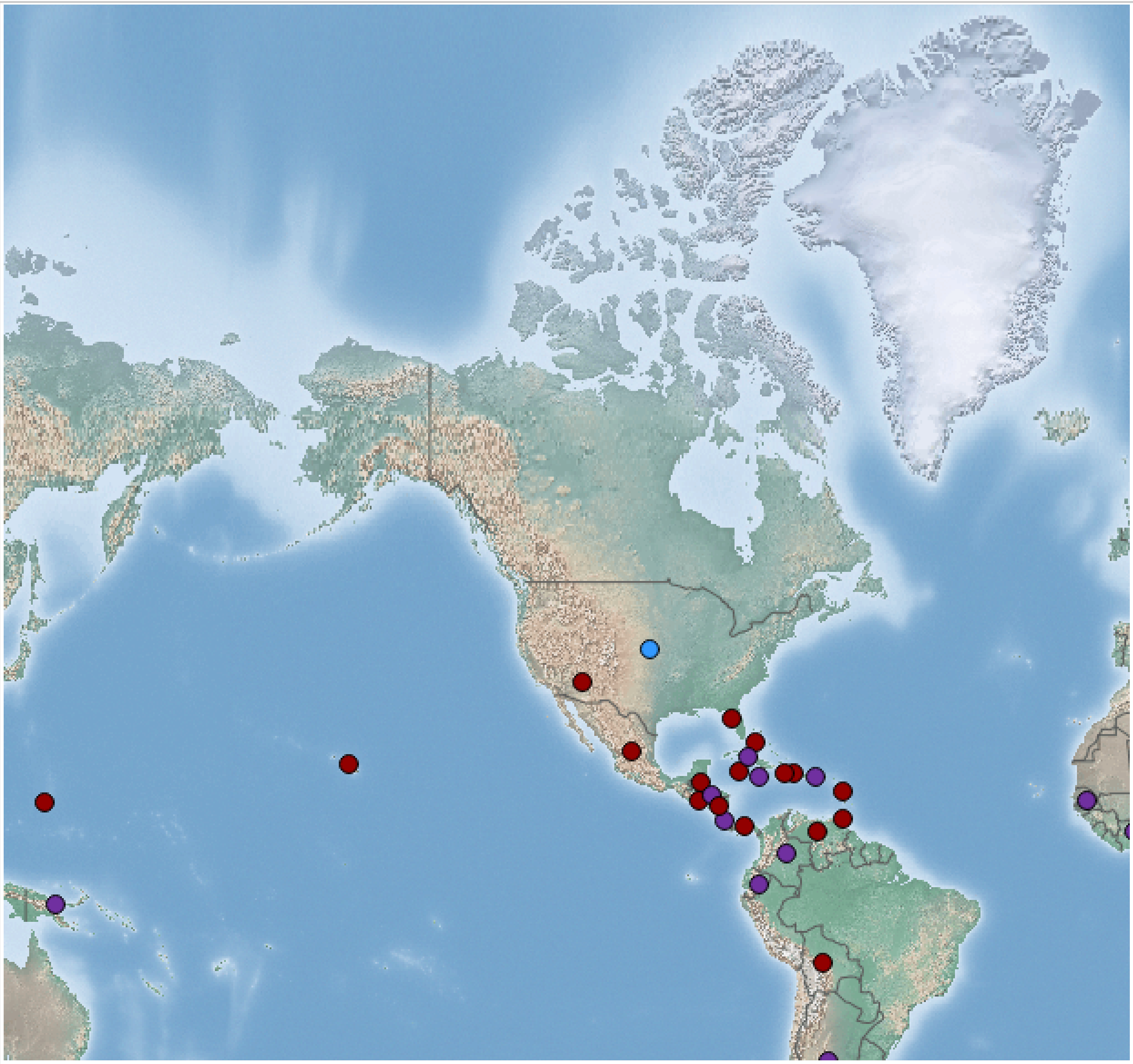
Localised	Present, no further details
Widespread	



North America

Analyzed by: Density

Localised	Present, no further details
Widespread	



Central America

Analyzed by: Density

Localised	Present, no further details
Widespread	

South America

Analyzed by: Density

Localised	Present, no further details
Widespread	

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Panicum repens (torpedo grass)

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Pictures

Picture	Title	Caption	Copyright
	Inflorescence and rhizome	Left, panicles exserted 10-15 cm above foliage, about 10 (5-20) cm long, with 1-3 branches per node, usually quite stiffly erect. Right, rhizomes up to 1 cm thick, nodes at 10-15 cm intervals tend to be swollen, each bearing a viable but often dormant bud.	©Chris Parker/Bristol, UK
	Whole plant - line drawing	a, Ligule, ventral view; b1-2, spikelet, two views.	SEAMEO-BIOTROP

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Identity

Preferred Scientific Name

Panicum repens L. 1762

Preferred Common Name

torpedo grass

Other Scientific Names

Panicum aquaticum A.Rich. 1851
Panicum arenarium Brot. 1804
Panicum chromatostigma Pilg. 1902
Panicum convolutum Beauv. ex Spreng. 1825
Panicum hygrocharis Steud. 1854
Panicum ischaemoides Retz. 1786
Panicum leiogonum Delile 1812
Panicum nyanzense K. Schum., 1897

International Common Names

English: creeping panic
Spanish: gramma del norte
French: panic rampant
Portuguese: escalracho

Local Common Names

Argentina: paja voladora
Bangladesh: baranda
Brazil: capim-torpedo
Brunei Darussalam: huma; kerunong
Cambodia: chhlong
Cuba: alpiste de tierra
Egypt: beid el-homaar; neseela na'-ame; zommaar; zommeirentaya
Germany: Torpedogras
India: injipilla; karigaddi
Indonesia: jajahean; lampuyangan; rumput jae-jae
Indonesia/Java: suket balungan; suket lempuyangan
Israel: dohan zohel
Italy: panico strisciante
Japan: haikibi
Malaysia: kerunong padi; metubong; rumput kerbau; telur padi
Mexico: zacate carrillo
Myanmar: myet-kha
Netherlands: victoriagras
Pakistan: chimacara; surpurrcharela
Philippines: luya-luyahan; maralaya
Poland: proso rozlogowe
Senegal: bamba subu; ekena; eselek

South Africa: kruipgras
Sri Lanka: etora
Taiwan: pu-shu-tsao
Thailand: ya-chan ka; yakhaemman; ya-onoi
Turkey: tuylu dari
USA/Hawaii: wainaku grass

EPPO code

PANHY (Panicum hygrocharis)
PANRE (Panicum repens)

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Summary of Invasiveness

As a rhizomatous perennial species, P. repens has proved to be a difficult to control invasive plant in some areas where it has been introduced, most notably in Florida, USA. In the USA, it is listed as a prohibited noxious weed in Arizona and a noxious weed in Alabama, Hawaii and Texas. In Florida it is designated an invasive exotic (FLEPPC, 2004). It is not included on the Australian noxious weed list nor on the Global Invasive Species Database of IUCN. It is considered invasive and a danger in the Pacific region (PIER, 2004).

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Taxonomic Tree

Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Monocotyledonae
Order: Cyperales
Family: Poaceae
Genus: Panicum
Species: Panicum repens

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Notes on Taxonomy and Nomenclature

P. repens is a name universally recognized, with no synonyms currently used. The only confusions may occur in East Africa, with the closely related P. repentellum, and in the Americas, with P. gouini (see Similarities with Other Pests).

Description

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P. repens is a rhizomatous perennial grass which can form extensive dominant swards with foliage and inflorescences up to 100 cm high, though more commonly to about 50 cm.

Culms have bladeless scales at the base. Leaves are in two ranks, bright green to slightly glaucous, stiff, almost erect, 15-20 cm long, about 1 cm wide, tapering gradually to an acute tip, sparsely hairy on the upper surface, smooth and sometimes with a waxy bloom on the lower. Leaf sheaths have long white hairs along the margin. The ligule is a very short membrane, 0.5 mm long, fringed with long white hairs.

Robust rhizomes, up to 1 cm thick, grow horizontally at depths down to 20 cm or more and up to several metres distance. Nodes at 10-15 cm intervals tend to be swollen and each bears a viable but often dormant bud.

Panicles exserted 10-15 cm above foliage, about 10 (5-20) cm long, with 1-3 branches per node, usually quite stiffly erect. Spikelets 2-flowered pale green/glaucous, sometimes tinged with purple, oblong-ovate, acute or slightly acuminate, 2.5-3 mm long. Lower glume 1-3 nerved, broadly ovate one-fifth to one-third as long as the spikelet, upper glume and lower lemma similar, 7-nerved, as long as the spikelet. Upper lemma shorter, pale and glossy. Anthers three, yellow-orange, stigmas purple, caryopsis (seed) lanceolate, pale, white or straw-coloured.

Plant Type

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Aquatic
Grass / sedge
Herbaceous
Perennial
Vegetatively propagated

Distribution

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P. repens is an Old World species, most widespread in Africa and Asia but now occurring throughout the tropics and sub-tropics between about 35°S and 43°N. Although it has been suggested that further spread northwards in the USA is unlikely owing to its susceptibility to freezing conditions (Wilcut et al., 1988a), it does persist in Masvingo Province of Zimbabwe where temperatures fall below 0°C in some years. In the tropics it may occur up to 2000 m altitude.

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Distribution Table

The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Bangladesh (/isc/datasheet/108369)	Present		Introduced		Not invasive	Holm et al., 1979	
Brunei Darussalam (/isc/datasheet/108378)	Present		Introduced		Not invasive	Moody, 1989; Waterhouse, 1993	
Cambodia (/isc/datasheet/108472)	Present		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
China (/isc/datasheet/108398)	Present		Introduced		Not invasive	Holm et al., 1979	
-Hong Kong (/isc/datasheet/108678)	Present		Introduced		Not invasive	Holm et al., 1979	
India (/isc/datasheet/108459)	Restricted distribution				Not invasive	Holm et al., 1977	
-Andhra Pradesh (/isc/datasheet/108721)	Present		Introduced		Not invasive	Naidu and Lakshmi, 2000	
-Assam (/isc/datasheet/108723)	Present		Introduced		Not invasive	Shukla, 1996	
-Bihar (/isc/datasheet/108724)	Present		Introduced		Not invasive	Shukla, 1996	
-Karnataka (/isc/datasheet/108738)	Present		Introduced		Not invasive	Shukla, 1996	
-Kerala (/isc/datasheet/108737)	Present		Introduced		Not invasive	Musthafa and Potty, 2001	
-Maharashtra (/isc/datasheet/108740)	Present		Introduced		Not invasive	Suryawanshi et al., 2001	
-Meghalaya (/isc/datasheet/108741)	Present		Introduced		Not invasive	Shukla, 1996	
-Odisha (/isc/datasheet/108746)			Introduced		Not invasive	Jena et al., 2002	
-Rajasthan (/isc/datasheet/108749)	Present		Introduced		Not invasive	Sharma and Bhunia, 1999	
-Tamil Nadu (/isc/datasheet/108751)	Present		Introduced		Not invasive	Shukla, 1996	
-Tripura (/isc/datasheet/108752)	Present		Introduced		Not invasive	Shukla, 1996	
-Uttarakhand (/isc/datasheet/108754)	Present		Introduced		Not invasive	Pandey et al., 2002	
Indonesia (/isc/datasheet/108455)	Present		Introduced		Not invasive		
-Irian Jaya (/isc/datasheet/108713)	Present		Introduced		Not invasive	Soerjani et al., 1987	
-Java (/isc/datasheet/108714)	Present		Introduced		Not invasive	Soerjani et al., 1987	
-Kalimantan (/isc/datasheet/108715)	Present		Introduced		Not invasive	Soerjani et al., 1987	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Sulawesi (/isc/datasheet/108718)	Present		Introduced		Not invasive	Soerjani et al., 1987	
-Sumatra (/isc/datasheet/108719)	Present		Introduced		Not invasive	Soerjani et al., 1987	
Iraq (/isc/datasheet/108461)	Present		Introduced		Not invasive	Holm et al., 1979	
Israel (/isc/datasheet/108457)	Present		Introduced		Not invasive	Holm et al., 1979	
Japan (/isc/datasheet/108467)	Present		Introduced		Not invasive	Holm et al., 1979	
Korea, DPR (/isc/datasheet/108476)	Present		Introduced		Not invasive	Holm et al., 1979	
Korea, Republic of (/isc/datasheet/108477)	Present		Introduced		Not invasive	Holm et al., 1979	
Laos (/isc/datasheet/108481)	Present		Introduced		Not invasive	Moody, 1989; Waterhouse, 1993	
Malaysia (/isc/datasheet/108514)	Widespread		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
Myanmar (/isc/datasheet/108503)	Present		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
Nepal (/isc/datasheet/108524)	Present		Introduced		Not invasive	Moody, 1989	
Philippines (/isc/datasheet/108535)	Widespread		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
Saudi Arabia (/isc/datasheet/108552)	Restricted distribution		Introduced		Not invasive	Holm et al., 1979	
Singapore (/isc/datasheet/108557)	Present		Introduced		Not invasive	Waterhouse, 1993	
Sri Lanka (/isc/datasheet/108485)	Widespread		Introduced		Not invasive	Holm et al., 1979	
Taiwan (/isc/datasheet/108590)	Widespread		Introduced		Not invasive	Holm et al., 1979	
Thailand (/isc/datasheet/108580)	Widespread		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
Vietnam (/isc/datasheet/108604)	Present		Introduced		Not invasive	Holm et al., 1979; Waterhouse, 1993	
Africa							
Botswana (/isc/datasheet/108385)	Present		Native		Not invasive	Gibbs et al., 1990	
Cameroon (/isc/datasheet/108397)	Present		Native		Not invasive	Hepper and ed., 1972	
Central African Republic (/isc/datasheet/108391)	Present		Native		Not invasive	Holm et al., 1979	
Côte d'Ivoire (/isc/datasheet/108394)	Present		Native		Not invasive	Hepper and ed., 1972	
Egypt (/isc/datasheet/108418)	Present		Native		Not invasive	Täckholm, 1974	
Ethiopia (/isc/datasheet/108422)	Present		Native		Not invasive	Fröman and Persson, 1974	
Ghana (/isc/datasheet/108436)	Present		Native		Not invasive	Hepper and ed., 1972	
Guinea (/isc/datasheet/108440)	Widespread		Native		Not invasive	Holm et al., 1979	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Kenya (/isc/datasheet/108470)	Present		Native		Not invasive	Clayton and Renvoize, 1982	
Liberia (/isc/datasheet/108487)	Present		Native		Not invasive	Hepper and ed., 1972	
Mali (/isc/datasheet/108502)	Present		Native		Not invasive	Hepper and ed., 1972	
Morocco (/isc/datasheet/108493)	Present		Native		Not invasive	Holm et al., 1979	
Namibia (/isc/datasheet/108516)	Present		Native		Not invasive	Gibbs et al., 1990	
Niger (/isc/datasheet/108518)	Present		Native		Not invasive	Hepper and ed., 1972	
Nigeria (/isc/datasheet/108520)	Present		Native		Not invasive	Hepper and ed., 1972	
Senegal (/isc/datasheet/108564)	Present		Native		Not invasive	Hepper and ed., 1972	
Sierra Leone (/isc/datasheet/108562)	Present		Native		Not invasive	Hepper and ed., 1972	
South Africa (/isc/datasheet/108613)	Present		Native		Not invasive	Holm et al., 1979	
Sudan (/isc/datasheet/108555)	Present		Introduced		Not invasive	Holm et al., 1979	
Swaziland (/isc/datasheet/108573)	Present		Native		Not invasive	Gibbs et al., 1990	
Tanzania (/isc/datasheet/108591)	Present		Native		Not invasive	Clayton and Renvoize, 1982	
-Zanzibar (/isc/datasheet/108793)	Present		Native		Not invasive	Clayton and Renvoize, 1982	
Uganda (/isc/datasheet/108594)	Present		Native		Not invasive	Clayton and Renvoize, 1982	
Zimbabwe (/isc/datasheet/108616)	Present		Native		Not invasive	Holm et al., 1979	
North America							
USA (/isc/datasheet/108597)	Present					Holm et al., 1977	
-Alabama (/isc/datasheet/108796)	Present		Introduced		Invasive	Hitchcock, 1950	
-California (/isc/datasheet/108799)	Present		Introduced		Invasive	USDA-NRCS, 2004	
-Florida (/isc/datasheet/108804)	Present		Introduced		Invasive	Hitchcock, 1950	
-Hawaii (/isc/datasheet/108806)	Widespread		Introduced		Invasive	Holm et al., 1977	
-Louisiana (/isc/datasheet/108813)	Present		Introduced		Invasive	Hitchcock, 1950	
-Mississippi (/isc/datasheet/108820)	Present		Introduced		Invasive	Hitchcock, 1950	
-North Carolina (/isc/datasheet/108822)	Present		Introduced		Not invasive	USDA-NRCS, 2004	
-South Carolina (/isc/datasheet/108835)	Present		Introduced		Not invasive	USDA-NRCS, 2004	
-Texas (/isc/datasheet/108838)	Present		Introduced		Invasive	Hitchcock, 1950	
Central America and Caribbean							

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Costa Rica (/isc/datasheet/108402)	Present					Retana-Sánchez et al., 2013	
Cuba (/isc/datasheet/108405)	Present		Introduced		Not invasive	Holm et al., 1979	
Dominican Republic (/isc/datasheet/108414)	Present		Introduced		Not invasive	Holm et al., 1979	
Puerto Rico (/isc/datasheet/108541)	Present		Introduced		Not invasive	Holm et al., 1979	
South America							
Argentina (/isc/datasheet/108359)	Present		Introduced		Not invasive	Holm et al., 1979	
Bolivia (/isc/datasheet/108379)	Present		Introduced		Not invasive	Holm et al., 1979	
Brazil (/isc/datasheet/108381)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Bahia (/isc/datasheet/108630)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Goias (/isc/datasheet/108634)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Mato Grosso do Sul (/isc/datasheet/108637)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Minas Gerais (/isc/datasheet/108636)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Parana (/isc/datasheet/108643)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Rio de Janeiro (/isc/datasheet/108644)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Santa Catarina (/isc/datasheet/108649)	Present		Introduced		Not invasive	Lorenzi, 1982	
-Sao Paulo (/isc/datasheet/108651)	Present		Introduced		Not invasive	Lorenzi, 1982	
Paraguay (/isc/datasheet/108544)	Present		Introduced		Not invasive	Holm et al., 1979	
Uruguay (/isc/datasheet/108598)	Present		Introduced		Not invasive	Holm et al., 1979	
Europe							
Albania (/isc/datasheet/108354)	Present		Introduced		Not invasive	Tutin et al., 1980	
Cyprus (/isc/datasheet/108408)	Present		Introduced		Not invasive	Meikle, 1977	
France (/isc/datasheet/108429)	Present		Introduced		Not invasive	Tutin et al., 1980	
-Corsica (/isc/datasheet/108704)	Present		Introduced		Not invasive	Tutin et al., 1980	
Greece (/isc/datasheet/108443)	Present		Native		Not invasive	Tutin et al., 1980	
Italy (/isc/datasheet/108464)	Present		Native		Not invasive	Tutin et al., 1980	
Portugal (/isc/datasheet/108542)	Present		Introduced		Not invasive	Tutin et al., 1980	
Spain (/isc/datasheet/108421)	Present		Introduced		Not invasive	Tutin et al., 1980	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Balearic Islands (/isc/datasheet/108701)	Present		Introduced		Not invasive	Tutin et al., 1980	
Yugoslavia (former) (/isc/datasheet/108610)	Present		Introduced		Not invasive	Tutin et al., 1980	
Oceania							
Australia (/isc/datasheet/108362)	Present		Introduced		Not invasive	Holm et al., 1979	
Northern Mariana Islands (/isc/datasheet/108505)	Present		Introduced		Not invasive	PIER, 2004	
Palau (/isc/datasheet/108543)	Present		Introduced		Not invasive	PIER, 2004	

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History of Introduction and Spread

P. repens has become established as an invasive species beyond its natural range through introduction as a fodder species. It is cultivated on wet alluvial sandy soils in Africa, South America, North America and India but is very difficult to eradicate once established. After it was introduced into Pakistan for this purpose it did not persist (Cope, 1982).

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Risk of Introduction

The greatest risk of further spread would be through introduction to a new area for use as a forage or for stabilising eroded soils. A full risk assessment should be carried out prior to any introduction. The species is a prohibited plant in southern USA.

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Habitat

A plant of generally wet places, both coastal and inland, occurring naturally along the edges of rivers, irrigation channels, lakes and brackish shorelines. It does not tolerate long-term submergence (Thayer and Haller, 1990), but may occur as a component of floating islands, in succession to, or as a co-dominant with e.g. *Eichhornia crassipes* or *Cyperus papyrus*. Natural habitats are often sandy, but it is able to persist in heavy soils that remain moist due to high rainfall, poor drainage or irrigation. It is most commonly a weed of perennial plantation crops in the humid tropics, but may also occur in moist sub-tropical situations (e.g. southern Europe) and as a weed in annual crops where tillage is not sufficiently deep and drainage is poor.

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Habitat List

Category	Habitat	Presence	Status
Littoral	Coastal areas	Present, no further details	
Terrestrial-managed	Cultivated / agricultural land	Present, no further details	Harmful (pest or invasive)
	Managed forests, plantations and orchards	Present, no further details	Harmful (pest or invasive)
	Managed grasslands (grazing systems)	Present, no further details	Harmful (pest or invasive)
Terrestrial-natural/semi-natural	Riverbanks	Present, no further details	Harmful (pest or invasive)
	Wetlands	Present, no further details	Harmful (pest or invasive)

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Host Plants and Other Plants Affected

Plant name	Family	Context
Ananas comosus (pineapple) (/isc/datasheet/5392)	Bromeliaceae	Main
Arachis hypogaea (groundnut) (/isc/datasheet/6932)	Fabaceae	Main
Camellia sinensis (tea) (/isc/datasheet/10781)	Theaceae	Main
Capsicum annuum (bell pepper) (/isc/datasheet/15784)	Solanaceae	Main
Citrus (/isc/datasheet/13436)	Rutaceae	Main
Cocos nucifera (coconut) (/isc/datasheet/11788)	Arecaceae	Main
Coriandrum sativum (coriander) (/isc/datasheet/15300)	Apiaceae	Main
Glycine max (soyabean) (/isc/datasheet/25400)	Fabaceae	Main
Hevea brasiliensis (rubber) (/isc/datasheet/27999)	Euphorbiaceae	Main
Hibiscus sabdariffa (Roselle) (/isc/datasheet/27129)	Malvaceae	Main
Musa (banana) (/isc/datasheet/35124)	Musaceae	Main
Oryza sativa (rice) (/isc/datasheet/37964)	Poaceae	Main
Saccharum officinarum (sugarcane) (/isc/datasheet/48160)	Poaceae	Main
Zea mays (maize) (/isc/datasheet/57417)	Poaceae	Main

Biology and Ecology

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Genetics

Accessions from Egypt and India are diploid with a chromosome number of 2n = 36 (MOBOT, 2004).

Physiology and phenology

P. repens is a serious weed mainly on account of its perennial habit, including its ability to spread and persist by rhizomes in any moist situations where there is inadequate deep tillage. Once a new plant is established, rhizomes develop within a few weeks, growing horizontally for several metres, usually at 5-20 cm depth, but sometimes deeper. Hossain et al. (1996) reported rhizomes mostly in the top 30 cm but some down to 42 cm in a reddish soil in southern Japan. They also recorded that one rhizome node could give rise to over 20,000 new rhizome buds in 365 days. Most axillary buds on the rhizome remain dormant until there is fragmentation by cultivation. Pieces of rhizomes with six nodes are able to regenerate from 8-16 cm depth (Wilcut et al., 1988a). Under suitable conditions, new plants can develop from any single-node segment of rhizome. P. repens is resistant to fire (Weber, 2003).

Reproductive biology

Seeds are usually produced in considerable numbers but may be unimportant as a means of spread in some localities. Flowering and seed production are said to be rare, e.g. in Java, while Chandrasena and Dhammika (1988) show that different clones of the weed in Sri Lanka may differ significantly in flowering behaviour. Seeds are sometimes claimed to be non-viable but Moreira (1976a, 1978) has shown germination levels up to 100%. Dormancy may be high in young seed, but germination can be enhanced by chilling, nitrate and alternating temperatures, e.g. between 20 and 30°C. Populations in Florida, USA, do not produce viable seed (Weber, 2003).

Ecology

The weed can occur in a wide range of soil types and is not sensitive to pH between 4.2 and 6.7 (Wilcut et al., 1988a) or to moderate-to-high salinity (up to 10,000 p.p.m.) (Peng et al., 1977; Peng and Twu, 1979; Nemoto et al., 1987). Although adapted to wet conditions and presumably needing these for active growth, it can, once established, survive moderately prolonged drought conditions, particularly where there is a high water table. Optimum temperatures for growth are 30-35°C and it is killed by persistent frost (Wilcut et al., 1988b). It prefers open sunny conditions but persists in semi-shaded plantation crop situations.

Latitude/Altitude Ranges

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Latitude North (°N)	Latitude South (°S)	Altitude Lower (m)	Altitude Upper (m)
		620	1500

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Air Temperature

Parameter	Lower limit	Upper limit
Mean annual temperature (ºC)	19	27
Mean maximum temperature of hottest month (ºC)	25	31
Mean minimum temperature of coldest month (ºC)	16	22

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Rainfall

Parameter	Lower limit	Upper limit	Description
Dry season duration	0	7	number of consecutive months with <40 mm rainfall

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Rainfall Regime

Bimodal
Summer
Uniform
Winter

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Soil Tolerances

Soil drainage

- impeded
- seasonally waterlogged

Soil reaction

- acid

Soil texture

- heavy
- light
- medium

Special soil tolerances

- saline

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Parasteneotarsonemus panici (/isc/datasheet/38811)	Herbivore					
Toya tuberculosa (/isc/datasheet/54283)	Pathogen					
Ustilago hypodytes (/isc/datasheet/55941)	Pathogen					

Notes on Natural Enemies

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Lists of natural enemies are given by Moreira (1976b) and by Waterhouse (1994) but there are no reports of serious damage from natural insect enemies or fungi, nor serious consideration of their potential for biological control. Waterhouse (1994) also noted that most of the arthropod enemies are polyphagous pests of crops which might explain the absence of any serious attempt to find biological control agents. Insects do not hold promise but records of fungal pathogens merit investigations. There may be host-specific species or forma speciales which might be introduced into areas where they are not present. There is one report of the white amur (grass carp - Ctenopharyngodon idella) consuming P. repens where it occurs as part of a floating island vegetation (Sutton et al., 1977).

Means of Movement and Dispersal

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Natural dispersal

P. repens spreads by means of rhizomes. Seed is rarely produced.

Agricultural practices

P. repens is planted in grazing land and may invade adjacent areas if not carefully managed. A careful impact assessment should be made before introducing the species as forage to a new area.

Plant Trade

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Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Bulbs/Tubers/Corms/Rhizomes				Pest or symptoms usually visible to the naked eye
True seeds (inc. grain)				Pest or symptoms not visible to the naked eye but usually visible under light microscope

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Wood Packaging

Wood Packaging not known to carry the pest in trade/transport
Loose wood packing material
Non-wood
Processed or treated wood
Solid wood packing material with bark
Solid wood packing material without bark

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Impact Summary

Category	Impact
Animal/plant collections	None
Animal/plant products	None
Biodiversity (generally)	Negative
Crop production	Negative
Environment (generally)	Negative
Fisheries / aquaculture	Negative
Forestry production	None
Human health	None
Livestock production	None
Native fauna	Negative
Native flora	Negative
Rare/protected species	None
Tourism	Negative
Trade/international relations	None
Transport/travel	Negative

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Impact

P. repens is a troublesome weed in a wide range of perennial crops, being noted by Holm et al. (1977) as a serious or principal weed of sugarcane in Taiwan and Hawaii; pineapple in West Africa; tea in India, Indonesia and Sri Lanka; various orchard crops in Thailand; rubber, coconut and oil palm in Malaysia; also of rice in Indonesia and Sri Lanka. In a number of these situations it is listed as one of the three most serious weeds. There are few estimates of crop losses but Peng and Sze (1974) report that in Taiwan rhizome density can reach 15 t/ha, while a density of 5 t/ha can cause 50% reduction in sugarcane yield. It is also reported to have allelopathic effects (Perera et al., 1989; Chon, 1989).

P. repens may act as an alternative host to rice leafhopper, Ustilago and Pyricularia spp. (Holm et al., 1977).

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Impact: Biodiversity

As P. repens spreads by means of rhizomes, it can form dense pure swards that replace native species (Weber, 2003). In the Lake Okeechobee area of Florida, USA, the grass has spread over thousands of acres of the Lake's western marsh, displacing native plants and the valuable fish and wildlife habitat that they once provided (LOPP, 2004).

Social Impact

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P. repens can build up along irrigation canals and drainage ditches requiring costly control programmes. It also has to be controlled in golf course turf in Florida, USA (Busey, 2003).

Risk and Impact Factors

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Invasiveness

Proved invasive outside its native range

Uses

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P. repens has been widely used as a forage species. Its salt tolerance makes it a useful species for reclaiming saline soils (Ghaly, 2002). It is a source of ethno-medicines in India (Kaushal-Kumar, 2002).

Uses List

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Animal feed, fodder, forage

Fodder/animal feed
Forage

Environmental

Erosion control or dune stabilization

Similarities to Other Species/Conditions

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Not readily confused with other commonly occurring perennial grass weeds but in eastern and southern Africa, a closely related species P. repentellum also occurs, in similar wet habitats. The latter is distinguished by a smaller more delicate habit, and nerveless lower glume. In southern USA, Central and South America, a further closely related species, P. gouini(i), occurs. This is also less robust and almost glabrous. It is not certain to what extent either of these species may also occur as weeds.

Prevention and Control

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Cultural

The use of leguminous smothering crops is important and effective in plantation crops in sufficiently humid climatic conditions, e.g. in oil palm or rubber. In Florida wetlands, maintenance of high water levels favours indigenous species and reduces spread of P. repens (David, 1999).

Mechanical

Among traditional weeding methods, hoeing and hand-weeding are ineffective, owing to strong and rapid regrowth from the underground rhizome system. Tillage can be effective but it must be deep enough to disturb as many of the rhizomes as possible, and persistent enough and under the right climatic and soil conditions to result in good desiccation. One or two cultivations under wet conditions may serve only to spread the problem.

Chemical

Older herbicides used for control of P. repens include dalapon and asulam and these may still have applicability in particular situations, e.g. in sugarcane (Peng et al., 1977; Yeh and Wang, 1980) and along irrigation channels (Panchal, 1981). MSMA was reported by Coats (1974) to be inferior to asulam for control of P. repens in turf, but MSMA has been tested with some success in tea (e.g. Soedarsan et al., 1974). Quinclorac has also been shown to be an effective treatment in turf (Busey, 2003). Otherwise the herbicide of choice where crop safety allows, is glyphosate. Split doses a few weeks apart have given better results than a single application (Chandrasena, 1990). At lower doses activity may be decreased in hard water (Ca 5 mM) or in the presence of iron salts (Shilling et al., 1990a) or in mixtures with triazine or urea herbicides, whereas activity may be enhanced by various additives including ammonium sulphate, kaolin and surfactants (Kathiravetpillai and Punyasiri, 1989; Shilling et al., 1990b; Reddy and Singh, 1992). Fluazifop-butyl was not fully effective in Florida citrus (Singh et al., 1985) and Seth and Madin (1984) found glyphosate superior to fluazifop-butyl. However, working with fluazifop-P-butyl, Chandrasena (1989, 1991) was able to improve performance with surfactant and oil additives. In pot experiments Parker (1982) found both fluazifop-butyl and sethoxydim to have activity at least equal to that of glyphosate. These two graminicides should be of value in broad-leaved crops. Imazapyr has given longer-lasting control than glyphosate in irrigation channels (Nir, 1988).

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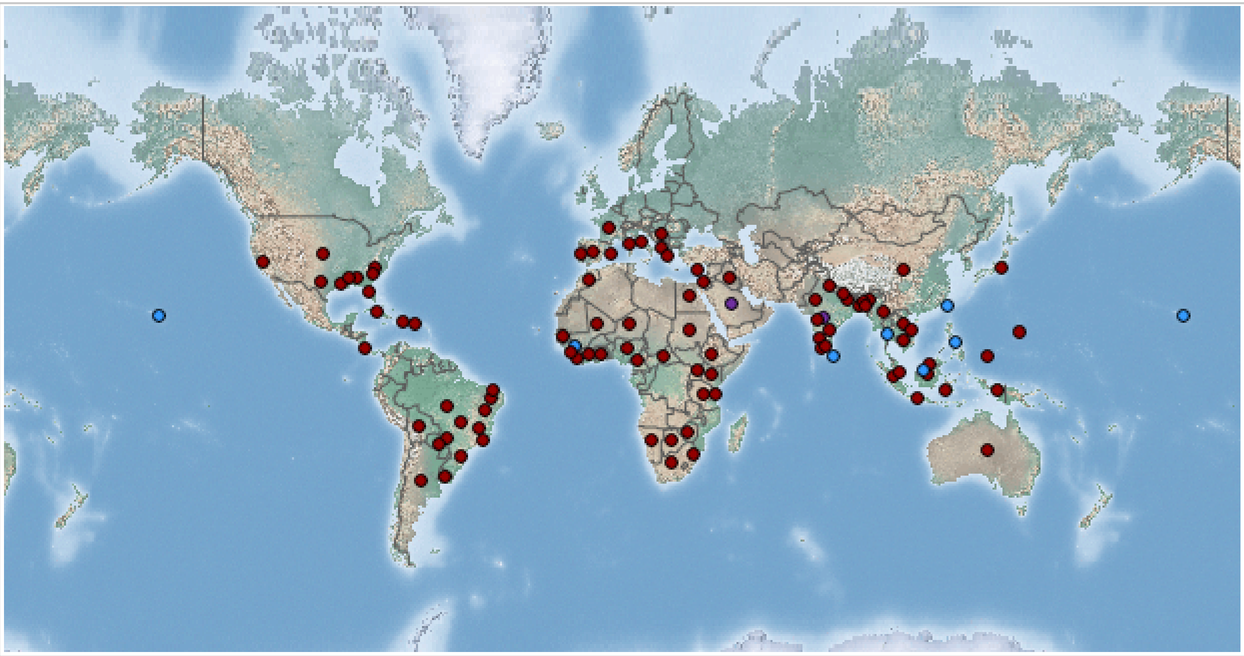
World Map

Analyzed by: Density

Present, no further details	Widespread
Localised	



Africa

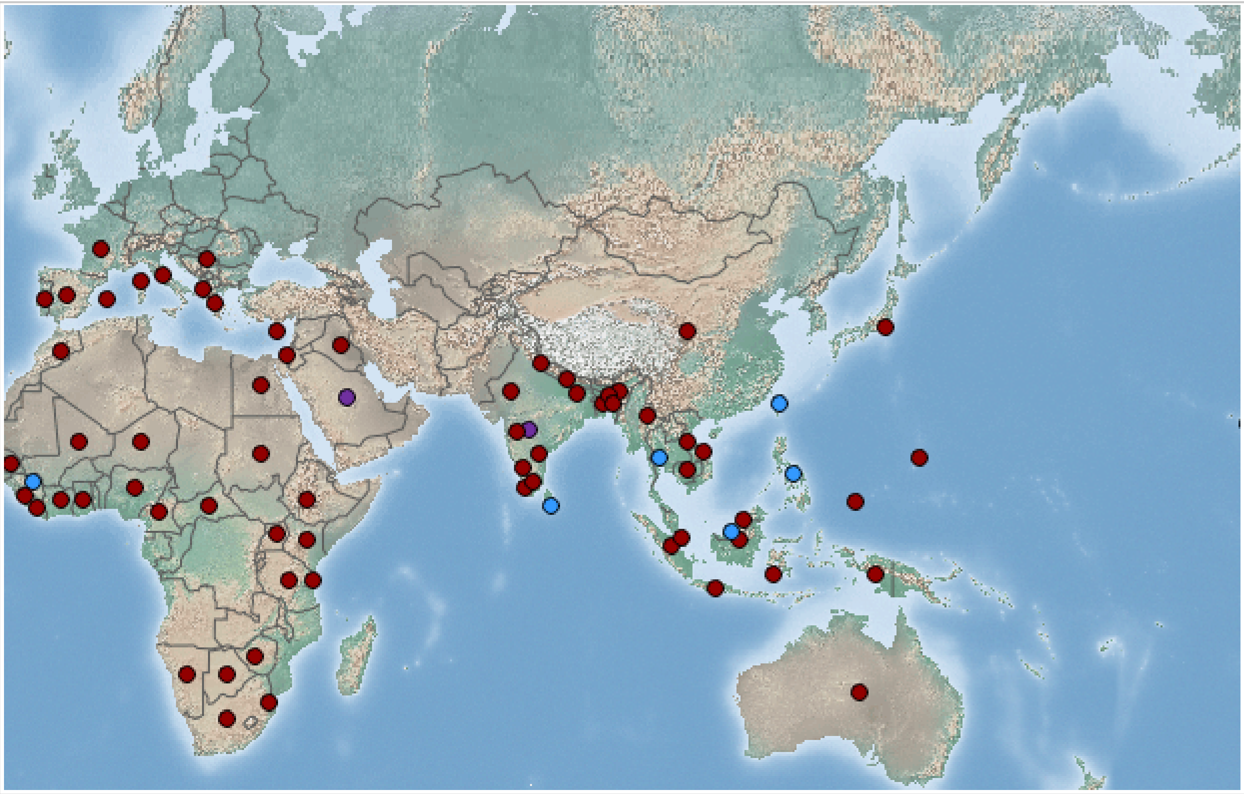
Analyzed by: Density

Present, no further details	Widespread
Localised	

Asia

Analyzed by: Density

Present, no further details	Widespread
Localised	



Europe

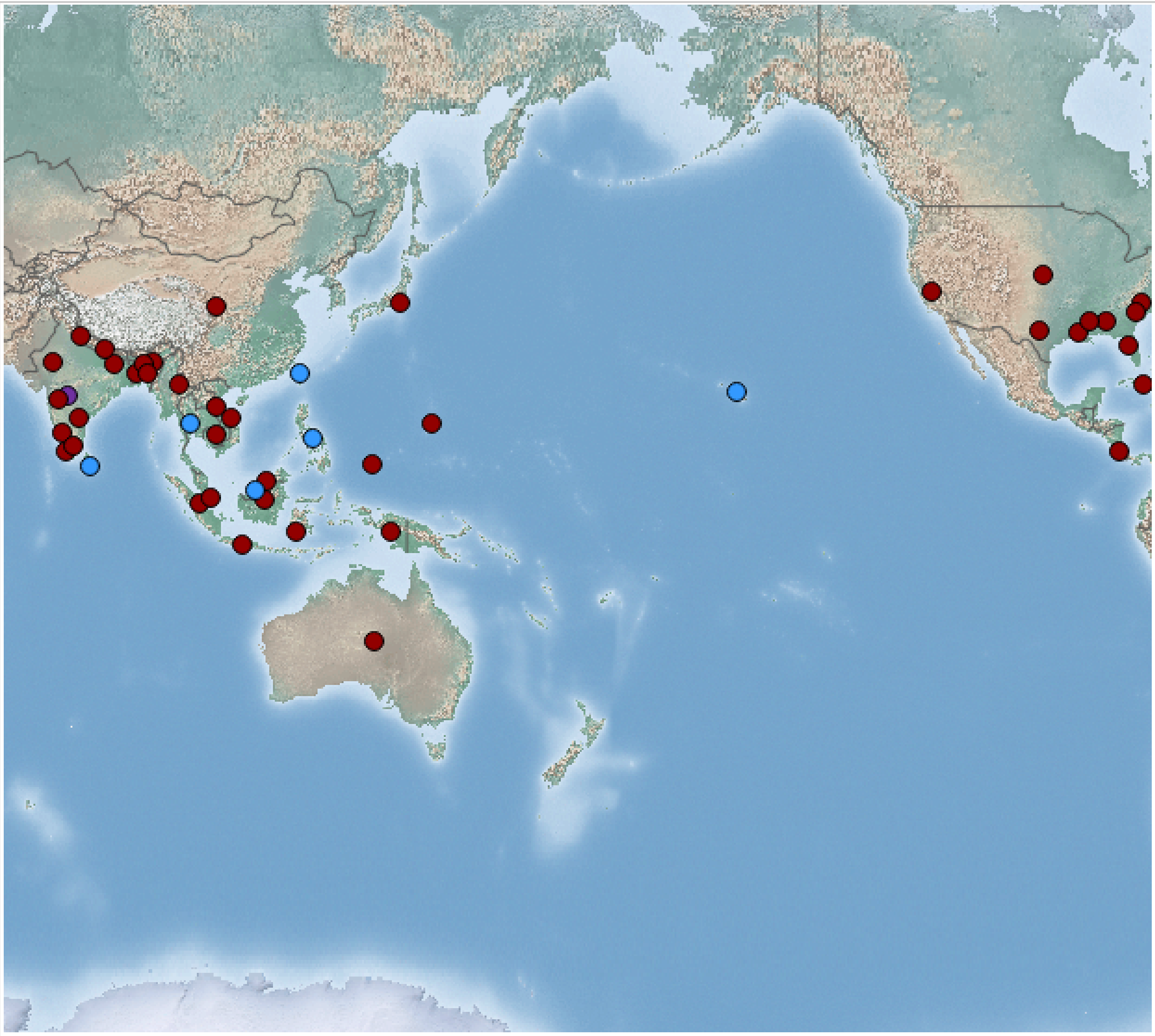
Analyzed by: Density

Present, no further details	Widespread
Localised	

Pacific

Analyzed by: Density

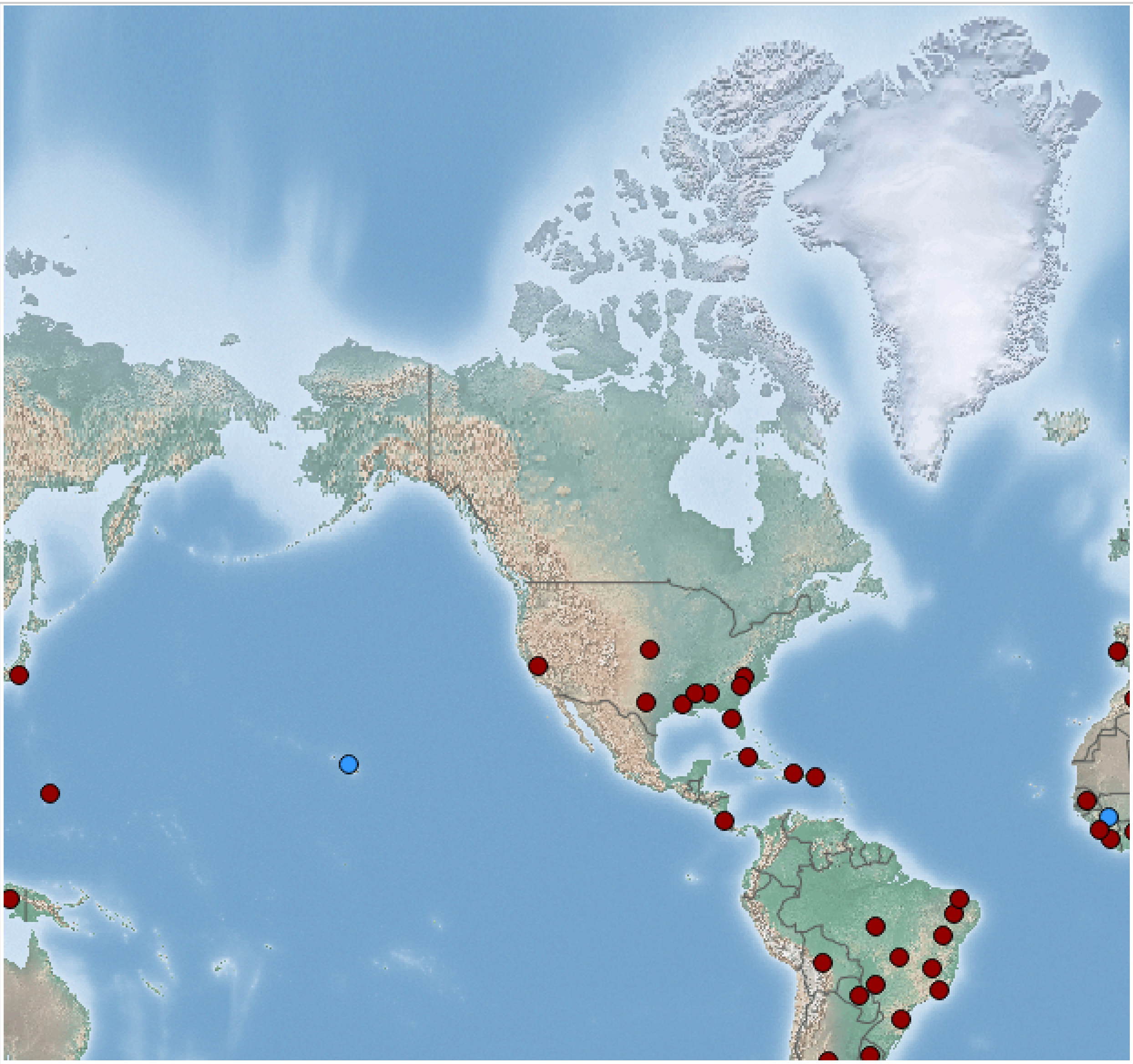
Present, no further details	Widespread
Localised	



North America

Analyzed by: Density

Present, no further details	Widespread
Localised	



Central America

Analyzed by: Density

Present, no further details	Widespread
Localised	

South America

Analyzed by: Density

Present, no further details	Widespread
Localised	

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Parkinsonia aculeata (Mexican palo-verde)

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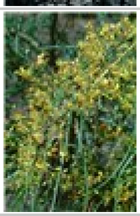
Pictures

Picture	Title	Caption	Copyright
	Small branchy tree	Small branchy tree with heavy pod crop growing in semi-arid conditions, Manabi, Ecuador.	Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	Small branchy trees	Baja California Norte, Mexico.	Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	On saline soil	Natural stand on saline soil with salt crust, deep black vertisols, Zacapa, Guatemala.	Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	Flowering shoot		Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	Ornamental flowers		Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	Ripe indehiscent pods		Colin Hughes, Dept. Plant Sciences, Univ. Oxford
	Dispersal of seed pods	Ripe pods of P. aculeata float in water for up to 14 days, promoting effective seed dispersal.	Colin Hughes, Dept. Plant Sciences, Univ. Oxford

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Identity

Preferred Scientific Name

Parkinsonia aculeata L.

Preferred Common Name

Mexican palo-verde

Other Scientific Names

Parkinsonia spinosa H.B.K.
Parkinsonia thornberi M.E. Jones

International Common Names

English: Barbados flower fence; Jerusalem thorn; Mexican paloverde; parkinsonia; retama
Spanish: Cina-cina; palo verde
French: Epine de Jerusalem; Genet epineux

Local Common Names

Argentina: cina cina; retamo rojo; sina sina
Barbados: holy thorn; royal cashiaw
Brazil: espinho de Jerusalem; rosa da turquia; rosa da turquina; turco
Costa Rica: sulphato
Cuba: espinillo; junco marino; palo de rayo; pararrayo
El Salvador: sulphato
Gambia: barkasoñé; barkasonyo; julugodi; parkasonu
Germany: Jerusalemdorn; Stacheliger Ginsterbaum
Ghana: zugu-bai-tia
Guatemala: palo de rayo; sulphatillo; sulphato
India: adanti; bawal; kikar; pardeshi baval; ram baval; rombawal; sima tumma; sima-tumma; vedi-badhal; vilayati babul; vilayati kikar
Italy: Ginestra spinosa; Spina di Jerusalem
Mexico: bacapore; bagote; cacaporo; cahuinga; guacóporo; guichebella; guichibelle; haocóporo; junco; junco marino; mezquite extranjero; mezquite verde; quechi-pelle; retama china; retama de cerda
Nicaragua: espino negro; sauce del playa
Niger: sassabaanii
Nigeria: bàgàarùwàr maka; bàgàarùwàr másàr; dán-sárkín ítáátúwàà; jannatu; sassabaanii; sharan labbi; shukar hali
Pakistan: kabuli kikar; vilayati kikar
Senegal: barkasoñé; barkasonyo; parkasonu
Somalia: geed walaayo
Sri Lanka: belaiti kikar
USA: horsebean

EPPO code

PAKAC (Parkinsonia aculeata)

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Summary of Invasiveness

This is one of the most widespread and well-known woody weeds in hot regions, and has become naturalized and shown weedy tendencies in all countries where it exists, whether native or introduced. It is disliked for its thorns, forming dense impenetrable thickets that degrade pasture, choke waterways and prevent cattle reaching water. It was often introduced as a fodder, hedging or ornamental tree, with an ability to tolerate the driest and most saline sites and waterlogging, but prolific seeding led to rapid spread. It is a prohibited weed in Australia and a serious pest in many other countries.

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Taxonomic Tree

- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Fabales
            - Family: Fabaceae
              - Subfamily: Caesalpinioideae
                - Genus: Parkinsonia
                  - Species: Parkinsonia aculeata

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Notes on Taxonomy and Nomenclature

The genus Parkinsonia is a member of the legume family (Fabaceae), subfamily Caesalpinioideae. As currently delimited it contains 29 species native to the Americas and Africa.

Parkinsonia aculeata is an easily recognized and morphologically well delimited species first described and illustrated in Plumier's Nova Plantarum Americanum Genera (1703). The original Linnaean citation was in the Hortus Cliffortianus (1737). Two species were described which were later placed in synonymy with P. aculeata, i.e. P. spinosa H.B. & K. and P. thornberi M.E. Jones; neither name gained wide usage. The most significant taxonomic controversy connected with the species concerns its dubious relationship with three east African species (P. scioana (Chiovenda) Brenan, P. anacantha Brenan and P. raimondoi Brenan), one south African species (P. africana Sond.) and with the small Central American genus Cercidium Tul. There has been more than a century of confusion surrounding the delimitation and subdivision of Parkinsonia L. and Cercidium (reviewed by Carter, 1974). Carter argued that Cercidium forms a discrete, easily recognisable genus confined to the Americas and preferred to consider Parkinsonia as monotypic, comprising only P. aculeata. However, a recent detailed study of the two genera suggests that the species of Cercidium should be transferred to Parkinsonia, and that P. africana and Cercidium are more closely related to P. aculeata than the East African species (Hawkins, 1996).

Description

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P. aculeata is a shrubby tree, growing to a height of 4-10 m. Lone trees or well spaced trees may be unbranched to 1-1.5 m with a well-developed bole up to 30 cm diameter, but it is common to find low-branched or multi-stemmed individuals. Trunk fissured, black-brown. Smaller branches and shoots green. Branches prominently armed. Leaves bi-pinnate. The petiole and primary rachis reduced, 10-30 mm long, and stoutly spinescent. Secondary rachis, 1-3 pairs congested at the base of the primary rachis, 18-40 cm long, flattened, and bearing 25-60 pairs of tiny, weakly-mucronate obovate-elliptic leaflets which are often deciduous. Paired stipules spinescent. Inflorescences racemose, 4-20 cm long, on short, actively growing axillary shoots. Pedicels 1.5-2 cm long, proximally jointed. Flower petals 5, yellow, clawed banner petal 9-13 mm long, flecked with orange, turning deep orange-brown and folding forwards post-pollination. Calyx lobes obovate-lanceolate, reflexed. Fruits indehiscent, orange-brown glabrous pods, subterete, constricted and flattened between seeds. Seeds 2-8 per pod, 8-11 mm long, dark and light brown or grey mottled.

Plant Type

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Broadleaved
Perennial
Seed propagated
Shrub
Tree
Woody

Distribution

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Although the majority of authors agree that P. aculeata is native to the New World, there are difficulties in identifying the historical distribution of the species. The literature suggests P. aculeata was well established throughout Mexico, the West Indies and South America by the 1700s, but that the natural or original distribution of P. aculeata in the Americas may have been more restricted than either that or present day distributions. Several authors have noted that the natural distribution of P. aculeata is difficult to ascertain (Isley, 1975; McVaugh, 1987; Woods, 1992). Extensive isolated pure stands of P. aculeata are found throughout southern USA, Mexico and Central America at seasonally flooded former lake bed sites, coastal estuaries or lagoons with deep black vertisols. P. aculeata is rarely found outside these sites, which are often highly disjunct, except as a putatively recent invader of roadsides, railway lines or irrigation channels, or where planted. Hughes (1989) has suggested that these Central American and Mexican sites may represent the true natural distribution of the species.

It appears that the native distribution is larger than stated in the Forestry Compendium (CABI, 2003). PIER (2001) states that it is native to southern USA, the Caribbean, Mexico and northern South America, and Garcia (2000) notes that it is also native to northern Argentina. Starr et al. (2003) state that the native distribution is disputed. It is likely that it should include at least the whole of mainland Central America. Also, descriptions of native vegetation complexes in Peru (Pasiecznik et al., 2001) suggest that it is native to dry coastal areas there, and thus, probably, Ecuador, Colombia and Venezuela. Wiggins and Porter (1971) state it is native to the Galapagos, disputed by Starr et al. (2003). The native distribution published here has been taken as that of ILDIS (2003), to include most of Central and South America, the USA and the Bahamas.

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Asia								
Cambodia (/isc/datasheet/108472)	Present		Introduced				Lock and Heald, 1994; PIER, 2001; ILDIS, 2003	
India (/isc/datasheet/108459)	Widespread		Introduced	before 1850			ILDIS, 2003	
-Andhra Pradesh (/isc/datasheet/108721)	Present		Introduced			Planted		
-Gujarat (/isc/datasheet/108732)	Present		Introduced			Planted		
-Haryana (/isc/datasheet/108734)	Present		Introduced			Planted		
-Karnataka (/isc/datasheet/108738)	Present		Introduced			Planted		
-Madhya Pradesh (/isc/datasheet/108743)	Present		Introduced			Planted		
-Maharashtra (/isc/datasheet/108740)	Present		Introduced			Planted		
-Odisha (/isc/datasheet/108746)	Present		Introduced			Planted		
-Rajasthan (/isc/datasheet/108749)	Present		Introduced			Planted		
-Tamil Nadu (/isc/datasheet/108751)	Present		Introduced			Planted		
-Uttar Pradesh (/isc/datasheet/108753)	Present		Introduced			Planted		
Indonesia (/isc/datasheet/108455)	Present							Present based on regional distribution.
-Java (/isc/datasheet/108714)	Present		Introduced			Planted		
Iran (/isc/datasheet/108462)	Present		Introduced	before 1850		Planted	Lock and Simpson, 1991	
Iraq (/isc/datasheet/108461)	Present		Introduced			Planted	Lock and Simpson, 1991	
Israel (/isc/datasheet/108457)	Present		Introduced	before 1932		Planted	Post and Dinsmore, 1932	
Jordan (/isc/datasheet/108466)	Present		Introduced			Planted		

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Laos (/isc/datasheet/108481)	Present		Introduced			Planted	Lock and Heald, 1994	
Lebanon (/isc/datasheet/108482)	Present		Introduced			Planted		
Oman (/isc/datasheet/108529)	Present		Introduced			Planted	Lock and Simpson, 1991	
Pakistan (/isc/datasheet/108537)	Present		Introduced	before 1850		Planted	ILDIS, 2003	
Saudi Arabia (/isc/datasheet/108552)	Present		Introduced			Planted		
Singapore (/isc/datasheet/108557)	Present		Introduced			Planted		
Sri Lanka (/isc/datasheet/108485)	Present		Introduced			Planted	ILDIS, 2003	
Syria (/isc/datasheet/108572)	Present		Introduced	before 1850			Post and Dinsmore, 1932	
Thailand (/isc/datasheet/108580)	Present		Introduced				Lock and Heald, 1994; PIER, 2001	
Vietnam (/isc/datasheet/108604)	Present		Introduced				Lock and Heald, 1994; PIER, 2001	
Yemen (/isc/datasheet/108609)	Present		Introduced			Planted	Lock and Simpson, 1991	
Africa								
Algeria (/isc/datasheet/108415)	Present		Introduced			Planted		
Angola (/isc/datasheet/108357)	Present		Introduced			Planted		
Cameroon (/isc/datasheet/108397)	Present		Introduced			Planted		
Cape Verde (/isc/datasheet/108406)	Present		Introduced	before 1895		Planted	ILDIS, 2003	
Chad (/isc/datasheet/108576)	Present		Introduced			Planted		
Congo (/isc/datasheet/108392)	Present		Introduced			Planted		
Egypt (/isc/datasheet/108418)	Present		Introduced	before 1932		Planted	Post and Dinsmore, 1932	
Ethiopia (/isc/datasheet/108422)	Present		Introduced			Planted		
Gambia (/isc/datasheet/108439)	Present		Introduced			Planted		
Ghana (/isc/datasheet/108436)	Present		Introduced			Planted		

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Kenya (/isc/datasheet/108470)	Present		Introduced		Invasive	Planted	Brenan, 1967	
Libya (/isc/datasheet/108492)	Present		Introduced			Planted		
Madagascar (/isc/datasheet/108498)	Present		Introduced			Planted	ILDIS, 2003	
Mauritania (/isc/datasheet/108507)	Present		Introduced			Planted		
Mauritius (/isc/datasheet/108510)	Present		Introduced				PIER, 2001	
Morocco (/isc/datasheet/108493)	Present		Introduced			Planted		
Mozambique (/isc/datasheet/108515)	Present		Introduced		Invasive	Planted	Palgrave, 1977	
Niger (/isc/datasheet/108518)	Present		Introduced			Planted		
Nigeria (/isc/datasheet/108520)	Present		Introduced			Planted	Keay et al., 1964	
Réunion (/isc/datasheet/108546)	Present		Introduced			Planted	PIER, 2001	
Senegal (/isc/datasheet/108564)	Present		Introduced		Invasive	Planted		
Sierra Leone (/isc/datasheet/108562)	Present		Introduced			Planted		
Somalia (/isc/datasheet/108565)	Present		Introduced		Invasive		Madany, 1991; Thulin, 1993	
South Africa (/isc/datasheet/108613)	Present		Introduced		Invasive	Planted	Palgrave, 1977	
Sudan (/isc/datasheet/108555)	Present		Introduced			Planted		
Tanzania (/isc/datasheet/108591)	Present		Native				Brenan, 1967	
Uganda (/isc/datasheet/108594)	Present		Introduced			Planted	Brenan, 1967	
Zimbabwe (/isc/datasheet/108616)	Present		Introduced		Invasive	Planted	Palgrave, 1977	
North America								
Mexico (/isc/datasheet/108513)	Present		Native		Invasive	Planted, Natural	ILDIS, 2003	
USA (/isc/datasheet/108597)	Present							Present based on regional distribution.
-Alabama (/isc/datasheet/108796)	Present						,	
-Arizona (/isc/datasheet/108798)	Present		Native			Planted		
-California (/isc/datasheet/108799)	Present		Native		Invasive	Planted		
-Florida (/isc/datasheet/108804)	Present					Planted		
-Georgia (/isc/datasheet/108805)	Present					Planted		

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
-Louisiana (/isc/datasheet/108813)	Present					Planted		
-Mississippi (/isc/datasheet/108820)	Present						,	
-Nevada (/isc/datasheet/108828)	Present		Native				,	
-New Mexico (/isc/datasheet/108827)	Present		Native		Invasive	Planted		
-South Carolina (/isc/datasheet/108835)	Present					Planted		
-Texas (/isc/datasheet/108838)	Present		Native		Invasive	Planted		
-Utah (/isc/datasheet/108839)	Present		Native				,	
Central America and Caribbean								
Bahamas (/isc/datasheet/108382)	Present		Native				ILDIS, 2003	
Costa Rica (/isc/datasheet/108402)	Present		Native			Planted, Natural	ILDIS, 2003	
Cuba (/isc/datasheet/108405)	Present		Introduced		Invasive		Oviedo Prieto et al., 2012	
Dominican Republic (/isc/datasheet/108414)	Present					Planted	ILDIS, 2003	
El Salvador (/isc/datasheet/108571)	Present		Native			Planted	ILDIS, 2003	
Guatemala (/isc/datasheet/108445)	Present		Native			Planted, Natural	ILDIS, 2003	
Haiti (/isc/datasheet/108453)	Present						ILDIS, 2003	
Jamaica (/isc/datasheet/108465)	Present		Introduced			Planted	ILDIS, 2003	
Martinique (/isc/datasheet/108506)	Present					Planted		
Netherlands Antilles (/isc/datasheet/108356)	Present					Planted		
Nicaragua (/isc/datasheet/108521)	Present		Native			Planted, Natural		
Panama (/isc/datasheet/108530)	Present		Native				ILDIS, 2003	
Puerto Rico (/isc/datasheet/108541)	Present					Planted	,	
Saint Kitts and Nevis (/isc/datasheet/108475)	Present					Planted		
Saint Vincent and the Grenadines (/isc/datasheet/108600)	Present					Planted		
United States Virgin Islands (/isc/datasheet/108603)	Present					Planted		
South America								
Argentina (/isc/datasheet/108359)	Present		Native				Garcia, 2000	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Bolivia (/isc/datasheet/108379)	Present		Native			Planted	ILDIS, 2003	
Brazil (/isc/datasheet/108381)	Present							Present based on regional distribution.
-Bahia (/isc/datasheet/108630)	Present		Native			Planted	ILDIS, 2003	
-Ceara (/isc/datasheet/108631)	Present		Native			Planted		
-Paraiba (/isc/datasheet/108640)	Present		Native				ILDIS, 2003	
-Pernambuco (/isc/datasheet/108641)	Present		Native				ILDIS, 2003	
-Sao Paulo (/isc/datasheet/108651)	Present		Native			Planted		
Colombia (/isc/datasheet/108399)	Present		Native			Planted	ILDIS, 2003	
Ecuador (/isc/datasheet/108416)	Present		Native			Planted	ILDIS, 2003	
-Galapagos Islands (/isc/datasheet/108700)	Present		Native				Wiggins and Porter, 1971	
French Guiana (/isc/datasheet/108434)	Present		Native			Planted		
Paraguay (/isc/datasheet/108544)	Present		Native			Planted		
Peru (/isc/datasheet/108532)	Present		Native			Planted	ILDIS, 2003	
Suriname (/isc/datasheet/108568)	Present		Native			Planted	ILDIS, 2003	
Uruguay (/isc/datasheet/108598)	Present		Native			Planted	ILDIS, 2003	
Venezuela (/isc/datasheet/108601)	Present		Native			Planted		
Europe								
Cyprus (/isc/datasheet/108408)	Present		Introduced	before 1895		Planted		
Greece (/isc/datasheet/108443)	Present		Introduced		Invasive	Planted	Le, 1984; Le Houerou, 1984	
Greece (/isc/datasheet/108443)	Present		Introduced		Invasive	Planted	Le, 1984; Le Houerou, 1984	
Italy (/isc/datasheet/108464)	Present		Introduced	before 1850	Invasive	Planted	Orlando and Grisafi, 1977	
Spain (/isc/datasheet/108421)	Present		Introduced				Pasiecznik, 1989; Hyde et al., 1990	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Oceania								
Australia (/isc/datasheet/108362)	Present							Present based on regional distribution.
-Australian Northern Territory (/isc/datasheet/108619)	Present		Introduced		Invasive		Miller and Pickering, 1980; Wilson and Miller, 1987; Woods, 1992	
-New South Wales (/isc/datasheet/108620)	Present		Introduced		Invasive		Miller and Pickering, 1980; Wilson and Miller, 1987; Woods, 1992	
-Queensland (/isc/datasheet/108621)	Present		Introduced		Invasive		Miller and Pickering, 1980; Wilson and Miller, 1987; Woods, 1992	
-Western Australia (/isc/datasheet/108625)	Present		Introduced		Invasive		Miller and Pickering, 1980; Wilson and Miller, 1987; Woods, 1992	
Guam (/isc/datasheet/108446)	Present		Introduced	1970s			,	
Micronesia, Federated states of (/isc/datasheet/108427)	Present		Introduced				Swarbrick, 1997	
New Caledonia (/isc/datasheet/108517)	Present		Introduced			Planted	Swarbrick, 1997	

History of Introduction and Spread

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It may be assumed that P. aculeata can now be found in most tropical, sub-tropical and Mediterranean countries. The documentation of introductions and the establishment of naturalized populations of P. aculeata outside of the New World is incomplete. Introduction to Australia was in the mid to late 1800s (Woods, 1992). Extensive weedy populations are now established across the Northern Territories and Western Australia, and there are infestations in Queensland and northern New South Wales (Miller and Pickering, 1980; Wilson and Miller, 1987; Woods 1992). Promotion in Australia as an evergreen hedge (von Mueller, 1888) does not indicate the earliest intercontinental movement of the species. Specimens collected from former Persia and present day Senegal, India, Pakistan and the Mascarenes prior to 1850 are deposited in the Kew herbarium.

The use of P. aculeata throughout arid regions of the British Empire, and later the Commonwealth, as an ornamental, for soil fixation and as a hedging plant was documented by Troup and Joshi (1983) and by Streets (1962). P. aculeata has a widespread distribution in Africa, and is becoming naturalized in many areas. Dale (1953) recommended P. aculeata for forestry usage in Uganda, and Brenan (1967) noted cultivation of P. aculeata in Uganda, Kenya and Tanzania. Neither were aware of naturalization in East Africa, though more recently an extensive naturalized population has been discovered in the vicinity of Nakuru, Kenya. P. aculeata is cultivated for ornament, shade, wind-breaks and hedging and is sometimes naturalized in Somalia (Madany, 1991; Thulin, 1993). Palgrave (1977) noted cultivation of P. aculeata as an ornamental in South Africa, and naturalized populations also in Mozambique along the Limpopo River, between Nelspruit in the Transvaal and Maputo in Mozambique and in the vicinity of Bulawayo, Zimbabwe.

P. aculeata is planted throughout West Africa (Hutchison and Dalziel, 1928) and is commonly planted in dry zone Nigerian towns and villages (Keay et al., 1964). It has been introduced to the Cape Verde Islands as a forestry species: specimens deposited at Kew were collected from Cape Verde as early as 1895; specimen notes from 1919 indicate the use of P. aculeata as a hedging plant. P. aculeata was not included in the first edition of the Flora of Syria, Palestine and Sinai (Post, 1896); in the second edition Post and Dinsmore (1932) noted widespread cultivation. Lock and Simpson (1991) indicate cultivation in Iran, Iraq, Oman and South Yemen. Le Houérou (1984) considered P. aculeata well adapted to the climate of the Mediterranean zone, indeed, naturalized individuals have been reported from Sicily (Orlando and Grisafi, 1977) and the species appears to be established as a weed in the environs of Athens.

The distribution of P. aculeata in Asia, other than in India, is less extensive, and may represent more recent introductions. Lock and Heald (1994) note that P. aculeata is sometimes cultivated in Cambodia, Laos, Thailand and Vietnam.

Risk of Introduction

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Since spontaneous populations are found wherever the species is introduced, the potential utility at any site must be weighed against the risk of infestation before P. aculeata is chosen for planting. In Australia, P. aculeata has been declared a P2 or a P3 weed under the Rural Lands Protection Act 1985 (DNR, 1998); P2 being that the plant must be destroyed, individual landholders are required to destroy all plants on the land concerned; and P3 being that the number and density of infestations must be significantly and progressively reduced, with individual landholders required to destroy all plants or take other action as approved by the local government in accordance with the act.

Habitat

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P. aculeata, like many other woody legumes adapted to dry regions, appears particularly invasive on degraded rangelands, although not being nitrogen-fixing, it cannot have a comparative advantage in terms of soil nitrogen. It is tolerant of drought, waterlogging and saline conditions, and is still often selected for planting where foresters seek 'anything that grows' in harsh, degraded or marginal lands, or particular seasonally flooded sites which are not tolerated by other species.

Habitat List

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Category	Habitat	Presence	Status
Littoral	Coastal areas	Present, no further details	Harmful (pest or invasive)
Terrestrial-managed	Cultivated / agricultural land	Present, no further details	Harmful (pest or invasive)
	Disturbed areas	Present, no further details	Harmful (pest or invasive)
	Managed grasslands (grazing systems)	Present, no further details	Harmful (pest or invasive)
	Rail / roadsides	Present, no further details	Harmful (pest or invasive)
Terrestrial-natural/semi-natural	Deserts	Present, no further details	Harmful (pest or invasive)
	Natural grasslands	Present, no further details	Harmful (pest or invasive)
	Riverbanks	Present, no further details	Harmful (pest or invasive)

Hosts/Species Affected

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P. aculeata is generally a weed of rangelands, only rarely is it considered a problem weed in cultivated land.

Biology and Ecology

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Genetics

Data from tree breeding and provenance trials for P. aculeata are lacking. The conservation status of the species, in terms of interspecific variation, has not been examined. The establishment of extensive weedy populations, ready regeneration from seed or coppice stumps, and abundance in its putative range suggests that the species is not at risk (Stewart et al., 1992). Natural hybrids have been described between P. aculeata and C. praecox (Ruiz and Pavón) Harms., a thorny arid zone species with a disjunct distribution spanning the arid regions of tropical and subtropical North and South America (Carter, 1974; Hawkins, 1996). The hybrids, which are unarmed, have been identified as a potential new agroforestry species (Hughes, 1989), although they may pose a novel and significant threat of weediness. Hybrids are known to often display increased weedy tendencies (Abbott, 1992), so novel hybrids of Parkinsonia should be utilized with particular care or avoided.

Physiology and Phenology

Plants flower in the second or third growth season (Parsons and Cuthbertson, 1992). In Central America peak flowering is from February to March, with sporadic flowering thereafter. Flowering is somewhat later in Mexico and the southern USA, with peak flowering occurring between April and May. In India, flowering is in April and May, with sporadic flowering almost throughout the year (Troup and Joshi, 1983). In Australia, plants usually flower in May or June but, as elsewhere, sporadic flowering can occur throughout the year (Parsons and Cuthbertson, 1992). Leaflets may be partially or completely deciduous in the dry season, but the phyllodial secondary rachises are persistent.

Reproductive Biology

Propagation of P. aculeata is generally by seed and seeding is prolific, though pods are indehiscent. Mahmoud and El-Sheikh (1981) noted two types of seed, light seeds which are water permeable and germinate freely, and dark seeds which appear to have a harder seed coat and require pre-treatment. Seedlings germinate over a wide temperature range, varying from continuous exposure to temperatures between 15°C and 35°C to alternating temperature regimes of 20/10°C, 25/15°C and 30/20°C (Parsons and Cuthbertson, 1992). Propagation is also reported by (root or shoot) cuttings or air-layering (Singh, 1989).

Environmental Requirements

It is tolerant of a wide range of soil and climate types. It may be assumed that triggers for invasion would include flooding, which would spread seed widely and provide improved conditions for establishment. P. aculeata is extremely hardy and thrives in moist and semi-arid environments, surviving seasonal flooding and a dry season of greater than 8 months duration. A mean annual rainfall between 250 mm and 1000 mm is tolerated, though the species is most valuable in dry areas and may exhibit weedy tendencies where mean annual rainfalls exceed 500 mm (Hocking, 1993; Luna, 1996). Temperatures as high as 48°C and mild frosts are tolerated, although die-back occurs after intense or extended frosts (Hocking, 1993).

Seedlings tolerate a wide range of soil pH, from 3 to 11 (Parsons and Cuthbertson, 1992) and moderate to excessively saline soils (Webb et al., 1984; Singh, 1989; Luna, 1996). Although many authors suggest that P. aculeata will not tolerate waterlogging (Webb et al., 1984; Singh, 1989; Luna, 1996), P. aculeata is known to favour seasonally flooded sites which other species are less able to tolerate (Miller and Pickering, 1980; Hughes, 1989; Killeen et al., 1993). Although the natural distribution of P. aculeata is arguably limited to seasonally flooded black cotton vertisols (Hughes, 1989), tolerance of soil types is wide. Good growth has been reported from shallow and skeletal soils, gravelly, rocky gullies and hillsides and deeper loamy valley soils (Hocking, 1993). The use of P. aculeata as a soil-binding species for sandy sites has been reported (Abohassan and Rudolph, 1978; Mahmoud and El-Sheikh, 1981; Troup and Joshi, 1983).

Associations

P. aculeata is visited by large and small bees. P. aculeata does not fix nitrogen and thus has no association with Rhizobia (Sprent, 1986). It is found in similar vegetation associations through Central America and northern South America, often with Acacia spp. (e.g. A. farnesiana in Central America and the USA), Caesalpinia spp., Capparis spp., Cercidium spp., Leucaena spp. and Prosopis spp. (Pasiecznik et al., 2001).

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Latitude/Altitude Ranges

Latitude North (°N)	Latitude South (°S)	Altitude Lower (m)	Altitude Upper (m)
38	-34	0	600

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Air Temperature

Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	0	
Mean annual temperature (ºC)	20	28
Mean maximum temperature of hottest month (ºC)	22	32
Mean minimum temperature of coldest month (ºC)	18	24

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Rainfall

Parameter	Lower limit	Upper limit	Description
Dry season duration	6	9	number of consecutive months with <40 mm rainfall
Mean annual rainfall	200	1000	mm; lower/upper limits

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Rainfall Regime

Summer
Uniform
Winter

Soil Tolerances

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Soil drainage

free
impeded
seasonally waterlogged

Soil reaction

acid
neutral
very acid

Soil texture

heavy
light
medium

Special soil tolerances

saline

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Natural enemies

Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Mimosestes ulkei (/isc/datasheet/34234)	Herbivore	Seeds				
Penthobruchus germaini (/isc/datasheet/39370)	Herbivore	Seeds				
Rhinacloa callicrates (/isc/datasheet/47172)	Herbivore	Leaves			Australia	

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Notes on Natural Enemies

No pests and diseases of importance have been noted for P. aculeata. Singh (1989) noted termite damage to seedlings. In India the larvae of Enarmonia malesana bore in pods, and Icerya aegyptiaca and Pseudoaonidia teserata feed on sap (Troup and Joshi, 1983). Woods (1992) made a study of possible biological control agents of P. aculeata, and collected 65 phytophagous insect species from P. aculeata growing in the Sonoran desert region of the southwestern USA and Mexico. P. aculeata is noted as a secondary host of Icerya aegyptiaca, but this species is so polyphagous, widespread, and injurious to commercial crop species it cannot be considered for biological control.

Means of Movement and Dispersal

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Birds are known to spread seed, and although the pods are not particularly palatable, wild mammals and livestock must surely play a part. Oceanic dispersal may be possible, though this is not certain. Effective water dispersal of pods facilitates invasion of seasonally flooded land and of water courses.

The main reason for international spread was intentional introduction as a fodder tree, for hedging, or as an ornamental. However, awareness of its status as a weed now means further introductions are less likely. The attractive characteristics of P. aculeata (performance under difficult or harsh environmental conditions; coppicing ability, pollarding response and resistance to browsing; plentiful production of seed) are those which are also problematic weedy characteristics (Hughes, 1994).

Impact Summary

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Category	Impact
Animal/plant collections	None
Animal/plant products	Negative
Biodiversity (generally)	None
Crop production	None
Environment (generally)	Negative
Fisheries / aquaculture	None
Forestry production	None
Human health	None
Livestock production	Negative
Native fauna	None
Native flora	None
Rare/protected species	None
Tourism	None
Trade/international relations	None
Transport/travel	None

Impact

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Effects upon livestock grazing are considerable in Australia, though no specific economic data has been forthcoming. Not only does competition affect the production of forage grasses, but access to water sources is restricted by the presence of extensive stands, and the thorns may have negative effects on livestock through damage to hooves and infected sores.

Environmental Impact

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Invasion of watercourse may have a negative impact upon the hydrology of a region.

Impact: Biodiversity

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Reports are not available on invasion of protected areas, though considering the spread of this species, this must have surely occurred. There are no known instances of P. aculeata threatening another species survival, but rather the reverse, that the dense thickets formed may provide a welcome refuge for birds and small mammals from predators or hunters.

Social Impact

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Thorns are considered an occasional hazard.

Risk and Impact Factors

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Invasiveness

- Invasive in its native range
- Proved invasive outside its native range

Impact mechanisms

- Produces spines, thorns or burrs

Likelihood of entry/control

- Highly likely to be transported internationally deliberately
- Difficult to identify/detect as a commodity contaminant

Uses

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P. aculeata is a small fast-growing, light-demanding tree most commonly used as a thorny hedge species, as a shade tree or an ornamental. In a hedgerow system, lopping may provide leaf or pods for fodder when other foods are not available. Trees are browse-resistant, and withstand pruning and coppicing well. P. aculeata is widely used as a thorn hedge and as an ornamental, shade or shelterbelt tree (Howes, 1946; Cunliff, 1974; Troup and Joshi, 1983; Webb et al., 1984; Dimmitt, 1987). It is recommended for planting in extreme site conditions (Stewart et al., 1992) and may therefore be of value in the rehabilitation of extremely degraded sites, for example in the reclamation of wastelands, gullied areas and mining spoil (Hocking, 1993). Use as a sand-binding species and for afforesting sandy waste lands has been reported (Abohassan and Rudolph, 1978; Mahmoud and El-Sheikh, 1981; Joshi, 1983). P. aculeata is particularly well suited for afforestation of heavy, poorly-draining soils which are not tolerated by other species. P. aculeata can be a valuable bee plant (Eisikowitch and Masad, 1982). Perez-Arbelaez (1956) noted use as a shade tree for coffee and cocoa, although little shade is given.

Wood is used as firewood and for charcoal and sometimes in paper-making (Thonner, 1915; Standley and Steyermark, 1937; Deshaprabhu, 1966; Hocking, 1993; Burkill, 1995; Luna, 1996). The wood is considered easy to work, but it is brittle and of dubious durability (Stewart et al., 1992). It is also small, but may be used for making tool handles, or light poles and posts (Singh, 1989; Luna, 1996).

Leaves and pods are reported to be used as fodder (Mahmoud and El-Sheikh, 1981; Webb et al., 1984; Stewart et al., 1992). Hocking (1993) noted that leaves and twigs are sometimes fed to goats in India, and Singh (1989) noted use of the leaves for sheep and goat fodder. Trees are not browsed by cattle or horses (Burkill, 1995). In west tropical Africa children eat the flowers and seed (Burkill, 1995), and in Sonora-Chihuahua, Mexico the raw seeds are eaten by the Warihio Indians (Gentry, 1963). In India, the seeds of P. aculeata have been investigated as a minor human food source (Rajaram and Janardhanan, 1991). The use of P. aculeata in native medicine has been described: an infusion of the leaves is considered to have diaphoretic, arbotifacient and antiseptic properties, and to be valuable for fevers, for epilepsy, and to stop vomiting (Perez-Arbelaez, 1956; Burkill, 1995).

Uses List

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Animal feed, fodder, forage

Fodder/animal feed

Environmental

Agroforestry
Boundary, barrier or support
Erosion control or dune stabilization
Revegetation
Shade and shelter
Soil improvement
Windbreak

Fuels

Charcoal
Fuelwood

General

Ornamental

Human food and beverage

Honey/honey flora

Materials

Carved material
Fibre
Wood/timber

Medicinal, pharmaceutical

Source of medicine/pharmaceutical

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Wood Products

Charcoal

Pulp

Short-fibre pulp

Roundwood

Building poles
Posts

Woodware

Industrial and domestic woodware
Tool handles

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Prevention and Control

Cultural Control

With a sufficient fuel load, fire can kill smaller seedlings, however adult plants will usually survive (DNR, 1998). Singh (1989) noted that waterlogging and browsing animals could negatively affect seedling survival. In Australia, improving pasture conditions is suggested to manage P. aculeata through competition (DNR, 1998).

Mechanical Control

Small seedlings and juveniles can be hand pulled, taking care not to injure oneself on the thorns (Starr et al., 2003). Mechanical removal by bulldozing, pulling with a tractor or grubbing gives effective control, especially where subsequent seedling growth can be controlled (Parsons and Cuthbertson, 1992). In Australia (DNR, 1998), blade ploughing or ripping is found to be effective, though it can only be done in level areas away from watercourses. In addition, follow up work is crucial for total control as disturbance often leads to subsequent seed germination.

Chemical Control

Good control of mature trees is possible with herbicides, with basal bark or cut stump treatments usually giving better results than an overall spray (Parsons and Cuthbertson, 1992). Picloram + 2,4-D or triclopyr in diesel oil applied to the basal 75 cm of trunk, completely circling it and thoroughly drenching the bark was effective, as were cut stump treatments, swabbing the whole of the butt with picloram, 2,4-D or triclopyr as basal bark sprays immediately after cutting (Parsons and Cuthbertson, 1992). Alternatively, hexazinone can be applied to the soil surface close to the base of the stems and when washed into the soil by subsequent rains slowly kills the shrubs. The severed aerial growth should be burned when dry.

Biological Control

In Australia, three biological organisms have been introduced to try to reduce the invasion of Jerusalem thorn, two seed beetles (Penthobruchus germaini and Mimosestes ulkei) which attack the mature seeds, and one leaf bug (Rhinacloa callicrates) which feeds on the leaves and shoots (DNR, 1998). Although all three insects have established at release sites, Penthobruchus germaini is currently the most effective at establishing and attacking seeds of P. aculeata. The following information on biological control agents introduced to Australia for control of P. aculeata is from DNR (1998).

Penthobruchus germaini is a small brown beetle from Argentina. It was first released in Australia in 1995 and has established more readily than Mimosestes ulkei. It has established and spread rapidly at all release sites in Australia. Up to 95% seed predation has been documented in some of the release sites. This species is documented as a very important tool in the management of P. aculeata in Australia. Female beetles lay up to 350 eggs of the surface of seed pods. Larvae tunnel into seeds soon after hatching. Each larvae spends its developmental period in the same seed which it enters after hatching. There it will eat all of the living contents of the seed preventing germination of that seed before exiting from the end of the seed and seed pod. Life cycle ranges from 5-12 weeks. This species is not reported from Hawaii (Nishida, 1994).

Mimosestes ulkei is a small 2-toned grey beetle from the USA, first released in Australia in 1993. It has established at several release sites in Australia, though not nearly as readily as Penthobruchus germaini. The life cycle and means of attack of this seed beetle is similar to that of P. germaini. Female beetles lay clusters of eggs in cracks and holes in seed pods. The larvae tunnels into seeds after hatching where it spends the rest of its developmental stage eating the living contents, preventing germination of that seed. Larvae pupate then exit through the side of the seed then out of the pod. Life cycle ranges from 5-12 weeks.

Rhinacloa callicrates was introduced into Queensland, Australia; under evaluation (Julien, 1992). It was imported from the USA, first released in Australia in 1989, and has established in Queensland, though it does not have a significant impact on P. aculeata (Starr et al., 2003).

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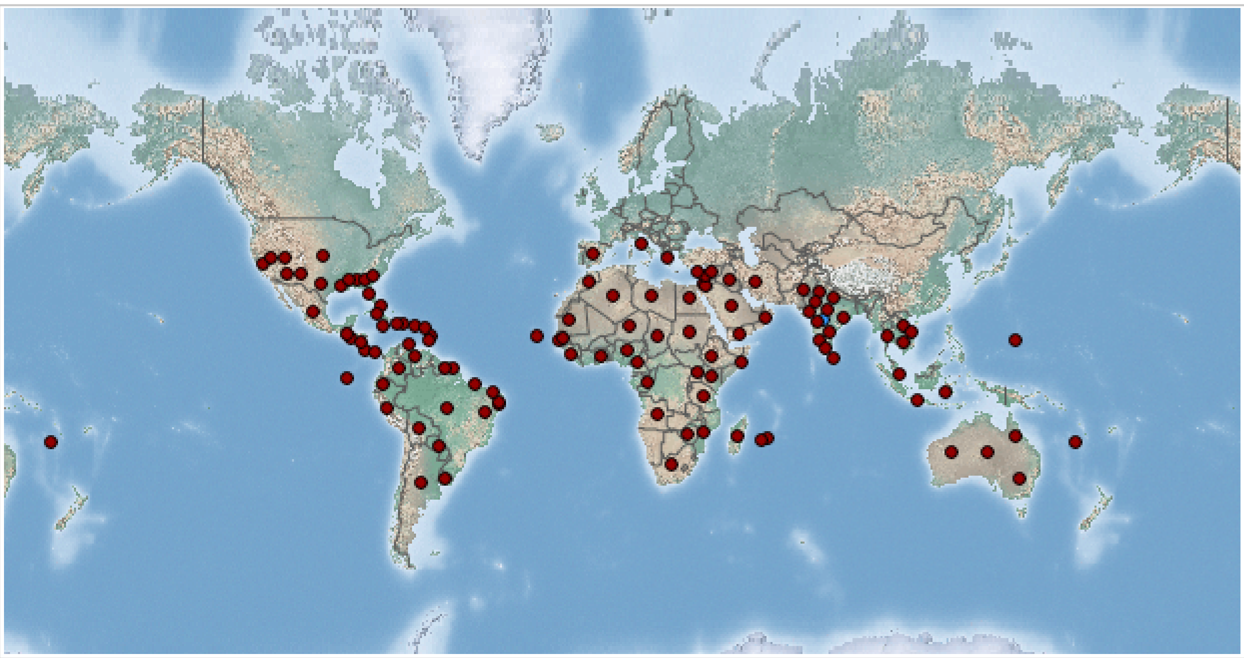
World Map

Analyzed by: Density

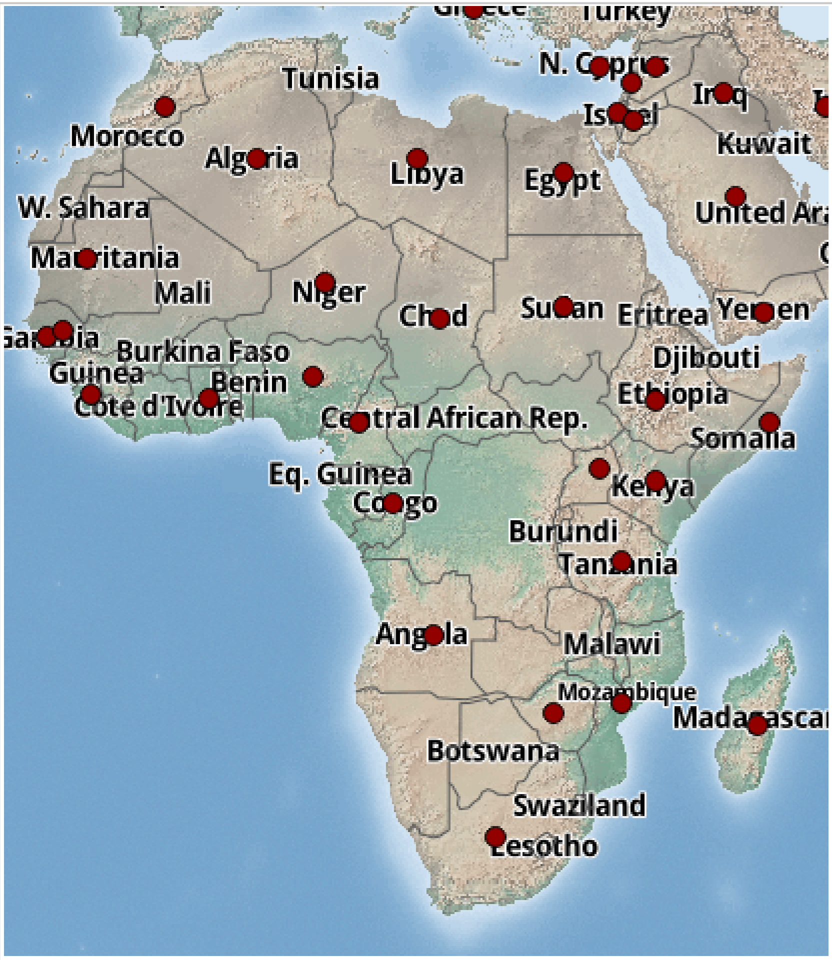
Present, no further details	Widespread
Present	



Africa

Analyzed by: Density

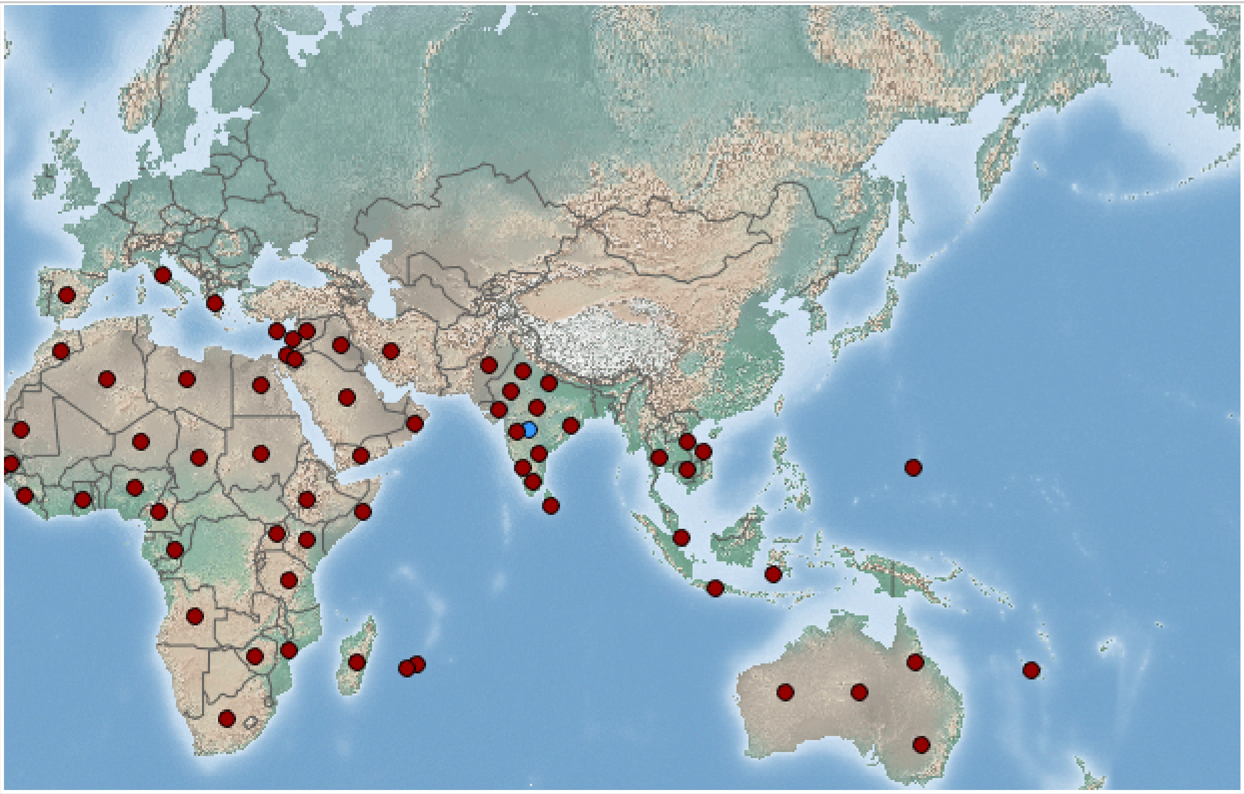
Present, no further details	Widespread
Present	



Asia

Analyzed by: Density

Present, no further details	Widespread
Present	



Europe

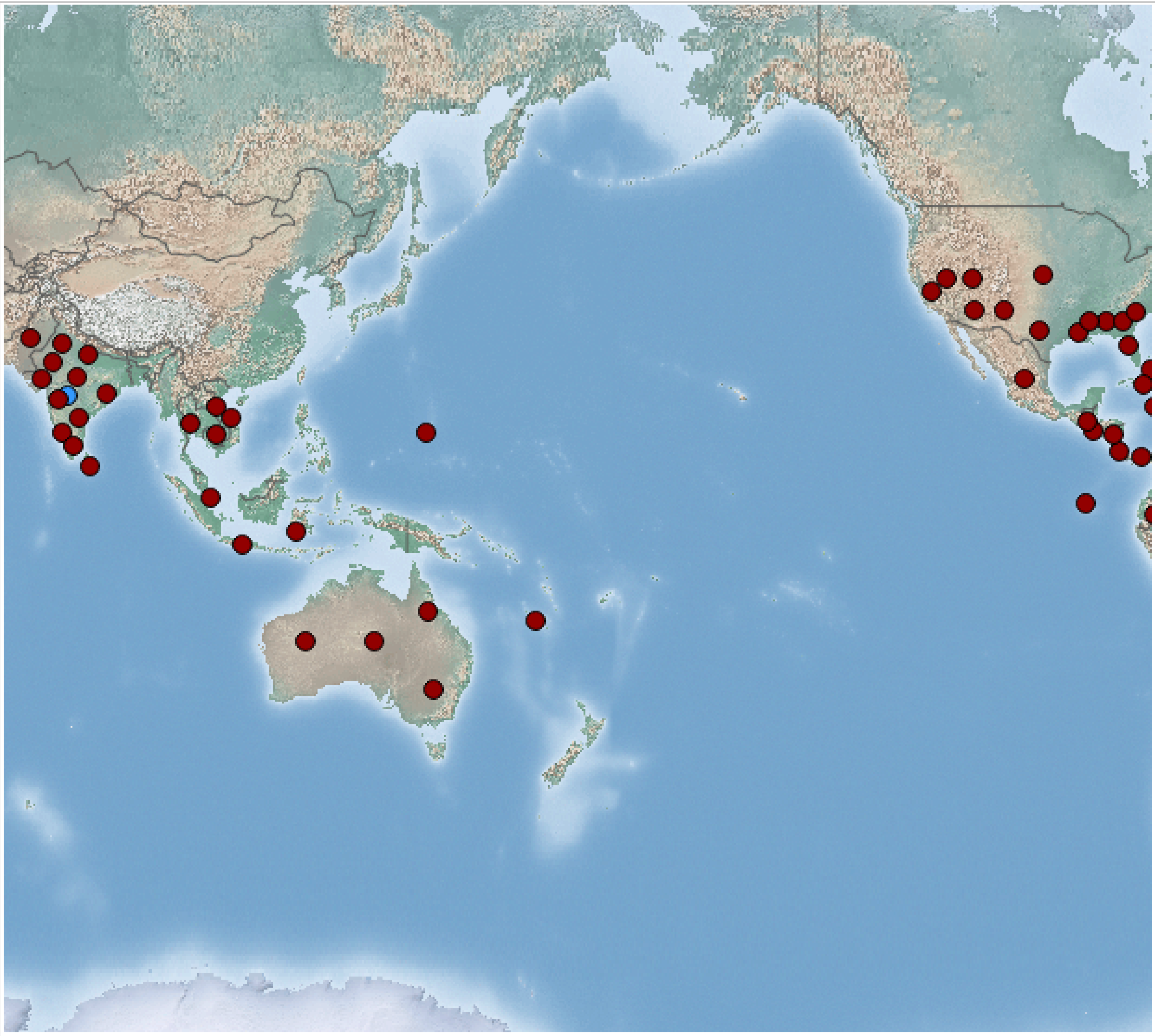
Analyzed by: Density

Present, no further details	Widespread
Present	

Pacific

Analyzed by: Density

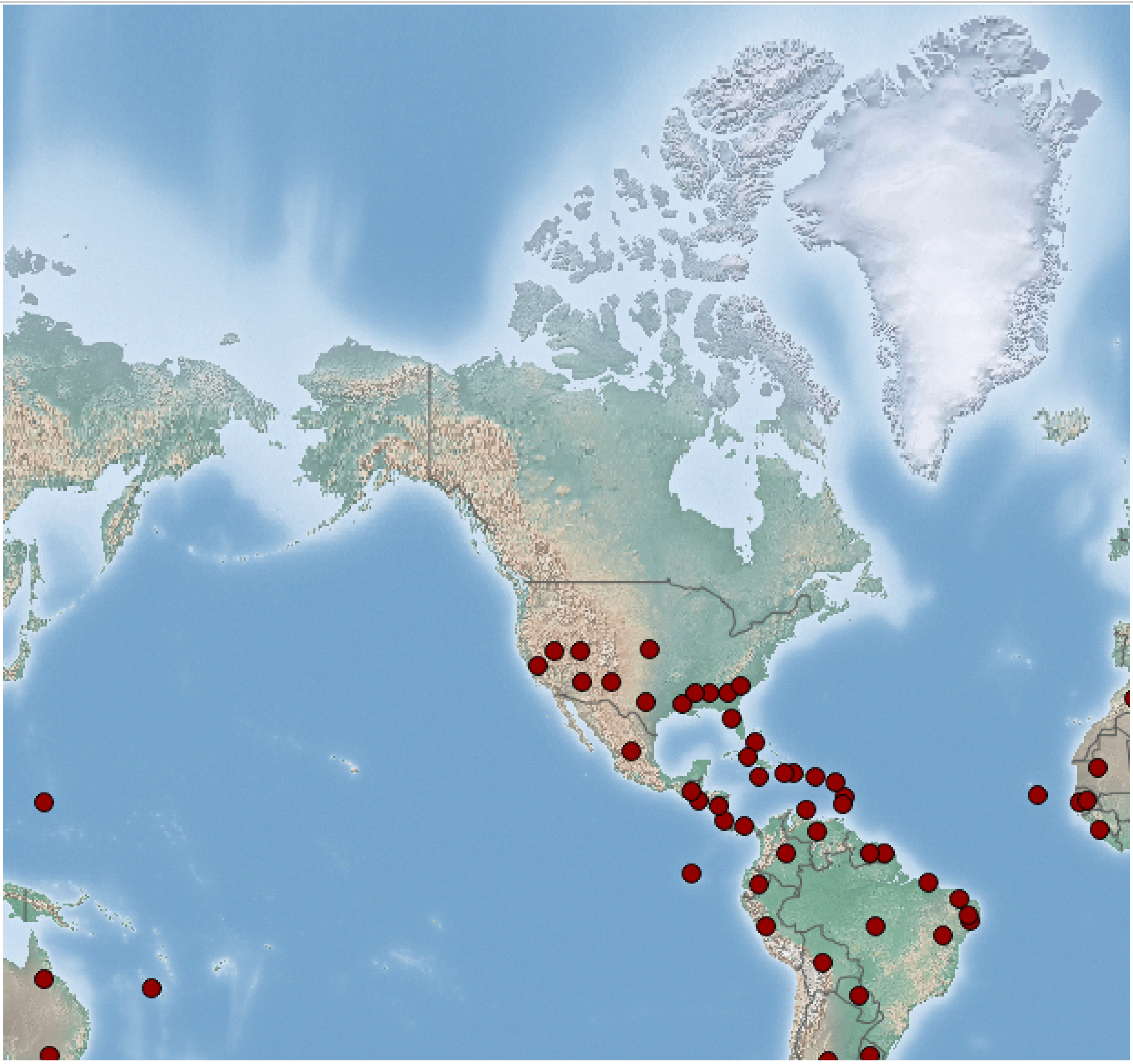
Present, no further details	Widespread
Present	



North America

Analyzed by: Density

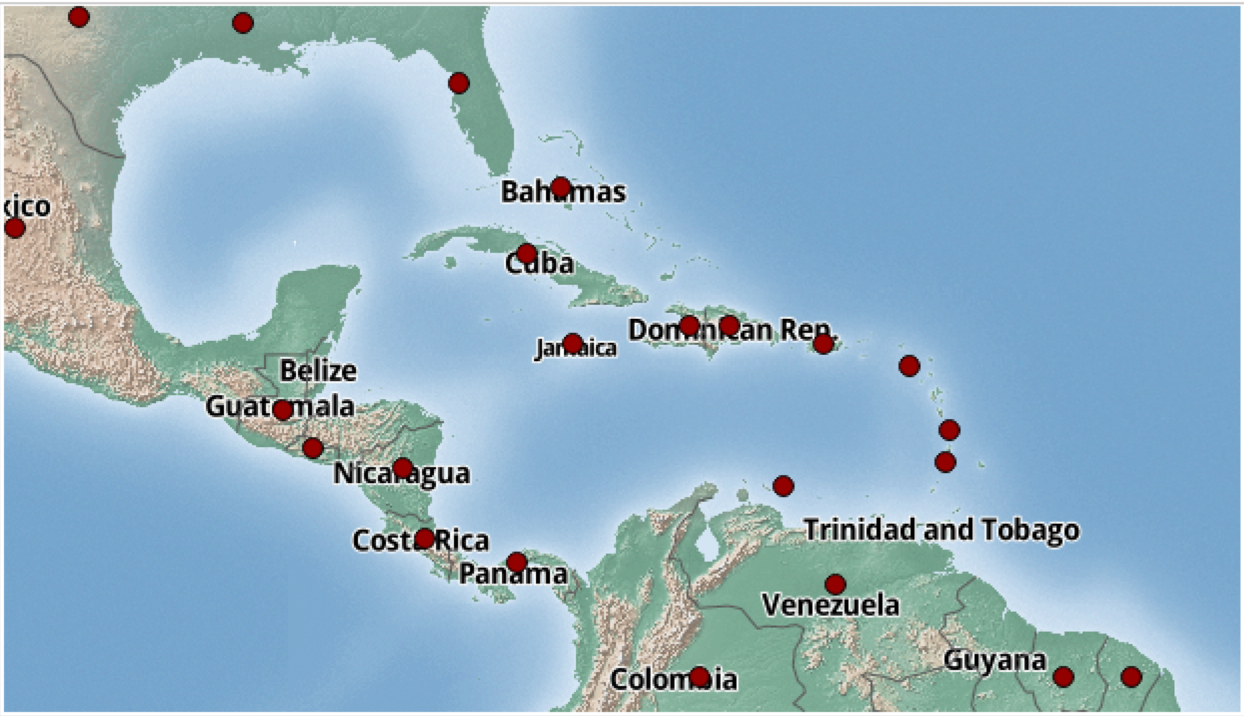
Present, no further details	Widespread
Present	



Central America

Analyzed by: Density

Present	Present, no further details
Widespread	



South America

Analyzed by: Density

Present	Present, no further details
Widespread	

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Pennisetum setaceum (fountain grass)

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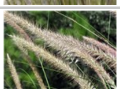
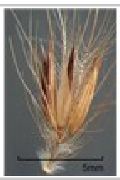
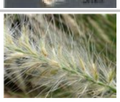
Pictures

Picture	Title	Caption	Copyright
	Infestation	Pennisetum setaceum (fountain grass); infestation. USA.	©John M. Randall/The Nature Conservancy/Bugwood.org - CC BY 3.0
	Infestation	Pennisetum setaceum (fountain grass); infestation. Kahoolawe, Lua Makika, Hawaii, USA. May 2005.	©Forest Starr & Kim Starr - CC BY 4.0
	Infestation	Pennisetum setaceum (fountain grass); infestation, in a wash. USA.	©John M. Randall/The Nature Conservancy/Bugwood.org - CC BY 3.0
	Flowering spikes	Pennisetum setaceum (fountain grass); flowering spikes. Puu Kole, Hawaii, USA. July 2004.	©Forest Starr & Kim Starr - CC BY 4.0
	Inflorescences	Pennisetum setaceum (fountain grass); inflorescences, habit. Green Cay Nature Center, Boynton Beach, Florida, USA. September 2009.	©Forest Starr & Kim Starr - CC BY 4.0
	Spikelet	Pennisetum setaceum (fountain grass); spikelet. Disseminule with some bristles removed to reveal spikelet cluster. Fort Collins, Colorado, USA	©D. Walters and C. Southwick/Table Grape Weed Disseminule ID/USDA APHIS ITP/Bugwood.org - CC BY-NC 3.0 US
	Seedhead	Pennisetum setaceum (fountain grass); close-up of seedhead. Green Cay Nature Center, Boynton Beach, Florida, USA. July 2016.	©Forest Starr & Kim Starr - CC BY 4.0
	Active management	Pennisetum setaceum (fountain grass); active management, by hand pulling. Kahoolawe, Lua Kealialalo, Hawaii, USA. May 2005.	©Forest Starr & Kim Starr - CC BY 4.0

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Identity

Preferred Scientific Name

Pennisetum setaceum (Forsskal) Chiovenda, 1923

Preferred Common Name

fountain grass

Other Scientific Names

Cenchrus setaceus (Forssk.) Marrone
Pennisetum cupreum Hitchc
Pennisetum erythraeum Chiovenda
Pennisetum macrostachyum Fresenius
Pennisetum orientale var. altissimum
Pennisetum parisii Trab
Pennisetum phalariodes Schultes
Pennisetum ruppelii Steud
Pennisetum scoparium Chiovenda
Pennisetum spectabile Figari & De Notaris
Pennisetum spectabile Figari & De Notaris
Pennisetum tiberiadis Boiss

International Common Names

English: african fountain grass; crimson fountain grass; fountain grass; tender fountain grass
Spanish: plumacho; rabo de gato; yerba de fuente

Local Common Names

Germany: afrikanisches Lampenputzergras; einjähriges Lampenputzergras
South Africa: Pronkgras
Sweden: fjäderborstgräs

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Summary of Invasiveness

Pennisetum setaceum, commonly known as fountain grass, is a popular ornamental plant and has been planted widely in areas with warm, arid climates. It has spread by seed into natural areas from cultivated plants. Fountain grass has become invasive in Hawaii and the southern continental United States, Australia, the Canary Islands, and southern Africa. It establishes monocultures in many different habitats, but is particularly problematic in dry grasslands and early successional habitats. It increases fire frequency and the ability of fires to spread within a landscape and threatens rare plant species (Benton, 2009).

Fountain grass is listed as a category one invasive species in South Africa (PlantZAfrica, 2012). It is regulated as a noxious weed in the USA in Hawaii (USDA-NRCS, 2012) and Nevada (Nevada Department of Agriculture, 2012; Weed Center, 2012) and is on the noxious weed watch list in New Mexico (Weed Center, 2012). It is also listed as a noxious weed in New Zealand (HEAR, 2012) and in Australia in New South Wales and Queensland (Weeds Australia Database, 2012).

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Monocotyledonae
          - Order: Cyperales
            - Family: Poaceae
              - Genus: Pennisetum
                - Species: Pennisetum setaceum

Notes on Taxonomy and Nomenclature

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The synonym *Cenchrus setaceus* (Forssk.) Morrone is based on a phylogenetic study of morphological and DNA traits that showed that *Pennisetum* and *Cenchrus* species belong in the same genus (Chemisquy et al. 2010). An earlier name for *Pennisetum setaceum* was *Phalaris setacea* Forssk (ITIS, 2012).

Pennisetum setaceum var. *rubrum* is now considered a new species, *Cenchrus advena* or *Pennisetum advena* (Chemisquy et al., 2010).

In the APG III (Angiosperm Phylogeny Group) system, the Poaceae are in the Commelinids clade, Order Poales.

Description

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This perennial clump-forming grass bears pretty pink to purple seed heads, making it a popular ornamental grass. However, inflorescences can develop from light green (immature) to tan or light buff in colour (mature) with little or no traces of pink. These different inflorescences are seen especially under sunny or dry conditions (C Daehler, University of Hawaii, USA, personal communication, 2013). The slender (0.2-0.4 cm wide), arching leaves grow to 0.6 m. The flowers and seeds grow as dense, cylindrical, bristly panicles 8-35 cm long on stalks that can reach 1.2 m in height. Leaf sheaths are usually smooth but often have edges lined with white hairs (Encycloweedia, 2012). The plant's name, fountain grass, comes from the appearance of the leaves and seed heads forming a spray from the base of the plant.

Plant Type

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Grass / sedge
Herbaceous
Perennial
Seed propagated
Vegetatively propagated

Distribution

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P. setaceum is widely distributed in warm, arid climates. It is widespread on the Hawaiian islands (found on Kauai, Lanai, Oahu, Kahoolawe, East Maui, Hawaii islands). In the continental United States it grows in Oregon, California, Arizona, New Mexico and Colorado as well as in Louisiana, Florida, and Tennessee (Wunderlin and Hansen, 2008; University of Tennessee, 2012; Jepson Flora Project, 2012; GBIF, 2012). The species is widespread in southern and central California and in Arizona. It grows throughout southern California and in the Sacramento Valley, central coast, and San Francisco Bay area (Jepson Flora Project, 2012). In Arizona it occurs in most of the southern counties. It is described as naturalized and escaped from cultivation in Broward, Miami-Dade and Palm Beach counties in Florida. It grows in three counties in Tennessee (University of Tennessee, 2012).

Australia also lists it in several regions. It is most widespread in Queensland, New South Wales and Western Australia, but it also occurs in Victoria, South Australia, and in arid areas of the Northern Territories. New Zealand collections of fountain grass show that it occurs in several important ecological regions in the country (GBIF, 2012).

Fountain grass was introduced to southern Africa from North Africa and is considered invasive in Namibia and South Africa (Joubert and Cunningham, 2002).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Israel (/isc/datasheet/108457)	Present		Native			Valdes and Scholz, 2009	
Jordan (/isc/datasheet/108466)	Present		Native			Valdes and Scholz, 2009	
Lebanon (/isc/datasheet/108482)	Present		Native			Valdes and Scholz, 2009	
Oman (/isc/datasheet/108529)	Present		Native			USDA-ARS, 2012	
Philippines (/isc/datasheet/108535)	Widespread		Introduced			Marler and Moral, 2011	Mt. Pinatubo, Luzon
Qatar (/isc/datasheet/108545)	Present		Native			Norton et al., 2009	Rare, west coast
Saudi Arabia (/isc/datasheet/108552)	Present		Native			GBIF, 2012; USDA-ARS, 2012	Bani Razam; 45 km from Abha
Syria (/isc/datasheet/108572)	Present		Native			Valdes and Scholz, 2009	
Yemen (/isc/datasheet/108609)	Present		Native			USDA-ARS, 2012	
Africa							
Algeria (/isc/datasheet/108415)	Present		Native			GBIF, 2012; USDA-ARS, 2012; EPPO, 2014	El Kantara
Egypt (/isc/datasheet/108418)	Present		Native			USDA-ARS, 2012	
Eritrea (/isc/datasheet/108420)	Present		Native			USDA-ARS, 2012	
Ethiopia (/isc/datasheet/108422)	Present		Native			GBIF, 2012; USDA-ARS, 2012	
Kenya (/isc/datasheet/108470)	Present		Native			USDA-ARS, 2012	
Libya (/isc/datasheet/108492)	Present		Native			USDA-ARS, 2012	
Morocco (/isc/datasheet/108493)	Present		Native			Valdes and Scholz, 2009; EPPO, 2014	
Namibia (/isc/datasheet/108516)	Widespread		Introduced		Invasive	Joubert and Cunningham, 2002	Highland savannah and mountain savannah

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Somalia (/isc/datasheet/108565)	Present		Native			GBIF, 2012; USDA-ARS, 2012	Al Miskat Mountains
South Africa (/isc/datasheet/108613)	Widespread		Introduced		Invasive	USDA-ARS, 2012	
Spain							
-Canary Islands (/isc/datasheet/108702)	Widespread		Introduced			Andreu and Vilà, 2007; Valdes and Scholz, 2009; GBIF, 2012; EPPO, 2014	Tenerife, La Palma, Hierro, Gomero, Gran Canaria, Fuerteventura with Lobos, Lanzarote with Graciosa
Sudan (/isc/datasheet/108555)	Present		Native			USDA-ARS, 2012	
Swaziland (/isc/datasheet/108573)	Present		Introduced			EPPO, 2009	
Tanzania (/isc/datasheet/108591)	Present		Native			GBIF, 2012; USDA-ARS, 2012	Ngorongoro Conservation Area
Tunisia (/isc/datasheet/108584)	Present		Native			Valdes and Scholz, 2009; EPPO, 2014	
Zambia (/isc/datasheet/108614)	Present		Native			USDA-ARS, 2012	
Zimbabwe (/isc/datasheet/108616)	Present		Native			Hill, 1972	
North America							
Bermuda (/isc/datasheet/108377)	Present		Introduced		Not invasive	GBIF, 2012	Hamilton, waste places in town
Mexico (/isc/datasheet/108513)	Present		Introduced			Tellman, 2002; GBIF, 2012	Baja California, Coahuila, Guanajuato, Michoacan, Sonora
USA (/isc/datasheet/108597)	Present						Present based on regional distribution.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Arizona (/isc/datasheet/108798)	Widespread		Introduced		Invasive	Tellman, 2002; Arizona-Sonora Desert Museum, 2012; GBIF, 2012	Widespread Maricopa, Pima counties, along Colorado River in Mohave and LaPaz counties. Present in several other counties. Escaping cultivation in Sonora and Baja
-California (/isc/datasheet/108799)	Widespread		Introduced			Lovich, 2000; GBIF, 2012; Jepson Flora Project, 2012	Sacramento Valley, San Francisco Bay, south to Baja along coast, San Joaquin Valley
-Colorado (/isc/datasheet/108800)	Present		Introduced		Invasive	GBIF, 2012; USDA-NRCS, 2012	
-Florida (/isc/datasheet/108804)	Present		Introduced			Wunderlin and Hansen, 2008	Southeastern counties
-Hawaii (/isc/datasheet/108806)	Widespread		Introduced			Wagner et al., 2005; GBIF, 2012	Honolulu, Hawaii. Presumed eradicated from Maui and Kauai
-Louisiana (/isc/datasheet/108813)	Present		Introduced			USDA-NRCS, 2012	
-New Mexico (/isc/datasheet/108827)	Present		Introduced			GBIF, 2012	Rio Grande Bosque, Sandoval
-Oregon (/isc/datasheet/108832)	Present		Introduced			PIER, 2012	
-Tennessee (/isc/datasheet/108837)	Present		Introduced			University of Tennessee Herbarium, 2012	
Central America and Caribbean							
Guadeloupe (/isc/datasheet/108441)	Widespread		Introduced		Invasive	EPPO, 2009	
Puerto Rico (/isc/datasheet/108541)	Present		Introduced			Mas and Garcia-Molinari, 2006	
South America							

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Venezuela (/isc/datasheet/108601)	Present		Introduced		Not invasive	GBIF, 2012	Not certain if planted or naturalized in Maracay, Caracas and Muaco
Europe							
France (/isc/datasheet/108429)	Present					EPPO, 2014	
Italy (/isc/datasheet/108464)	Present		Native			Valdes and Scholz, 2009; EPPO, 2014	Native to Sicily, introduced Sardinia
-Sardinia (/isc/datasheet/108758)	Present					EPPO, 2014	
Malta (/isc/datasheet/108509)	Present					EPPO, 2014	
Portugal (/isc/datasheet/108542)	Present		Introduced		Not invasive	Valdes and Scholz, 2009	
Spain (/isc/datasheet/108421)	Present		Introduced			Dana et al., 2005; Antonio and Arnelas, 2006; EPPO, 2009; GBIF, 2012; EPPO, 2014	Andalucia, Granada, Almeria, Malaga, Marbella, Murcia, Valencia, Tenerife
-Balearic Islands (/isc/datasheet/108701)	Present					EPPO, 2014	
Oceania							
Australia (/isc/datasheet/108362)	Present						Present based on regional distribution.
-Australian Northern Territory (/isc/datasheet/108619)	Present		Introduced			Groves et al., 2005	Arid areas
-New South Wales (/isc/datasheet/108620)	Widespread		Introduced		Invasive	Csurhes and Edwards, 1998; Florabase, 2012; GBIF, 2012	
-Queensland (/isc/datasheet/108621)	Present		Introduced			Florabase, 2012; GBIF, 2012	Brisbane, Townsville, Port Curtis
-South Australia (/isc/datasheet/108622)	Present		Introduced			GBIF, 2012; USDA-ARS, 2012	Eyre Peninsula
-Victoria (/isc/datasheet/108624)	Present		Introduced			GBIF, 2012; USDA-ARS, 2012	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Western Australia (/isc/datasheet/108625)	Present		Introduced			Florabase, 2012; GBIF, 2012	Geraldton, Kimberleys, Red Hill, Wittecara Creek Reserve, John Forest National Park, Kwinana, Gosnells
Fiji (/isc/datasheet/108425)	Present		Introduced			USDA-ARS, 2012	
French Polynesia (/isc/datasheet/108533)	Present		Introduced		Not invasive	PIER, 2012	Cultivated on Hiva Oa, Raiatea, Tahiti, Rurutu
Guam (/isc/datasheet/108446)	Present		Introduced			PIER, 2012	
Micronesia, Federated states of (/isc/datasheet/108427)	Present		Introduced			USDA-ARS, 2012	
New Caledonia (/isc/datasheet/108517)	Widespread		Introduced		Invasive	PIER, 2012	
New Zealand (/isc/datasheet/108528)	Present		Introduced			Edgar and Connor, 2000; GBIF, 2012	Christchurch, Wanganui, Hamilton, North Island, Auckland, Western Northland Ecological Region, Waikato Ecological Region, Bay of Islands
Palau (/isc/datasheet/108543)	Present		Introduced		Not invasive	PIER, 2012	Cultivated

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History of Introduction and Spread

Fountain grass comes from North Africa and it began to be sold as an ornamental plant in the late 1800s. Seeds were available in the United States as early as 1883. Plants were introduced to Hawaii in the early twentieth century as ornamental plants with the earliest collection made in 1914 (Tunison, 1992; Halvorson and Guertin, 2003). The earliest herbarium collection made in California dates to 1932 (Consortium of California Herbaria Project, 2012). It was grown in Tucson, Arizona, as an ornamental plant as early as 1940. The New Zealand Plant Conservation Network (2012) lists it as having been introduced to New Zealand in 1982. The earliest herbarium specimens from Australia were collected in Brisbane in 1930 with specimens from New South Wales and Western Australia collected before 1940 (GBIF, 2012).

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Introductions

Introduced to	Introduced from	Year	Reason	Introduced by	Established in wild through		References	Notes
					Natural reproduction	Continuous restocking		
Australia	Africa	Pre 1930	Horticulture (pathway cause) (/isc/datasheet/109038)		Yes		Randall (2001); Randall (2002)	
Namibia	Africa	Pre 1985	Horticulture (pathway cause) (/isc/datasheet/109038)		Yes		Joubert and Cunningham (2002)	
New Zealand	Africa	1982	Horticulture (pathway cause) (/isc/datasheet/109038)		Yes		New Zealand Plant Conservation Network (2012); New Zealand Plant Conservation Network (NZPCN) (2012)	
USA	Africa	1880s-1900s	Horticulture (pathway cause) (/isc/datasheet/109038)		Yes		Tunison (1992)	

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Risk of Introduction

The main pathway for introduction of *P. setaceum* is through the horticultural trade. Plants and seeds are available at nurseries and by mail order. Seeds are easily dispersed by wind, water, animals and vehicles. Spread is often along roads and rivers (Rahlao et al., 2010a). It is most widespread in Hawaii and arid parts of Australia.

Fountain grass is listed as a category one invasive species in South Africa (PlantZAfrica, 2012) and is regulated as a noxious weed in the USA (Weed Center, 2012). It is also listed as a noxious weed in New Zealand (HEAR, 2012; EPPO, 2012) and in Australia in New South Wales and Queensland (Weeds Australia Database, 2012).

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Habitat

P. setaceum generally favours arid to semi-arid environments but occurs in mesic sites as well. It is outcompeted by other plants in wetter sites (EPPO, 2012). It often grows in disturbed areas such as along roadsides and railroad embankments and in mined areas (FloraBase, 2012). In natural areas in the southwestern USA and northern Mexico it has been found growing in grasslands, desert, desert shrublands, canyons, and rocky hillsides, coastal dunes, coastal sage scrub, and canyons. In Hawaii it grows on lava flows and rangeland at a wide range of elevations from sea level to 2900 m. In South Africa it is found in coastal vegetation, woodlands and grasslands (Rahlao et al. 2009; FloraBase, 2012).

Habitat List

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Category	Habitat	Presence	Status
Littoral	Coastal areas	Principal habitat	Harmful (pest or invasive)
	Coastal dunes	Principal habitat	Harmful (pest or invasive)
Terrestrial-managed	Disturbed areas	Principal habitat	Harmful (pest or invasive)
	Managed grasslands (grazing systems)	Principal habitat	Harmful (pest or invasive)
	Rail / roadsides	Principal habitat	Natural
	Urban / peri-urban areas	Principal habitat	Natural
	Urban / peri-urban areas	Principal habitat	Productive/non-natural
Terrestrial-natural/semi-natural	Arid regions	Principal habitat	Harmful (pest or invasive)
	Deserts	Principal habitat	Harmful (pest or invasive)
	Natural forests	Secondary/tolerated habitat	Harmful (pest or invasive)
	Natural grasslands	Principal habitat	Harmful (pest or invasive)
	Riverbanks	Principal habitat	Natural
	Rocky areas / lava flows	Principal habitat	Harmful (pest or invasive)
	Scrub / shrublands	Principal habitat	Harmful (pest or invasive)

Biology and Ecology

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Genetics

Poulin et al. (2005) found that there is no genetic variation among populations in the USA, as would be expected if the plants were completely apomictic (they form seeds asexually). *P. setaceum* is a triploid whereas *P. advena* is a hexaploid that may be pollen-sterile (Halvorson and Guertin 2003). Plants have high phenotypic plasticity allowing them to establish in a wide range of habitats (Le Roux et al., 2007).

Reproductive Biology

Plants begin to produce seeds within one year of seed germination (EPPO, 2012). *P. setaceum* mainly reproduces by self-pollination but occasionally produces seeds through cross-pollination; Halvorson and Guertin (2003) cite two studies that found some sexual reproduction in *P. setaceum*, however most seeds are produced through apomixis. Wind and gravity move pollen within the plant and between plants (Halvorson and Guertin 2003). Seed production is sometimes reported as very low (1.7-5.7% per plant or an average of 62 viable seeds per plant) (Goergen and Daehler, 2001), but others report that 80% of seeds produced are viable (Nonner, 2005; WeedBusters, 2012) and Poulin et al. (2007) counted an average of 100 seeds per plant in a greenhouse study. Milton et al. (2008) reported a case of pseudo-vivipary from flooded plants in South Africa where seeds produced young plants before dispersing. Seeds can remain viable for six years in soil (Halvorson and Guertin, 2003). They do not need light to germinate and can germinate when covered lightly with soil (Nonner, 2005).

Physiology and Phenology

P. setaceum is a C4 perennial bunchgrass that can live up to 20 years (Encycloweedia, 2012). Plants begin to produce seeds within one year (EPPO, 2012). Seeds germinate late spring to early summer. Seedlings require some moisture to establish (Rahlao et al., 2010b). Plants can flower over a long time period from spring to late fall before they go dormant in winter in temperate environments.

P. setaceum allocates much of its biomass to roots and shoots allowing it to be a good colonizer. It has high photosynthetic rates that also enable it to compete effectively. It also shows phenotypic plasticity in growth allocation and photosynthetic rates potentially allowing it to colonize a wider range of habitats (Williams et al., 1995; Le Roux et al., 2007; Poulin et al., 2007).

Associations

In Hawaii, more than 75% of the roots of *P. setaceum* were associated with vesicular-arbuscular mycorrhizae (Koske et al., 1992). Mycorrhizae help plants obtain nutrients.

Environmental Requirements

P. setaceum prefers regions with mild winters and summers with some moisture. Fountain grass prefers open sunny areas with well-drained soils, but will grow in soil types from clay to sand and can persist in light shade. It grows best in regions with median rainfall of less than 127 mm/year (EPPO, 2012) but can be found in areas with more than 600 mm rainfall/year (Joubert and Cunningham, 2002). This species cannot tolerate freezing temperatures.

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Climate

Climate	Status	Description	Remark
As - Tropical savanna climate with dry summer	Preferred	< 60mm precipitation driest month (in summer) and < (100 - [total annual precipitation{mm}/25])	
BW - Desert climate	Preferred	< 430mm annual precipitation	
Cs - Warm temperate climate with dry summer	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, dry summers	
Ds - Continental climate with dry summer	Preferred	Continental climate with dry summer (Warm average temp. > 10°C, coldest month < 0°C, dry summers)	

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Latitude/Altitude Ranges

Latitude North (°N)	Latitude South (°S)	Altitude Lower (m)	Altitude Upper (m)
44	-43		

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Soil Tolerances

Soil drainage

free

Soil reaction

neutral

Soil texture

heavy
light
medium

Special soil tolerances

infertile
shallow

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Notes on Natural Enemies

Natural enemies have not been studied for this species because several related species are economically important (Markin et al., 1992). Few insect or fungi species were found to attack fountain grass in Hawaii (Goergen and Daehler, 2001).

Means of Movement and Dispersal

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Natural Dispersal (Non-Biotic)

Seeds are dispersed by wind and water (Rahlao et al., 2010a). In Australia, seeds were found to have dispersed a quarter of a mile along a stream (Department of Primary Industries, Victoria 2012).

Vector Transmission (Biotic)

Seeds also attach to animal fur. Livestock are thought to be a vector for the movement of seeds (Halvorson and Guertin 2003).

Accidental Introduction

Wind created by the movement of vehicles disperses seeds along roadways. Seeds are also carried on vehicles. Introduction to the Canary Islands is thought to have occurred when machinery from the western Sahara was brought in to construct a new airport, but could also have come from plantings at the airport (Gobierno de Canarias, 1999).

Intentional Introduction

This ornamental plant is widely sold in the nursery industry. The popular variety 'Rubrum' which is now listed sometimes as a separate species, *Pennisetum advena*, has been used by landscape architects and home owners but tends to take on a brownish tinge that many landscapers find unattractive. *P. setaceum* is also available in the seed trade from at least two companies online and on E-Bay (B&T World Seeds in France and Hazzard's Seed Store, 2012). It is planted as an annual in colder regions.

Pathway Causes

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Cause	Notes	Long Distance	Local	References
Animal production (/isc/datasheet/108068)	Accidental dispersal on animal fur	Yes	Yes	Halvorson and Guertin, 2003
Breeding and propagation (/isc/datasheet/109026)	Ornamental plant sales	Yes	Yes	
Disturbance (/isc/datasheet/109028)	Roadsides, railways, mining		Yes	Florabase, 2012
Escape from confinement or garden escape (/isc/datasheet/109030)	Seed dispersal from ornamental plantings		Yes	Florabase, 2012
Flooding and other natural disasters (/isc/datasheet/109032)	Seed dispersal		Yes	Rahlao et al., 2009
Garden waste disposal (/isc/datasheet/109035)	Disposal of seed heads from previous year		Yes	Florabase, 2012
Habitat restoration and improvement (/isc/datasheet/109029)	Plants used for soil stabilization		Yes	Florabase, 2012
Hitchhiker (/isc/datasheet/109037)	Seeds stick to clothing, fur	Yes	Yes	Halvorson and Guertin, 2003
Horticulture (/isc/datasheet/109038)	Ornamental plants	Yes	Yes	Florabase, 2012
Interconnected waterways (/isc/datasheet/109043)	Seed dispersal	Yes		Florabase, 2012
Internet sales (/isc/datasheet/109044)	Seeds and plants available for purchase online	Yes		
Landscape improvement (/isc/datasheet/109045)	New plantings and seeds carried on equipment	Yes	Yes	Joubert and Cunningham, 2002
Nursery trade (/isc/datasheet/109049)	Ornamental plants	Yes	Yes	Florabase, 2012
Ornamental purposes (/isc/datasheet/109051)	Planted as ornamental	Yes	Yes	Florabase, 2012
Seed trade (/isc/datasheet/109056)	Listed by at least two online seed sellers and on E-Bay	Yes		Hazzard's Greenhouse, 2012; World Seeds, 2012

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Livestock (/isc/datasheet/109078)	Seeds		Yes	Halvorson and Guertin, 2003
Machinery and equipment (/isc/datasheet/109075)	One possible incidence recorded of movement of seeds	Yes		Joubert and Cunningham, 2002
Mail (/isc/datasheet/109076)	Seeds can be ordered by mail	Yes		Hazzard's Greenhouse, 2012; World Seeds, 2012
Water (/isc/datasheet/109085)	Seeds		Yes	Rahlao et al., 2010a
Wind (/isc/datasheet/109086)	Seeds	Yes		Rahlao et al., 2010a

Impact Summary

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Category	Impact
Economic/livelihood	Positive
Environment (generally)	Negative

Economic Impact

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Unpalatable to cattle except for young shoots (Motooka et al., 2003). It is eaten by goats and camels (Department of Primary Industries, Victoria 2012).

Environmental Impact

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The dry biomass produced by the plant increases fire frequency and spread by increasing fuel loads. It reduces moisture availability to surrounding plants and can alter nutrient-cycling (FloraBase, 2012).

Impact on Habitats

As an aggressive colonizer on lava flows this plant disrupts primary succession (Tunison 1992). It is fire-adapted and increases the intensity and spread of fires damaging dry land forest and scrub habitat. It limits shallow water resources to trees in a dryland forest in Hawaii (Cordell and Sandquist, 2008). Litton et al. (2008) studied carbon fluxes in a dry forest in Hawaii and found that *P. setaceum* increased the flux of carbon in and out of soils but did not change the total pool of carbon. It outcompetes the native grass *Heteropogon contortus* in Hawaii (Daehler and Carino, 1998).

Impact on Biodiversity

Thick stands reduce native species diversity (FloraBase, 2012). Fountain grass competes with rare native plants in Hawaii and the federally endangered *Haplostachys haplostachya* endemic to Hawaii. It also affects the endangered species *Argyranthemum lidii* on the island of Gran Canaria, the Canary Islands, Spain (IUCN, 2012).

In Hawaii, native species were especially negatively impacted in habitats with low resources (Questad et al. 2012). The increase in fire frequency in areas invaded by fountain grass can affect ground nesting birds and other animals (EPPO, 2012).

Threatened Species

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Threatened Species	Conservation Status	Where Threatened	Mechanism	References	Notes
Argyranthemum lidii (/isc/datasheet/119200)	EN (IUCN red list: Endangered) EN (IUCN red list: Endangered)	Canary Islands (/isc/datasheet/108702); Spain (mainland) (/isc/datasheet/108703)	Competition - monopolizing resources	IUCN, 2012	
Eragrostis deflexa (/isc/datasheet/119199)	National list(s) National list(s)	Hawaii (/isc/datasheet/108806)	Competition - monopolizing resources	Shaw, 1997	
Festuca hawaiiensis (Hawai'i fescue) (/isc/datasheet/119197)	USA ESA listing as endangered species USA ESA listing as endangered species	Hawaii (/isc/datasheet/108806)	Competition - monopolizing resources	Shaw, 1997	
Haplostachys haplostachya (/isc/datasheet/119201)	National list(s) National list(s)	Hawaii (/isc/datasheet/108806)	Competition - monopolizing resources	Shaw, 1997	

Risk and Impact Factors

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Invasiveness

- Proved invasive outside its native range
- Has a broad native range
- Pioneering in disturbed areas
- Long lived
- Reproduces asexually

Likelihood of entry/control

- Highly likely to be transported internationally deliberately
- Difficult to identify/detect as a commodity contaminant

Uses List

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Environmental

- Amenity
- Erosion control or dune stabilization
- Land reclamation
- Landscape improvement
- Soil conservation

General

- Botanical garden/zoo

Ornamental

- Propagation material
- Seed trade

Similarities to Other Species/Conditions

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Cenchrus advena, (Wipff and Veldkamp) Morrone, synonymous with *Pennisetum advena* and *Pennisetum setaceum* var. *rubrum*, is most similar in appearance and most closely related. This is a new name given to the variety with 54 chromosomes and red coloration in the leaves and inflorescenses (Wippf and Veldkamp, 1999). The origin of this species is unknown. *P. advena* rarely produces viable seeds. Its morphology is slightly different to *P.setaceum* as it has wider leaf blades without a thickened mid-vein, it usually has secondary branching at aerial culm nodes, and the inflorescence has 10-17 fascicles/cm mid-inflorescence, the inner bristle of the fascicle has 4-10 ciliate or plumose bristles, and the lower floret is staminate (Q-Bank, 2012). Whereas, *P. setaceum* has 8-10 fascicles/cm, the inner bristle of the fascicle has 8-16 ciliate bristles, and the lower floret is usually sterile, although sometimes staminate (Q-Bank, 2012).

P. setaceum is also similar in appearance to *Muhlenbergia emersleyi*, native to the Sonoran desert region in the United States. *M. emersleyi* grows to approximately 1m and has flattened, nodding seed heads as opposed to cylindrical seed heads. *Cenchrus ciliaris*, buffelgrass, is a smaller grass with branched stems and shorter cylindrical seed heads (Arizona -Sonora Desert Museum, 2012). *Pennisetum villosum* is also similar in appearance but has shorter, white seed heads and rhizomatous growth (Jepson Flora Project, 2012).

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Prevention and Control

Prevention

The European and Mediterranean Plant Protection Organization evaluated *P. setaceum* and listed it as a priority for action (Brunel et al., 2010). Fountain grass is also on a watch list for New Mexico and listed as a noxious weed in Nevada where it occurs infrequently still (Weed Center, 2012).

In Hawaii at the Pohakuloa Training Area, researchers studying control techniques for *P. setaceum* invited school groups, hosted teacher workshops, and led public tours on Earth Day to increase public awareness about fountain grass (Evans et al., 2005).

Containment/Zoning

Road and river interchanges, also associated with disturbances away from roads (Rahlao et al. 2010a). Questad et al. (2012) found that native species diversity declined more in lower resource habitats and recommend focusing on these habitats in addition to high diversity habitats.

Control

Physical/Mechanical Control

Seedlings are easily pulled out by hand and larger plants can be dug out using a pick or shovel. It is important to bag or otherwise destroy the seed heads to prevent further seed dispersal (Halvorson and Guertin, 2003). Skin irritation can occur from the leaves and seed heads so gloves should be worn (Queensland Government, 2012).

Biological Control

No biological control agents are currently being investigated.

Chemical Control

Herbicides containing fluazifop, quizalofop, sethoxydim, fenoxaprop, hexazinone, and glyphosate have been used to control fountain grass (FloraBase, 2012; Halvorson and Guertin, 2003). Some herbicides should not be used near waterways or trees.

Ecosystem Restoration

A study in Hawaii tested several techniques for re-establishing native vegetation (Cabin et al. 2002). Both reducing the abundance of *P. setaceum* and planting native species helped speed ecosystem restoration. Decreasing nitrogen levels may also favor native grasses (Carino and Daehler, 2002).

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Links to Websites

Website	URL	Comment
Australian weed risk assessment for Pennisetum setaceum	http://invasivespecies.org.au/traction/permalink/wra6747 (http://invasivespecies.org.au/traction/permalink/wra6747)	
Invasive species of south Africa	http://invasives.org.za/index.php?option=com_content&view=article&id=437&Itemid=106 (http://invasives.org.za/index.php?option=com_content&view=article&id=437&Itemid=106)	
Queensland Fact Sheet for Pennisetum setaceum	http://www.daff.qld.gov.au/documents/Biosecurity_EnvironmentalPests/IPA-African-Fountain-Grass-PP146.pdf (http://www.daff.qld.gov.au/documents/Biosecurity_EnvironmentalPests/IPA-African-Fountain-Grass-PP146.pdf)	
Sonoran Desert Museum, Invaders of the Sonoran Desert Region	http://www.desertmuseum.org/invaders/invaders_fountaingrass.php (http://www.desertmuseum.org/invaders/invaders_fountaingrass.php)	
Weed Busters New Zealand	http://weedbusters.co.nz/weed_info/detail.asp?WeedID=124 (http://weedbusters.co.nz/weed_info/detail.asp?WeedID=124)	

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Contributors

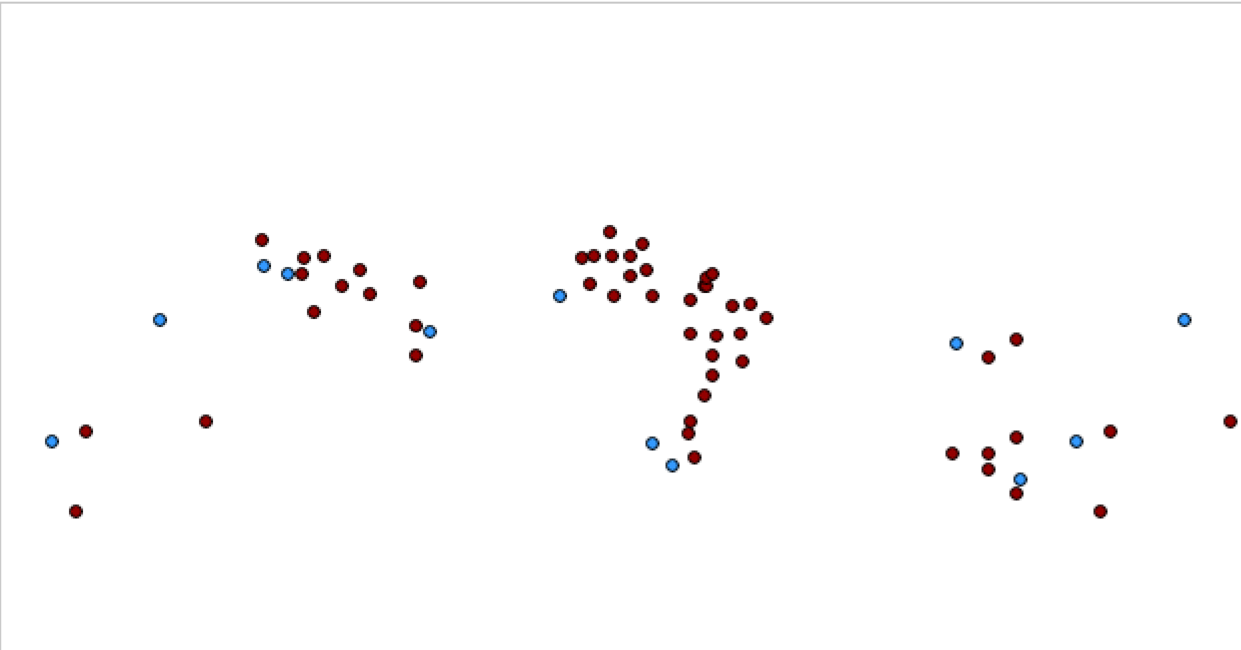
20/08/12 Original text by:

Sylvan Kaufman, Denton, Maryland, USA

World Map

Analyzed by: Density

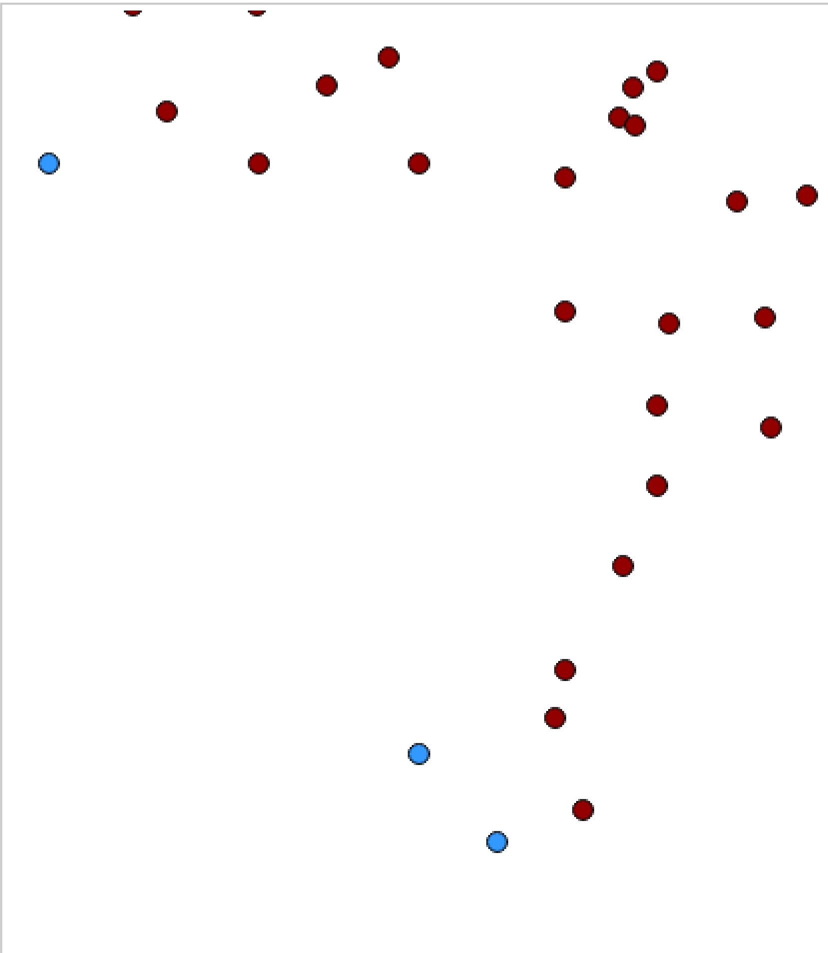
Present, no further details	Widespread



Africa

Analyzed by: Density

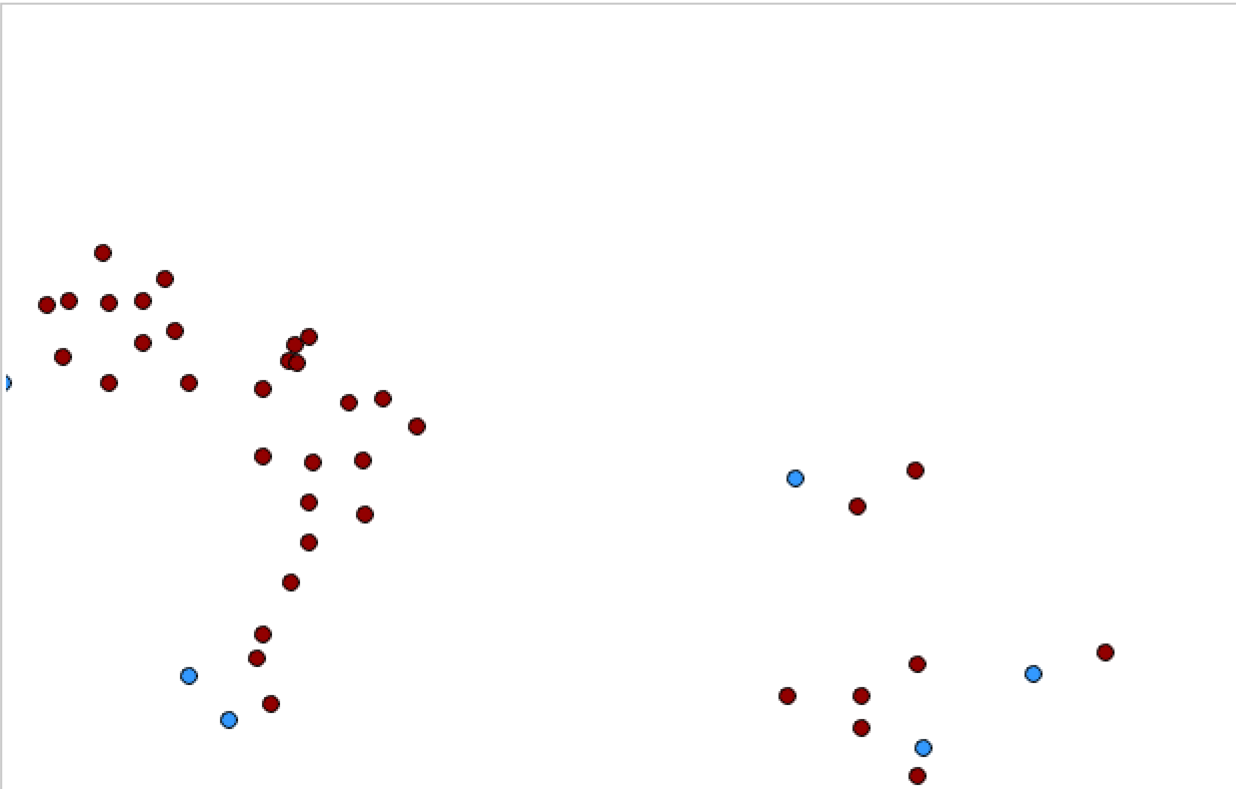
Present, no further details	Widespread



Asia

Analyzed by: Density

Present, no further details	Widespread



Europe

Pacific

North America

Central America

South America

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Tamarix chinensis (five-stamen tamarisk)

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Pictures

Picture	Title	Caption	Copyright
	Tree habit	Tamarix chinensis, ornamental tree.	Liu Mingting
	Flowers		Liu Mingting

Identity

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Preferred Scientific Name

Tamarix chinensis Lour. (1790)

Preferred Common Name

five-stamen tamarisk

Other Scientific Names

Tamarix amurensis Hort. ex Chow (1934)
Tamarix caspica Hort. ex Dippel (1893) nom. nud.
Tamarix elegans Spach (1836)
Tamarix gallica var. chinensis (Lour.) Ehrenb. (1827)
Tamarix gallica var. narbonensis Ehrenb.
Tamarix gallica var. subtilis Ehrenb.
Tamarix japonica Hort. ex Dippel
Tamarix juniperina Bge. (1833)
Tamarix libanotica Hort. ex Koch (1869)
Tamarix plumose Hort. ex Carr (1868) nom. nud.
Tamarix plumose Hort. ex Lavalle (1877)

International Common Names

English: Chinese tamarisk; salt cedar; saltcedar; tamarisk
Spanish: pinebete
French: tamaris à cinq étamine

Local Common Names

China: chengliu; hongjingtiao; sanchunliu; zhongguo chengliu
Germany: Chinesische Tamariske; Fuenfmaennige Tamariske; Sommertamariske
Israel: ashel
Italy: tamerice a cinque stami
Japan: gyoryu

EPPO code

TAACH (Tamarix chinensis)
TAAJU (Tamarix juniperina)

Summary of Invasiveness

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This species is fast growing and adapted to extreme environments, with high seed dispersal and vegetative reproduction capacity. Through depletion of soil water and nutrients, general vigour and the salinification of soil it outcompetes native flora, depletes resources for native fauna and has severe environmental consequences in the regions where it is invasive.

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Tamaricales
            - Family: Tamaricaceae
              - Genus: Tamarix
                - Species: Tamarix chinensis

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Notes on Taxonomy and Nomenclature

The weedy species of Tamarix in North America, small trees or shrubs, include a complex of four very similar species: T. ramosissima, T. chinensis, T. canariensis and, occasionally, T. gallica, plus the distinct T. parviflora, and their hybrids. These species are all deciduous. The distinctive, large evergreen tree, athel (T. aphylla) is also becoming weedy at a few locations (Barnes et al., 2004). Four other species have been introduced that are known only as ornamentals or that have become weakly naturalized (Baum, 1967; Crins, 1989). Recent DNA analyses throw some doubts on the value of the morphological differences by which some species are separated, but the current assumption is that the main invasive entity in North America is a hybrid of T. ramosissima with T. chinensis, while other entities include a hybrid between T. canariensis and T. gallica and the distinct species T. parviflora and T. aphylla (Gaskin and Schall, 2002, 2003). These authors also comment that although the two Asian species, T. ramosissima and T. chinensis overlap in China, hybrids have not been recorded from that region.

Ladyman (2003) refers to recent work suggesting that T. ramosissima and T. chinensis should be considered the same, while Zouhar (2003) refers to the possible hybridization of these species in the USA.

Further details of Tamarix taxonomy can be found in the datasheet on T. ramosissima.

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Description

See the datasheet on T. ramosissima for a description of the genus.

T. chinensis is a small tree or shrub, growing up to 8 m high and 30 cm d.b.h., with slender branchlets and grey-green foliage. It usually grows as a multi-stemmed shrub with red-brown to dark or blackish bark. The leaves look like scales, are 1.5-3.5 mm long and are deciduous. The flowers are tiny with five sepals, petals, stamens and a five-carpellate pistil, on a 2- to 7-cm long flower stalk. The petals are pink, white or red and 1-2.3 mm long. T. chinensis is similar to juniper or cedar in appearance. For further details, see Ladyman (2003).

Plant Type

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Broadleaved
Perennial
Seed propagated
Shrub
Tree
Vegetatively propagated
Woody

Distribution

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T. chinensis originates in northern China (Liaoning, Hebei and Shangdong Provinces) and the lower reaches of the Yangtse River valley (northern Jiangsu and Anhui Provinces). Ladyman (2003) notes that it forms dense stands in its native China, but does not specify whether it is considered an invasive there. Helmsley (1888) observed in the 19th century that T. chinensis in China was extensively cultivated and was rarely found in the wild. Gaskin and Schaal (2002) believe this helps explain the relative genetic uniformity within T. chinensis.

Gaskin and Schaal (2002) comment that, although Baum (1978) and others suggest the wide occurrence of both T.chinensis and T. ramosissima across China, their genetic analyses indicated the T. ramosissima genotype exclusively west of central China and the T. chinensis genotype exclusively east of central China.

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Asia								
Afghanistan (/isc/datasheet/108351)	Present		Native			Natural		
China (/isc/datasheet/108398)	Present		Native			Natural	,	
-Anhui (/isc/datasheet/108667)	Present		Native			Natural		
-Fujian (/isc/datasheet/108670)	Present		Introduced			Planted		
-Gansu (/isc/datasheet/108672)	Present		Introduced			Planted		
-Guangdong (/isc/datasheet/108671)	Present		Introduced			Planted		
-Guangxi (/isc/datasheet/108673)	Present		Introduced			Planted		
-Guizhou (/isc/datasheet/108674)	Present		Introduced			Planted		
-Hebei (/isc/datasheet/108677)	Present		Native			Natural		
-Henan (/isc/datasheet/108680)	Present		Native			Natural		
-Hubei (/isc/datasheet/108676)	Widespread		Native		Not invasive	Planted	Baum, 1978	
-Hunan (/isc/datasheet/108681)	Present		Introduced			Planted		
-Jiangsu (/isc/datasheet/108683)	Present		Native			Natural		
-Liaoning (/isc/datasheet/108685)	Present		Native			Natural		
-Nei Menggu (/isc/datasheet/108687)	Present		Introduced			Planted		
-Ningxia (/isc/datasheet/108688)	Present		Native			Natural		
-Shaanxi (/isc/datasheet/108694)	Present		Introduced			Planted		
-Shandong (/isc/datasheet/108692)	Present		Native			Natural		
-Shanxi (/isc/datasheet/108693)	Present		Native			Planted, Natural		
-Sichuan (/isc/datasheet/108691)	Present		Introduced			Planted		
-Xinjiang (/isc/datasheet/108696)	Present		Introduced			Planted		
-Yunnan (/isc/datasheet/108698)	Present		Introduced			Planted		

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
-Zhejiang (/isc/datasheet/108699)	Present		Introduced			Planted		
Iran (/isc/datasheet/108462)	Present		Native			Natural		
Iraq (/isc/datasheet/108461)	Present		Native			Natural		
Israel (/isc/datasheet/108457)	Present		Introduced			Planted		
Japan (/isc/datasheet/108467)	Present		Native			Natural		
Jordan (/isc/datasheet/108466)	Present		Introduced			Planted		
Korea, DPR (/isc/datasheet/108476)	Present		Native			Natural		
Korea, Republic of (/isc/datasheet/108477)	Present		Native			Natural		
Mongolia (/isc/datasheet/108504)	Present		Native			Natural	USDA-ARS, 2005	
Pakistan (/isc/datasheet/108537)	Present		Native			Planted, Natural		
Turkey (/isc/datasheet/108587)	Present		Native			Natural		
Turkmenistan (/isc/datasheet/108583)	Present		Native			Natural		
Africa								
South Africa (/isc/datasheet/108613)	Present		Introduced		Invasive		Henderson, 2001	
North America								
Mexico (/isc/datasheet/108513)	Present		Introduced		Invasive	Planted	Westbrooks, 1998	
USA (/isc/datasheet/108597)	Present		Introduced	early 1800s	Invasive		Westbrooks, 1998	
-Arizona (/isc/datasheet/108798)	Present		Introduced			Planted	USDA-NRCS, 2005	
-Arkansas (/isc/datasheet/108797)	Present		Introduced				USDA-NRCS, 2005	
-California (/isc/datasheet/108799)	Restricted distribution		Introduced		Invasive		Baum, 1967; Crins, 1989	
-Colorado (/isc/datasheet/108800)	Present		Introduced		Invasive		Rice, 2004; USDA-NRCS, 2005	
-Georgia (/isc/datasheet/108805)	Present		Introduced			Planted		
-Idaho (/isc/datasheet/108808)	Present		Introduced			Planted	Rice, 2004	
-Kansas (/isc/datasheet/108811)	Present		Introduced			Planted		
-Mississippi (/isc/datasheet/108820)	Present		Introduced			Planted		
-Montana (/isc/datasheet/108821)	Present		Introduced		Invasive		Rice, 2004; USDA-NRCS, 2005	
-Nevada (/isc/datasheet/108828)	Present		Introduced		Invasive	Planted	USDA-NRCS, 2005	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
-New Mexico (/isc/datasheet/108827)	Present		Introduced		Invasive	Planted	USDA-NRCS, 2005	
-North Carolina (/isc/datasheet/108822)	Present		Introduced				USDA-NRCS, 2005	
-North Dakota (/isc/datasheet/108823)	Present		Introduced		Invasive		Rice, 2004	
-Ohio (/isc/datasheet/108830)	Present		Introduced				USDA-NRCS, 2005	
-Oklahoma (/isc/datasheet/108831)	Present		Introduced				USDA-NRCS, 2005	
-Oregon (/isc/datasheet/108832)	Present		Introduced				Rice, 2004; USDA-NRCS, 2005	
-Texas (/isc/datasheet/108838)	Widespread		Introduced		Invasive		Baum, 1967; Crins, 1989	
-Utah (/isc/datasheet/108839)	Present		Introduced			Planted	USDA-NRCS, 2005	
-Vermont (/isc/datasheet/108841)	Present		Introduced			Planted		
-Washington (/isc/datasheet/108842)	Present		Introduced		Invasive		Rice, 2004	
-Wyoming (/isc/datasheet/108845)	Present		Introduced		Invasive		USDA-NRCS, 2005	
Europe								
Former USSR (/isc/datasheet/108570)	Present		Native			Natural		
Hungary (/isc/datasheet/108454)	Present		Introduced			Planted		
Romania (/isc/datasheet/108548)	Present		Introduced			Planted		

History of Introduction and Spread

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Aside from its origin in northern China, it is also widely cultivated in eastern and southwestern China, and in Japan, Korea and the USA outside its native range. Deciduous species of tamarisk (saltcedar) have become naturalized in riparian areas of the USA since the early 1800s, although there is some debate about which species are involved, due to difficulty in distinguishing between T. chinensis and T. ramosissima and taxonomic confusion (DeLoach, 1990; Sudbrock, 1993). T. chinensis is an aggressive colonizer on fertile soils and is considered as an alien invasive species in many US states (Hughes, 1993; DeLoach et al., 1996). For example, T. chinensis is listed specifically or as part of the Tamarix complex (T. chinensis, T. parviflora, T. ramosissima) as a noxious weed by the states of Colorado, Montana, Nevada, North Dakota, New Mexico, Washington and Wyoming (Rice, 2004). Westbrooks (1998) provides a collective profile of the history and status of three Tamarix species in the USA (T. chinensis, T. parviflora and T. ramosissima). According to this source, introduction occurred at some point in the early 1800s and the three species were recorded widely through a number of river catchments by the 1940s and may have been promoted by man-made alterations to river flooding regimes. Further influences thought to have encouraged spread include disturbance from off-road vehicles, grazing regimes, and deforestation of native trees (Westbrooks, 1998). A further example, from the Pecos River Valley in New Mexico is described in Ladyman (2003). At this site the first records of the species date from 1912 but, by 1915, 600 acres were covered. By 1960, 57,600 acres were occupied. The present status of this species records it from almost all the drainage systems in arid and semi-arid parts of southwestern USA (Westbrooks, 1998).

In South Africa it is a proposed category 1 weed in the north, west and eastern Cape and a proposed category 3 invader throughout the rest of the country (Henderson, 2001). Binggeli (1999) considers it a highly invasive species.

Risk of Introduction

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The high degree of invasiveness demonstrated by this species (and its close relative T. ramossisima) in the USA would advocate extreme caution in the use of this species in similar environmental circumstances elsewhere. Where it has already been introduced, its behaviour should be monitored to gain new insights into its ecology and behaviour, and to detect the earliest signs of invasion.

Habitat

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T. chinensis occurs naturally along muddy seashores and up to 3 km into deciduous broad-leaved forest zones of northern China, or on saline soils inland. In the USA, where it is invasive, it grows in desert riparian habitats such as desert washes, seeps and springs (CalEPPC, 1999). It also grows along roadsides in the USA (Ladyman, 2003). In slight contradiction of the observations above, Bean and Russo (1988) consider that, while T. ramosissima is halophilous, T. chinensis is not: they comment that T. ramosissima invades areas of higher salinity in standing water such as marshes, oases and lakes or salty river banks and salty steppes while T. chinensis establishes most readily along major river drainages.

Habitat List

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Category	Habitat	Presence	Status
Littoral	Coastal areas	Present, no further details	Harmful (pest or invasive)
Terrestrial-managed	Disturbed areas	Present, no further details	Harmful (pest or invasive)
	Managed forests, plantations and orchards	Present, no further details	
	Managed grasslands (grazing systems)	Present, no further details	
	Rail / roadsides	Present, no further details	Harmful (pest or invasive)
	Urban / peri-urban areas	Present, no further details	Harmful (pest or invasive)
Terrestrial-natural/semi-natural	Deserts	Present, no further details	Harmful (pest or invasive)
	Natural forests	Present, no further details	Harmful (pest or invasive)
	Natural grasslands	Present, no further details	Harmful (pest or invasive)
	Riverbanks	Present, no further details	Harmful (pest or invasive)
	Wetlands	Present, no further details	Harmful (pest or invasive)

Hosts/Species Affected

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The list of plants, both indigenous and introduced, that are displaced by saltcedar invasions would include virtually every plant known in riparian areas of the western USA and northern Mexico. The invasion and domination of native riparian plant communities most often follows the recession of flood waters or wildfires, which kill the native plants, and then allows the saltcedar seedlings to establish without competition.

Biology and Ecology

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Genetics

The chromosome number is 2n=24 for all species of the genus so far investigated (Baum, 1978).

Gaskin and Schaal (2002, 2003) have conducted an extensive DNA comparison of many species of the genus based on field collections by Gaskin throughout most of the Tamarix distribution in the Old World, and compared them with specimens of weedy species from many locations in the western USA. Gaskin found no hybrids in the Old World, although a few records are reported in the literature.

Gaskin and Schaal (2002), using introns selected from both chloroplastic and nuclear DNA, identified a strong concentration of haplotype 2/genotype 2/2 (= T. chinensis) in eastern China; also of haplotype 1/genotype 1/1 in eastern Kazakhstan and Turkmenistan (= T. ramosissima) and with scattered populations in Georgia and Azerbaijan and in Iran and Iraq. Haplotype 7 (not identified to species) was found in eastern Kazakhstan, Turkmenistan and Georgia and Azerbaijan, and genotype 12/12 (also not identified to species) was found in Azerbaijan.

Gaskin and Schaal (2003) identified four invasive genetic entities of Tamarix in the USA: T. aphylla, T. parviflora, and two entities that could not be defined at the species level but represented a T. ramosissima/T. chinensis entity and a T. gallica/T. canariensis entity. They also found evidence for hybridization between T. ramosissima, T. canariensis and T. gallica and T. aphylla which adds to the confusion in identification.

A comparison with US genotypes (Gaskin and Schaal, 2002) revealed that T. ramosissima was the dominant species in Montana, Wyoming, Nevada and southern California, and with a few sites in Oklahoma, Texas and Arizona. T. chinensis was the dominant species in Texas (especially western Texas) and New Mexico, with some sites in several other states. The T. ramosissima x T. chinensis hybrid was the most common genotype in New Mexico and was common in Oklahoma, Nevada, California and Montana. The unidentified 12/12 genotype and hybrids with T. ramosissima or T. chinensis were uncommon but found in nearly all western states. Hybrids with haplotype 7 were found in Idaho.

These species/hybrid complexes usually cannot be distinguished morphologically in the field. Some species or hybrids predominate and may be the only form in some areas but in other areas several species and hybrids may occur at the same site.

Physiology and Phenology

In the USA, T. chinensis flowers from April to August (Ladyman, 2003). Further details likely to be common to the weedy deciduous saltcedars can be found in the datasheet on T. ramosissima.

Reproductive Biology

This species is able to reproduce vegetatively from root suckers and from seed. Water and birds disperse the seed (Ladyman, 2003). A number of authors including Ladyman comment that the longevity of the seeds is short in humid conditions. Tamarix has a reproductive advantage over some native north American desert riparian trees and shrubs in that it can reproduce in the absence of regular seasonal flooding (Arizona Sonora Desert Museum, 2004).

Environmental Requirements

T. chinensis is unable to tolerate winter temperatures below -20°C, but has been introduced into the southern Xinjiang region of China for revegetation and landscaping purposes, thus surviving severe winters.

T. chinensis is light-demanding, but has good adaptability to dry atmospheric conditions, high temperatures in the dry season and low temperatures during winter. It grows on a variety of soils, tolerating dry, waterlogged and saline-alkaline soils. The leaves have the ability to exude salt and Chinese tamarisk grown in extreme saline-alkaline soils (approximately 1% or up to 15,000 p.p.m.) can effectively reduce soil salt content (Zheng, 1978; Liu, 1991). The deep taproot and fine root system allows T. chinensis to grow well even when partially covered by sand.

Associations

In its introduced North American range, the distribution overlaps with native cottonwoods (Populus spp.), a species which is outcompeted by introduced Tamarix.

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Latitude/Altitude Ranges

Latitude North (°N)	Latitude South (°S)	Altitude Lower (m)	Altitude Upper (m)
48	31	50	1200

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Air Temperature

Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	-30	
Mean annual temperature (ºC)	4	13
Mean maximum temperature of hottest month (ºC)	21	26
Mean minimum temperature of coldest month (ºC)	-5	4

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Rainfall

Parameter	Lower limit	Upper limit	Description
Dry season duration	0	6	number of consecutive months with <40 mm rainfall
Mean annual rainfall	50	1500	mm; lower/upper limits

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Rainfall Regime

Summer

Soil Tolerances

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Soil drainage

free
impeded
seasonally waterlogged

Soil reaction

acid
alkaline
neutral

Soil texture

heavy
light
medium

Special soil tolerances

infertile
saline
shallow
sodic

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Coniatus tamarisci (/isc/datasheet/15180)	Herbivore	Leaves				
Diorhabda elongata (/isc/datasheet/19048)	Herbivore	Leaves				
Psectrosema album (/isc/datasheet/23967)	Herbivore	Stems				
Trabutina mannipara (/isc/datasheet/54399)	Herbivore	Leaves/Stems				

Notes on Natural Enemies

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Most of the work on natural enemies has been carried out for T. ramosissima (see the separate datasheet for more details). It is reasonable to expect that the same pests could attack T. chinensis.

Potential biological control agents from France have been evaluated for use in the USA (Sobhian et al., 1998). These include a defoliating weevil Coniatus tamarisci (Fornasari, 1997). Ladyman (2003) cited recent work on an Israeli mealybug Trabutina mannipara and a chinese leaf beetle Diorhaba elongata (DeLoach et al., 1996), but noted the lack of a commercial control agent for use in the USA.

Means of Movement and Dispersal

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Natural Dispersal (Non-Biotic)

The small seeds are dispersed by water (Ladyman, 2003) and by wind.

Vector Transmission (Biotic)

Ladyman (2003) reports that birds can disperse seeds.

Intentional Introduction

This tree/shrub has been widely introduced to arid areas outside its native range including North America and South Africa where it has subsequently become invasive.

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Clothing, footwear and possessions (/isc/datasheet/108160)	Smuggled flowers, cuttings	Yes		
Containers and packaging - wood (/isc/datasheet/109066)	Cuttings, whole plants	Yes		

Plant Trade

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Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Bark				
Fruits (inc. pods)	seeds			
Leaves	whole plants			
Roots	whole plants			
Stems (above ground)/Shoots/Trunks/Branches				
True seeds (inc. grain)	seeds			

Plant parts not known to carry the pest in trade/transport
Bulbs/Tubers/Corms/Rhizomes
Flowers/Inflorescences/Cones/Calyx
Growing medium accompanying plants
Seedlings/Micropropagated plants
Wood

Impact Summary

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Category	Impact
Animal/plant collections	None
Animal/plant products	None
Biodiversity (generally)	Negative
Crop production	Negative
Environment (generally)	Negative
Fisheries / aquaculture	Negative
Forestry production	Negative
Human health	Negative
Livestock production	Negative
Native fauna	Negative
Native flora	Negative
Rare/protected species	Negative
Tourism	Negative
Trade/international relations	None
Transport/travel	None

Impact

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The control of T. chinensis is costly. The economic impact of saltcedars (Tamarix spp.) in North America is discussed in the datasheet on T. ramosissima.

Environmental Impact

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T. chinensis is implicated in increasing soil salinity by deposition of saline leaf litter and interfering in natural aquatic systems.

Impact: Biodiversity

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Stream flow and flooding regime may be affected by Tamarix spp. (Luken and Thieret, 1997). Westbrooks (1998) regards Tamarix spp. to constitute a major threat to native American plant assemblages. It is outcompeting native cottonwoods (Populus spp.) and other species. The impact on desert riparian systems is considered so severe that the habitat is now extremely rare (Westbrooks, 1998). Ladyman (2003) reports that tamarisk stands growing in the USA host 50% fewer small mammal species, and poorer reptile, amphibian and insect communities. The plant is also unsuitable as a nesting site for many of the indigenous birds and squirrels and there is little bird food associated with Tamarix, because the insect fauna is poorer and the seeds are not nutritious (Ladyman, 2003). The high tannin content of the leaves makes them relatively unpalatable for mammals (Ladyman, 2003). More details on the impact of Tamarix spp. on wildlife in the USA are included in the datasheet on T. ramosissima.

Risk and Impact Factors

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Invasiveness

Proved invasive outside its native range

Uses

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T. chinensis has been used to stabilize sand dunes and improve saline soils (15-20 years) before crop cultivation. The shoots are elastic and have traditionally been used to weave agricultural items, such as baskets and crates. The wood is hard and can be used to make agricultural tools and for fuelwood. Products include building timbers, fences, boxes and pulp. Young leaves and shoots are used to treat diaphoresis and measles. It has been planted in shelterbelts and as a windbreak/hedge plant and is also used in gardens as an ornamental plant.

Uses List

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Animal feed, fodder, forage

Fodder/animal feed

Environmental

Agroforestry
Boundary, barrier or support
Erosion control or dune stabilization
Revegetation
Shade and shelter
Soil improvement
Windbreak

Fuels

Fuelwood

General

Ornamental

Human food and beverage

Honey/honey flora

Materials

Carved material
Fibre
Wood/timber

Medicinal, pharmaceutical

Source of medicine/pharmaceutical

Wood Products

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Containers

Boxes
Cases

Pulp

Short-fibre pulp

Sawn or hewn building timbers

Exterior fittings
Fences

Wood-based materials

Fibreboard
Medium density fibreboard

Woodware

Industrial and domestic woodware
Pencils
Tool handles
Toys
Wood carvings

Similarities to Other Species/Conditions

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Baum (1968) provides a key which separates T. chinensis (and T. ramosissima) from T. canariensis and T. gallica by the insertion of the filaments between the lobes of the nectary disc (hololophic), while in the other two species they are inserted on the lobes themselves (synlophic) (well illustrated by Gaskin and Schaal, 2003). T. chinensis differs from T. ramosossima in having 'smaller, entire sepals, ovate petals and shorter bracts'. Bean and Russo (1988) emphasise the differences in petal shape: obovate (wider distally) in T. ramosissima and oblong-ovate (narrowed distally) in T. chinensis. Gaskin and Schaal (2003) also refer to differences in raceme width (3-4 mm in T. ramosissima and 5-7 mm in T. chinensis) and in the insertion of the filaments (below the sinuses of the disc in T. ramosissima and in the sinuses of the disc in T. chinensis). This paper incidentally includes excellent drawings of the leaves and nectary discs of several of the species/species complexes. While these differences may be seen under the microscope, they are not readily observable in the field.

Prevention and Control

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Cultural Control

Although fire is sometimes used to control this species it is not a recommended technique because the wood is difficult to burn because while cool fires may fail to kill the plant, hot fires may create bare ground that is unsuitable for indigenous species (Ladyman, 2003). See the T. ramosissima datasheet for other approaches likely to be applicable to T. chinensis.

Mechanical Control

Cutting and removal is effective only if the roots are removed or destroyed and without this, T. chinensis may be stimulated to produce new shoots (Ladyman, 2003). Cutting followed by some degree of shading (with dark plastic sheeting or by other vegetaion) has been more effective (Ladyman, 2003). See the T. ramosissima datasheet for other approaches likely to be applicable to T. chinensis.

Chemical Control

Ladyman (2003) reports that Tamarix is 'sensitive' to herbicides and that the best treatments involve cutting followed by herbicide treatment of stumps or cut-stump/frill applications. The technique relies on the herbicide being applied within a very short time after cutting and although expensive minimizes potential impacts on non-target species. See the datasheet on T. ramosissima for more details of chemical treatments for Tamarix control.

Biological Control

Potential biological control agents from France have been evaluated for use in the USA (Sobhian et al., 1998). Ladyman (2003) cited recent work on an Israeli mealybug Trabutina mannipara and a Chinese leafbeetle Diorhaba elongata, but noted the lack of a commercial control agent for use in USA.

Most of the biological control research in the USA has focussed on Tamarix ramosissima (see the separate datasheet); it is likely that biocontrol agents againts this species will also be effective against T. chinensis.

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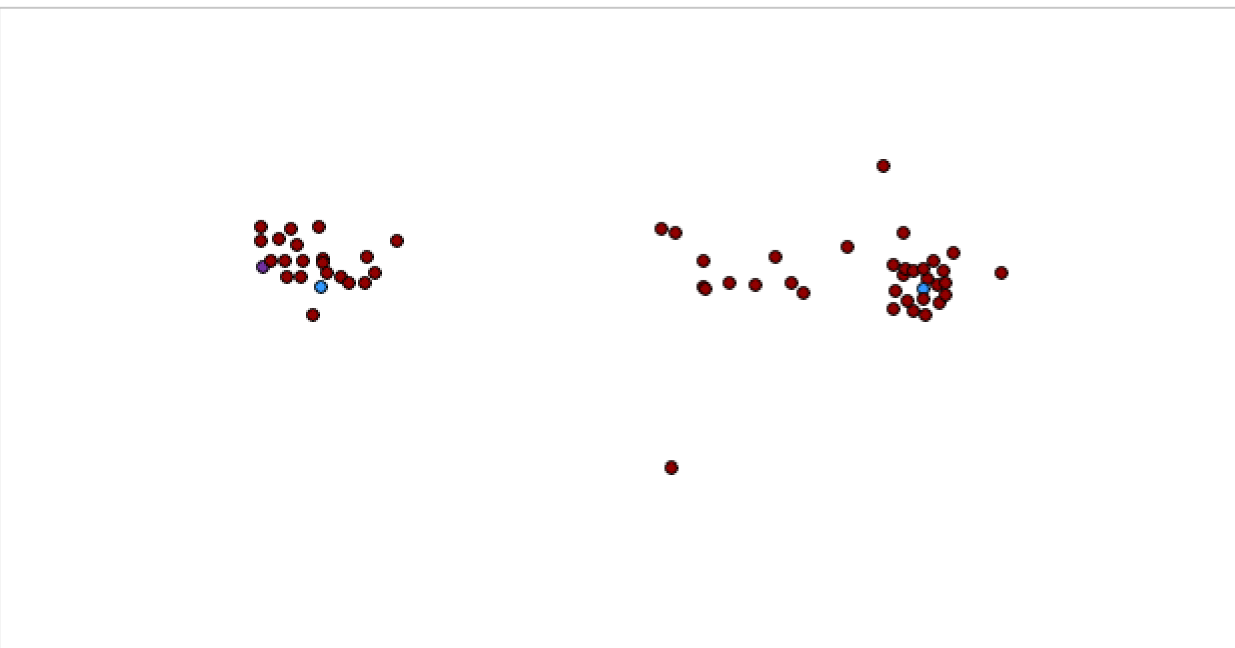
World Map

Analyzed by: Density

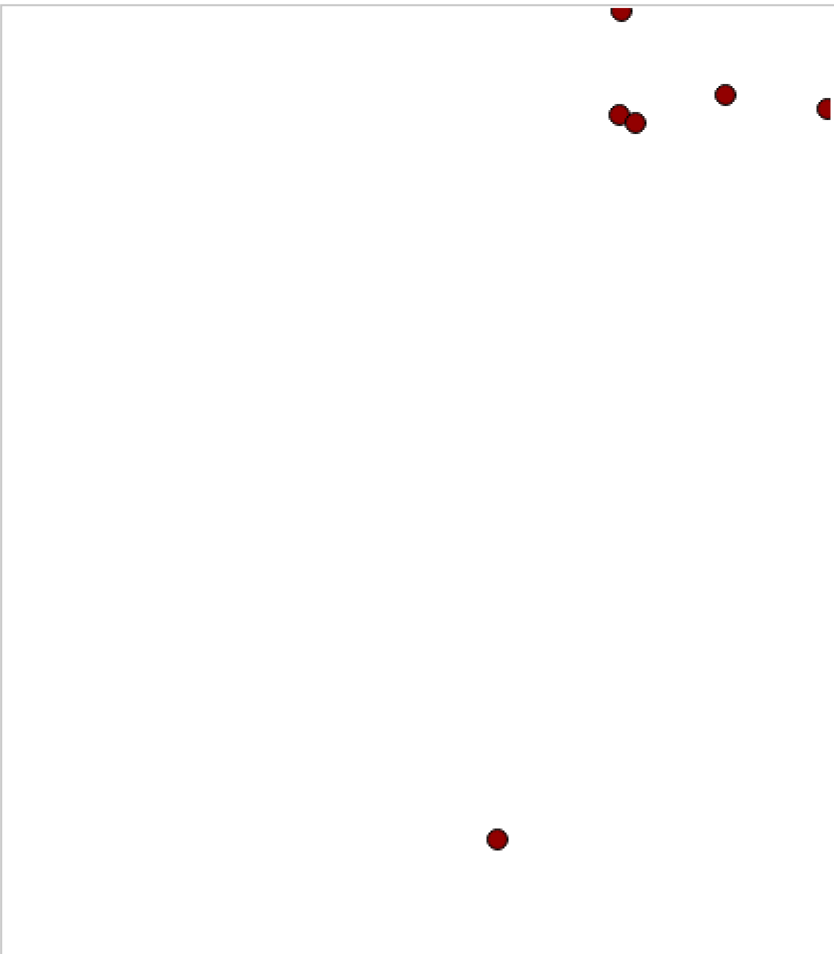
Present, no further details	Widespread
Localised	



Africa

Analyzed by: Density

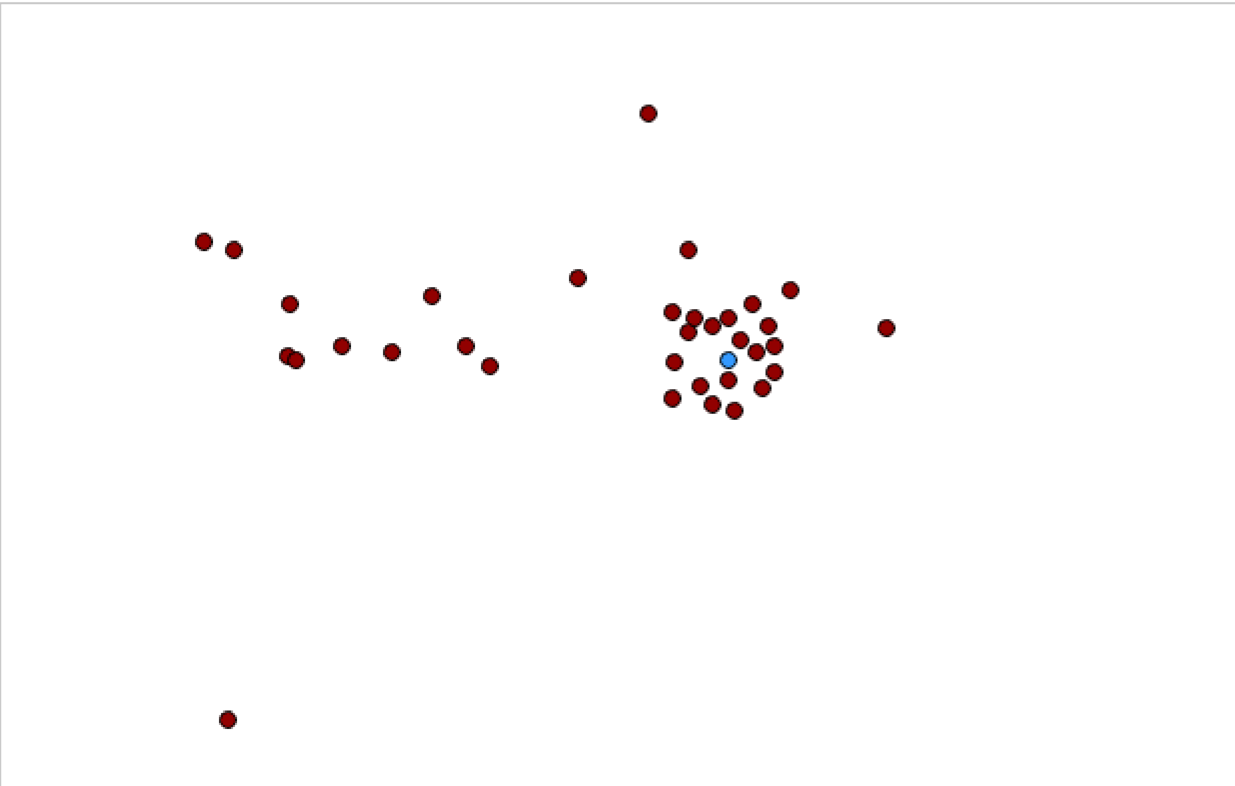
- Present, no further details
- Widespread
- Localised



Asia

Analyzed by: Density

Present, no further details	Widespread
Localised	



Europe

Pacific

North America

Central America

South America

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Tamarix parviflora (small-flower tamarisk)

Identity

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Preferred Scientific Name

Tamarix parviflora DC. (1828)

Preferred Common Name

small-flower tamarisk

Other Scientific Names

Tamarix cretica Bge.
Tamarix laxa var. subspicata Ehrenb. (1827)
Tamarix lucronensis Sennen & Elias (1928)
Tamarix parviflora var. cretica (Bge.) Boiss. (1867)
Tamarix petteri Presl ex Bge. (1852)
Tamarix rubella Batt. (1907)

International Common Names

English: saltcedar; salt-cedar; tamarisk
Spanish: pinebete
French: tamaris à petites fleurs

Local Common Names

Germany: Tamariske, Frühlings-; Tamariske, Kleinblütige
Israel: ashel
Italy: tamarice a piccolo fiori

EPPO code

TAAPA (Tamarix parviflora)

Summary of Invasiveness

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T. parviflora shares many of the inherent physiological characters that make the weedy Tamarix spp. adapted to natural or modified riparian ecosystems and make them appear to be more aggressive and better adapted to the invaded native ecosystems of western North America than are the native plant communities (DeLoach et al., 2000). They have an extremely high reproduction rate, the ability to produce seeds over a very long time period (throughout the growing season), very efficient means of seed dispersal, the ability to reproduce vegetatively as well as by seed, and mechanisms for rapid seed germination and seedling establishment. T. parviflora is apparently somewhat less aggressive than some of the other Tamarix species, but has proved invasive locally in the USA and is listed as a federal noxious weed in the USA (USDA-NRCS, 2005).

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Tamaricales
            - Family: Tamaricaceae
              - Genus: Tamarix
                - Species: Tamarix parviflora

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Notes on Taxonomy and Nomenclature

The weedy species of Tamarix in North America, all deciduous, small trees or shrubs, belong to a complex of four very similar species: T. ramosissima, T. chinensis, T. canariensis and, occasionally, T. gallica, plus the distinct T. parviflora, and their hybrids. The distinctive, large tree, athel (T. aphylla) is also becoming weedy at a few locations (Barnes et al., 2004). Four other species have been introduced that are known only as ornamentals or that have become weakly naturalized (Baum, 1967; Crins, 1989). Although there are difficulties in separating some species pairs in this genus, especially T. ramosissima/T. chinensis and T. gallica/T. canariensis, T. parviflora is quite distinct genetically and morphologically from other weedy Tamarix species (Baum, 1968; Gaskin and Schaal, 2002, 2003).

Further details of Tamarix taxonomy can be found in the datasheet on T. ramosissima.

Baum (1978) notes the fine morphological distinctions between T. parviflora and T. tetrandra Pall. ex M. Bieb, however, Zielinski (1994) considers T. parviflora a probable junior synonym of T. tetrandra. They are treated as separate species by USDA-ARS (2005).

The common name 'saltcedar' derives from the superficial resemblance of the leaves to Juniperus which is commonly called 'cedar' in the USA and the salt glands that excrete excess salts from saline ground water taken up by the roots. It is frequently used for all the weedy, decidous, small trees or shrubs of Tamarix (including T. parviflora) in the USA and Mexico. The large, evergreen T. aphylla is often distinguished by using the common name 'athel'.

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Description

See the datasheet on T. ramosissima for a description of the genus.

T. parviflora is a low tree or shrub, 2-3 m high (to 5 m in the USA), with brown to deep purple bark, entirely glabrous. Leaves sessile with narrow base, 2-2.5 mm long. Vernal inflorescences simple, aestival inflorescences rare. Racemes 1.5-4 cm long, 3-5 mm broad, densely flowered. Bracts triangular-acuminate, blunt, boat-shaped, almost completely diaphanous (not herbaceous), longer than pedicels. Pedicel much shorter than calyx. Calyx tetramerous. Sepals connate (connected) at the base, erose-denticulate, 1.25-1.5 mm long, the outer two trullate-ovate, acute and keeled, the inner ovate, obtuse. Corolla tetramerous, sub-persistent. Petals parabolic, ovate, 2 mm long, subentire or faintly erose, pink. Androecium a single whorl of four antesepalous stamens (inserted opposite the sepals); filaments inserted on the lobes of the nectary disc (synlophic). Flowering: March to June (Baum, 1978).

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Plant Type

Broadleaved
Perennial
Seed propagated
Shrub
Tree
Vegetatively propagated
Woody

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Distribution

T. parviflora is native in the Mediterranean area. In the USA it is most abundant in central California, but occurs less frequently in Arizona, New Mexico, Nevada and Utah and, rarely, in Texas. It also is found less commonly in other states (USDA-NRCS, 2005). It also occurs along the Afton River in Australia (John Gaskin, USDA-ARS, Sidney, MT, personal communication, 2004).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
Asia								
Israel (/isc/datasheet/108457)	Present		Native				USDA-ARS, 2005	
Turkey (/isc/datasheet/108587)	Widespread		Native		Not invasive	Natural	Baum, 1978	
Africa								
Algeria (/isc/datasheet/108415)	Restricted distribution		Native		Not invasive	Natural	Baum, 1978	
North America								
USA (/isc/datasheet/108597)	Present							Present based on regional distribution.
-Arizona (/isc/datasheet/108798)	Widespread		Introduced		Invasive		Baum, 1967	
-California (/isc/datasheet/108799)	Widespread		Introduced		Invasive		Baum, 1967	
-Colorado (/isc/datasheet/108800)	Present		Introduced				USDA-NRCS, 2005	
-Connecticut (/isc/datasheet/108801)	Present		Introduced				USDA-NRCS, 2005	
-Delaware (/isc/datasheet/108803)	Present		Introduced				USDA-NRCS, 2005	
-Florida (/isc/datasheet/108804)	Present		Introduced				USDA-NRCS, 2005	
-Idaho (/isc/datasheet/108808)	Present		Introduced				USDA-NRCS, 2005	
-Illinois (/isc/datasheet/108809)	Present		Introduced				USDA-NRCS, 2005	
-Kansas (/isc/datasheet/108811)	Present		Introduced				USDA-NRCS, 2005	
-Louisiana (/isc/datasheet/108813)	Present		Introduced				USDA-NRCS, 2005	
-Massachusetts (/isc/datasheet/108814)	Present		Introduced				USDA-NRCS, 2005	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
-Michigan (/isc/datasheet/108817)	Present		Introduced				USDA-NRCS, 2005	
-Mississippi (/isc/datasheet/108820)	Present		Introduced				USDA-NRCS, 2005	
-Missouri (/isc/datasheet/108819)	Present		Introduced				USDA-NRCS, 2005	
-Montana (/isc/datasheet/108821)	Present		Introduced				USDA-NRCS, 2005	
-Nevada (/isc/datasheet/108828)	Present		Introduced				USDA-NRCS, 2005	
-New Jersey (/isc/datasheet/108826)	Present		Introduced				USDA-NRCS, 2005	
-New Mexico (/isc/datasheet/108827)	Present, few occurrences		Introduced		Invasive		Baum, 1967	
-North Carolina (/isc/datasheet/108822)	Present		Introduced				USDA-NRCS, 2005	
-Oklahoma (/isc/datasheet/108831)	Present		Introduced				USDA-NRCS, 2005	
-Oregon (/isc/datasheet/108832)	Present		Introduced				USDA-NRCS, 2005	
-Pennsylvania (/isc/datasheet/108833)	Present		Introduced				USDA-NRCS, 2005	
-Tennessee (/isc/datasheet/108837)	Present		Introduced				USDA-NRCS, 2005	
-Texas (/isc/datasheet/108838)	Present, few occurrences		Introduced		Invasive		Baum, 1967	
-Utah (/isc/datasheet/108839)	Present		Introduced				USDA-NRCS, 2005	
-Virginia (/isc/datasheet/108840)	Present		Introduced				USDA-NRCS, 2005	
-Washington (/isc/datasheet/108842)	Present		Introduced				USDA-NRCS, 2005	
Europe								
Albania (/isc/datasheet/108354)	Restricted distribution		Native		Not invasive		Baum, 1978	
Croatia (/isc/datasheet/108452)	Restricted distribution		Native		Not invasive		Baum, 1978	
France (/isc/datasheet/108429)	Present							Present based on regional distribution.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Planted	Reference	Notes
-Corsica (/isc/datasheet/108704)	Restricted distribution		Native		Not invasive	Natural	Baum, 1978	
Greece (/isc/datasheet/108443)	Widespread		Native		Not invasive	Natural	Baum, 1978	
-Crete (/isc/datasheet/108711)	Present		Native				USDA-ARS, 2005	
Italy (/isc/datasheet/108464)	Restricted distribution		Native		Not invasive	Natural	Baum, 1978	
Serbia (/isc/datasheet/108549)	Restricted distribution		Native		Not invasive		Baum, 1978	
Slovakia (/isc/datasheet/108561)	Present						Kment, 2004	
Slovenia (/isc/datasheet/108559)	Restricted distribution		Native		Not invasive		Baum, 1978	
Spain (/isc/datasheet/108421)	Restricted distribution		Native		Not invasive	Natural	Baum, 1978	
Switzerland (/isc/datasheet/108393)	Present						Germann and Moretti, 2009	
Yugoslavia (former) (/isc/datasheet/108610)	Present					Natural		

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History of Introduction and Spread

Information was not found on the introduction and spread of T. parviflora as separate from the other Tamarix species. See the datasheet on T. ramosissima.

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Risk of Introduction

The major risk is from the introduction of cuttings by tourists for planting ornamentals, although the interception of cuttings by the port inspectors may be efficient.

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Habitat

T. parviflora, being a facultative phreatophyte, grows mainly in riparian habitats: in broad floodplains of rivers, along permanent or intermittent streams, around lakes and reservoirs, and at a depth to water table of 1-5 m; it can also grow (less densely) on upland areas or with its roots out of contact with the water table. It can grow in a wide variety of soils, and in both saline and fresh soils. It does not prefer saline soils but can tolerate salinity, giving it a competitive advantage over most plants which cannot.

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Habitat List

Category	Habitat	Presence	Status
Littoral	Coastal areas	Present, no further details	Harmful (pest or invasive)
Terrestrial-managed	Disturbed areas	Present, no further details	Harmful (pest or invasive)
	Managed forests, plantations and orchards	Present, no further details	
	Managed grasslands (grazing systems)	Present, no further details	
	Rail / roadsides	Present, no further details	Harmful (pest or invasive)
	Urban / peri-urban areas	Present, no further details	Harmful (pest or invasive)
Terrestrial-natural/semi-natural	Deserts	Present, no further details	Harmful (pest or invasive)
	Natural forests	Present, no further details	Harmful (pest or invasive)
	Natural grasslands	Present, no further details	Harmful (pest or invasive)
	Riverbanks	Present, no further details	Harmful (pest or invasive)
	Wetlands	Present, no further details	Harmful (pest or invasive)

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Biology and Ecology

T. parviflora is one of only four invasive taxonomic entities that Gaskin and Schaal (2003) could identify by DNA analysis.

The biology and ecology of T. parviflora has been little studied separately from the other Tamarix species but is probably similar to those (see the datasheet on T. ramosissima). It is less invasive than T. ramosissima which may be related to its limited period of blooming (only in the spring).

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Air Temperature

Parameter	Lower limit	Upper limit
Mean annual temperature (ºC)	-20	50
Mean maximum temperature of hottest month (ºC)		38

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Rainfall

Parameter	Lower limit	Upper limit	Description
Dry season duration	12	60	number of consecutive months with <40 mm rainfall
Mean annual rainfall	75	1000	mm; lower/upper limits

Rainfall Regime

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Uniform

Soil Tolerances

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Soil drainage

- free
- impeded
- seasonally waterlogged

Soil reaction

- acid
- alkaline
- neutral

Soil texture

- heavy
- light
- medium

Special soil tolerances

- infertile
- saline
- shallow
- sodic

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Pectrosema nigrum (/isc/datasheet/39415)	Herbivore	Stems				

Notes on Natural Enemies

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Psectrosema nigrum (Diptera: Cecidomyiidae) forms small stem galls on T. parviflora and T. gallica in southern France (Gagné et al., 1996). No other published field records of arthropods attacking T. parviflora have been found, although many of the literature records refer only to Tamarix sp. (e.g. Kovalev, 1995). Natural enemies of T. ramosissima have been studied in more detail and it is likely that some of these will also attack T. parviflora (see the datasheet on T. ramosissima).

Means of Movement and Dispersal

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Natural Dispersal (Non-Biotic)

Saltcedars disperse naturally and very efficiently by means of the huge quantity of small windblown or waterborne seeds. They also can disperse to a limited extent by the rooting of plant parts that wash downstream in floods.

Agricultural Practices

Saltcedars seldom grow in agricultural fields where they might be dispersed with baled hay, with seeds crops etc.; also the seeds would probably be blown out by combines harvesting crop seeds but these seeds probably only rarely or never establish.

Intentional Introduction

After dispersal by wind and water, the next greatest means of dispersal is probably the sale of ornamental plants by nurserymen, and the secondary spread of windblown seeds or cuttings from these plants. Dispersal from plantings for streambank erosion control or for windbreaks also has occurred.

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Clothing, footwear and possessions (/isc/datasheet/108160)	Smuggled flowers, cuttings	Yes		
Containers and packaging - wood (/isc/datasheet/109066)	Cuttings, whole plants	Yes		

Plant Trade

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Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Bark				
Fruits (inc. pods)	seeds		Yes	
Leaves	whole plants			
Roots	whole plants			
Stems (above ground)/Shoots/Trunks/Branches				
True seeds (inc. grain)	seeds			

Plant parts not known to carry the pest in trade/transport
Bulbs/Tubers/Corms/Rhizomes
Flowers/Inflorescences/Cones/Calyx
Growing medium accompanying plants
Seedlings/Micropropagated plants
Wood

Impact Summary

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Category	Impact
Animal/plant collections	None
Animal/plant products	None
Biodiversity (generally)	Negative
Crop production	Negative
Environment (generally)	Negative
Fisheries / aquaculture	Negative
Forestry production	Negative
Human health	None
Livestock production	Negative
Native fauna	Negative
Native flora	Negative
Rare/protected species	Negative
Tourism	Negative
Trade/international relations	None
Transport/travel	None

Impact

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Most impacts for T. parviflora are similar, but of somewhat less effect, than for T. ramosissima (see the separate datasheet) because it appears to be less aggressively invasive. However, T. parviflora occurs in dense stands in central California, USA, and so the impacts are serious in the area infested.

Impact: Biodiversity

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The list of indigenous and introduced plants that are displaced by saltcedar invasions in riparian areas of the western USA and northern Mexico includes amongst others Atriplex lentiformis, Baccharis salicifolia, Populus spp., Prosopis spp. and Salix spp. The invasion and domination of native riparian plant communities most often follows the recession of flood waters or wildfires, which kill the native plants, and then allows the saltcedar seedlings to establish without competition.

Risk and Impact Factors

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Invasiveness

Proved invasive outside its native range

Uses

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T. parviflora is frequently planted as an ornamental because of its showy, pink flowers in the spring. It has apparently been little planted as windbreaks or for streambank erosion control exept in central California, especially along Cache Creek and Bear Creek.

The datasheet on T. ramosissima contains further information that applies to saltcedars generally.

Similarities to Other Species/Conditions

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T. parviflora is easily distinguished from the other North American exotic T. ramosissima/T. chinensis (r/c) and T. canariensis/T. gallica (c/g) species/hybrid groups by having only four stamens, four petals and four lobes of the basal disc of the flowers, whereas the r/c and c/g species groups have pentamerous flowers. Also, the racemes of T. parviflora are shorter and arranged in dense inflorescences that occur in clusters along the upper stems, whereas the racemes of the r/c and c/g groups are longer and the inflorescences are much larger, much more open and paniculately branched, and usually are located on the branch terminals. T. parviflora is very distinct from T. aphylla which is a large evergreen tree, to 20 m tall and 1 m trunk diameter, with long, sparsely branched terminal twigs with closely adpressed, vaginate leaves, superficially appearing like long pine needles or Casuarina foliage, white flowers arranged in a spiral on the raceme, and is cold intolerant, being killed by a moderate freeze. Baum (1968) provides a useful key the European species of Tamarix, including T. parviflora, while Gaskin and Schaal (2003) include useful drawings of the leaves and nectary disc of this species.

Prevention and Control

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For details of the control measures that apply to the group of weedy, deciduous saltcedars in the USA, see the datasheet on T. ramosissima. The biological control programme in California, covers T. parviflora.

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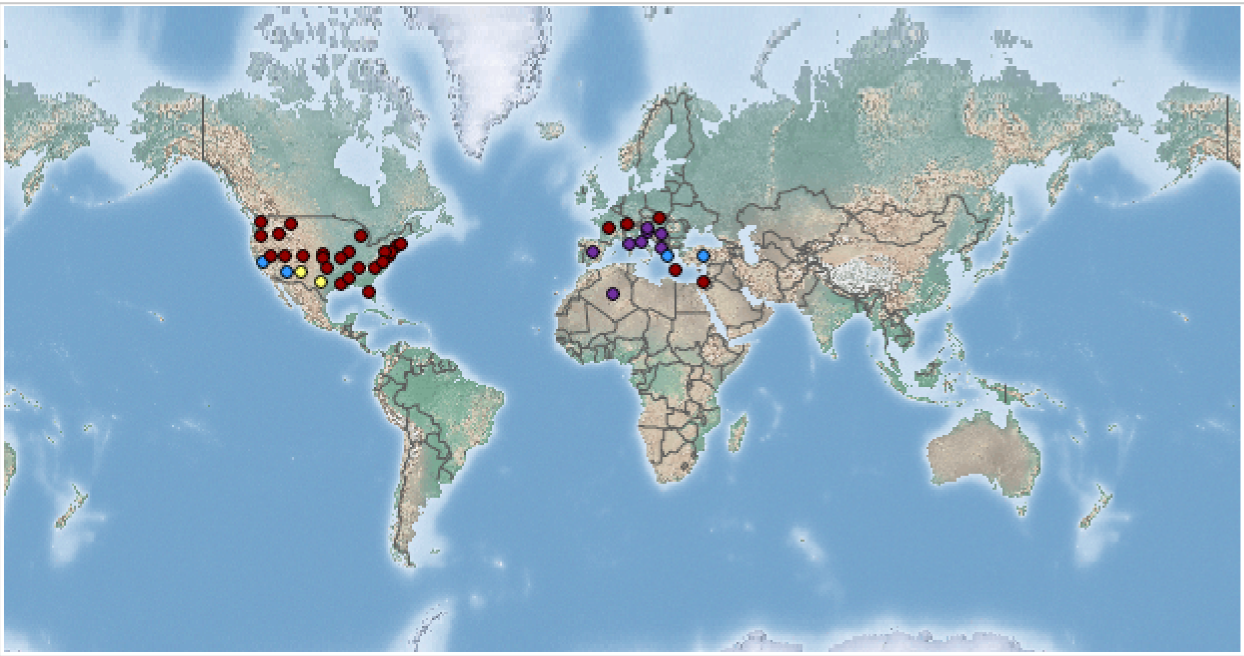
World Map

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports



Africa

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports

Asia

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports

Europe

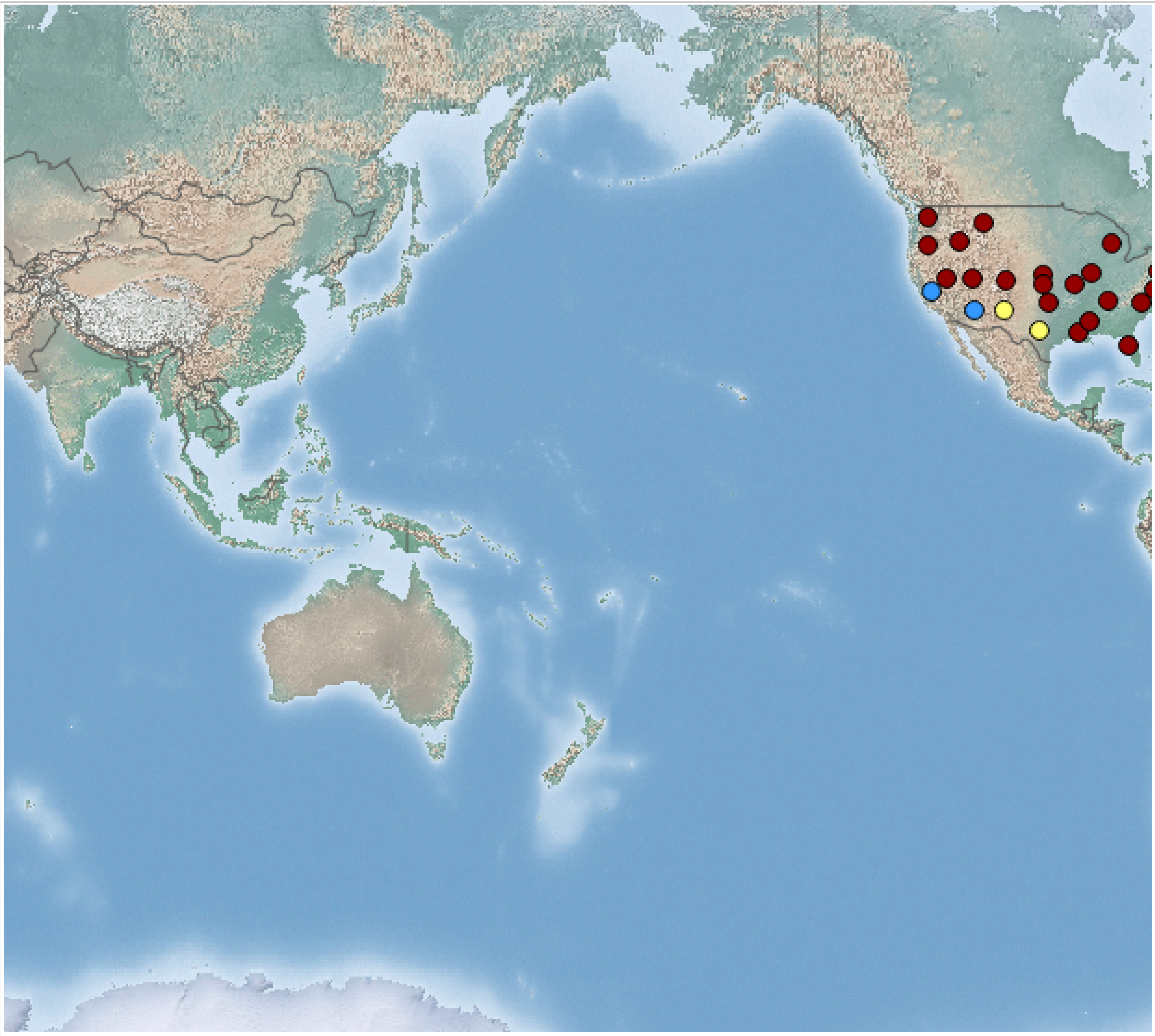
Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports

Pacific

Analyzed by: Density

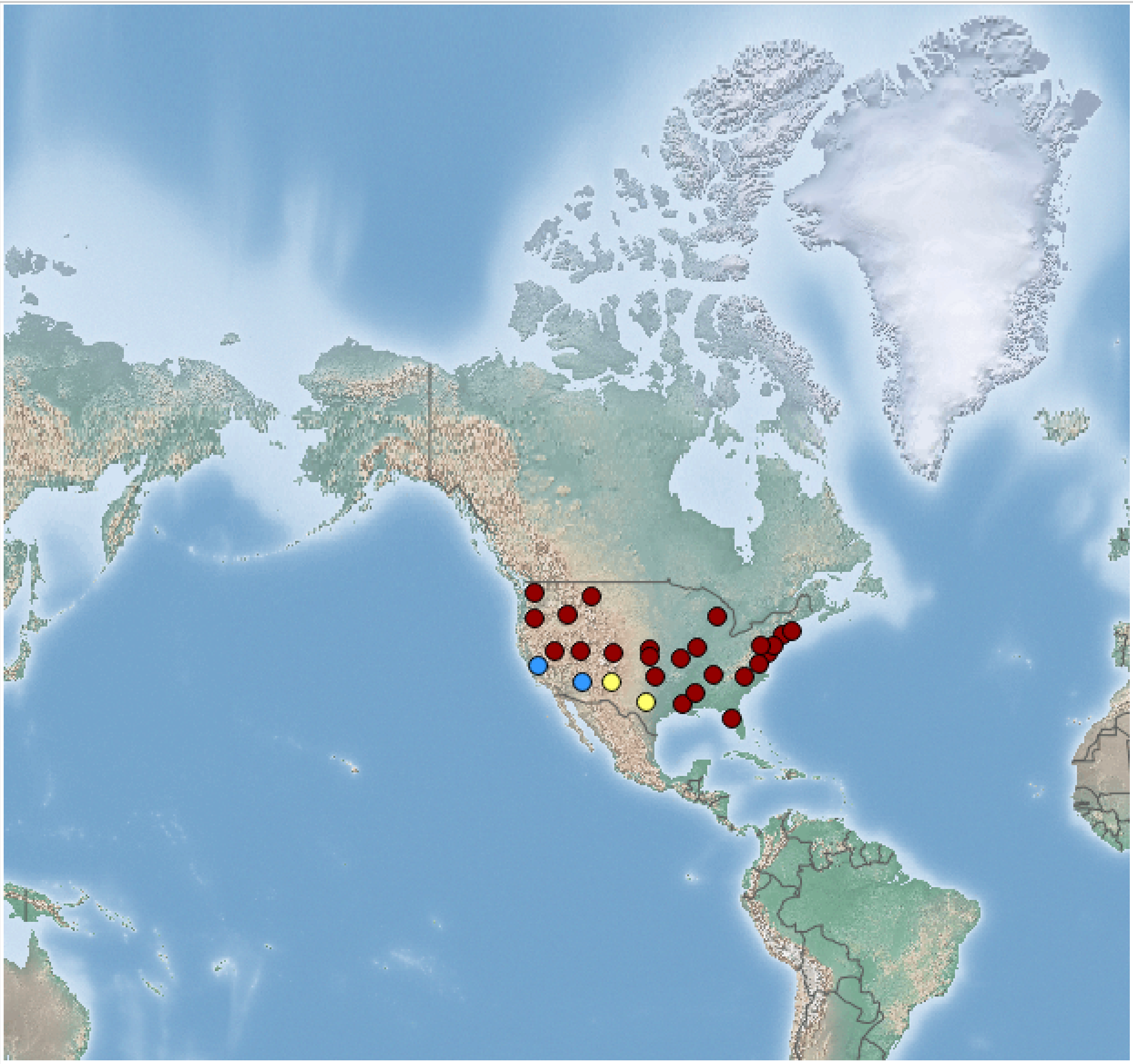
Localised	Present, no further details
Widespread	Occasional or few reports



North America

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports



Central America

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports

South America

Analyzed by: Density

Localised	Present, no further details
Widespread	Occasional or few reports

Date of report: 07 April, 2018

Invasive Species Compendium

Datasheet report for Trapa natans (waterchestnut)

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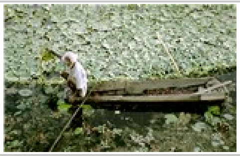
Pictures

Picture	Title	Caption	Copyright
	Water chestnut crop being harvested	Farmer harvesting his crop of T. natans in India.	©Chris Parker/Bristol, UK
	Plants in hand	Trapa natans plants with fruit being indicated by observer in India.	©Chris Parker/Bristol, UK

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Identity

Preferred Scientific Name

Trapa natans L. (1753)

Preferred Common Name

waterchestnut

Other Scientific Names

Trapa natans var. quadrispinosa Makino (1820)
Trapa quadrispinosa Roxb. (1820)

International Common Names

English: watercaltrop
Spanish: castagna de agua
French: noix aquatique

Local Common Names

Germany: Wassernuss
Italy: castana d'acqua; tribolo acquatico
Netherlands: waternoot
Sweden: vattennoet

EPPO code

TRPNA (Trapa natans)

Summary of Invasiveness

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T. natans is a productive, annual, floating-leaved plant which has been cultivated globally for the nutritious nut it produces (Hummel and Kiviat, 2004). It is an extremely important food crop in China and India and is protected in Europe (Hummel and Kiviat, 2004), but in its introduced range, it grows in thick stands that displace native vegetation and affect water quality. Thick beds of water chestnut can cause significant declines in dissolved oxygen that negatively affect sensitive fauna (Hummel and Findlay, 2006). The nearly impenetrable mats are of virtually no use to wildlife and interfere with boating, fishing and swimming, while the large, spiny nuts can cause injuries to swimmers (ISSG, 2005). *T. natans* sets abundant seed, making it difficult to eradicate once it is introduced (Les and Mehrhoff, 1999).

Taxonomic Tree

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- Domain: Eukaryota
  - Kingdom: Plantae
    - Phylum: Spermatophyta
      - Subphylum: Angiospermae
        - Class: Dicotyledonae
          - Order: Myrtales
            - Family: Trapaceae
              - Genus: Trapa
                - Species: Trapa natans

Notes on Taxonomy and Nomenclature

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The genus *Trapa* L. has been reported as having extremely confusing morphology worldwide; it has previously been classified as one polymorphic group or as one genus having up to around 20 different species (Takano and Kadono, 2005). The genus *Trapa* is presently placed in the monogeneric family Trapaceae (Missouri Botanical Garden, 2010), otherwise sometimes in the family Lythraceae (USDA-ARS, 2008), though it has also been placed in Hydrocaryaceae (Hummel and Kiviat, 2004) or in the family Onagraceae (Hsuan Keng, 1978). Most botanists recognize two species in the *Trapa* genus: *T. bicornis* and *T. natans*. *T. natans* is an important food crop; many regional varieties are grown in different parts of the world. Official accounts recognize two: *T. natans* var. *natans* L. and var. *bispinosa* (ITIS, 2007). In general, European lines are early flowering, but have lower yield, Asian lines have higher rosette densities and small fruits, while the Chinese and Indian lines have higher yields due to their large fruits (Lalith et al., 2007; Pshennikova, 2007).

Description

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T. natans is an herbaceous, floating-leaf aquatic species that often grows in water around 60 cm deep (PFAF, 2000). The floating leaves are arranged in a rosette, with leathery upper leaves up to 5 cm wide and broadly rhomboid, triangular, deltoid or broadly ovate (Hummel and Kiviat, 2004). The leaves are sharply serrate, with conspicuous venation and short, stiff hairs. The species also produces submersed leaves that are strikingly morphologically different (Bitonti et al., 1996). The submersed leaves are alternate, finely divided, and can grow up to 15 cm long (Mehrhoff et al., 2003). The petioles of the floating leaves have a spongy floating section that allows for the flotation of the leaf rosette, and each stem may produce several rosettes (Hummel and Kiviat, 2004). The plant also has white flowers with four 8 mm-long petals and four green sepals. The fruit is a single-seeded horned nut-like structure, sometimes referred to as a "turbinate drupe" that develops underwater and is approximately 3 cm wide (Mehrhoff et al., 2003). Single flowers are produced in axils of floating leaves (Hummel and Kiviat, 2004). The stem of the plant is flexible, from 1 to 5 m long, nodes of the stem have slender linear roots, while the plant is anchored in the sediment by the lower roots that emerged from the propagating seed hull (Hummel and Kiviat, 2004).

Plant Type

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Annual
Broadleaved
Herbaceous
Seed propagated
Vegetatively propagated

Distribution

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The genus *Trapa* is cultivated worldwide for the harvest of its large, nutritious nut. It currently occupies a wide yet discontinuous native range across Europe, Asia, and Africa, and has been introduced to North America and Australia. It was more widespread in Tertiary times than it is currently (Ithaka Harbors Inc, 2008). The variety *T. natans* var. *natans,* with its four-spined nutis widely distributed in Eurasia, Africa and the northeastern United States, whereas *T. natans* var. *bispinosa* (also known as *T. bicornis, T. bicornuta,* or *T. japonica)* a two-spined variety, grows in China, Japan, India and Southeast Asia (Hummel and Kiviat, 2004). It is preferentially associated with low-energy, high-nutrient systems (USDA-NRCS, 2008).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Asia							
Bangladesh (/isc/datasheet/108369)	Present		Native			The Bayscience Foundation, 2008	
China (/isc/datasheet/108398)	Unconfirmed record					, ; GBIF, 2008	
-Fujian (/isc/datasheet/108670)	Present		Native			The Bayscience Foundation, 2008	
-Guangdong (/isc/datasheet/108671)	Present		Native			The Bayscience Foundation, 2008	
-Guizhou (/isc/datasheet/108674)	Present		Native			The Bayscience Foundation, 2008	
-Hainan (/isc/datasheet/108675)	Present		Native			The Bayscience Foundation, 2008	
-Hubei (/isc/datasheet/108676)	Present		Native			The Bayscience Foundation, 2008	
-Hunan (/isc/datasheet/108681)	Present		Native			The Bayscience Foundation, 2008	
-Sichuan (/isc/datasheet/108691)	Present		Native			The Bayscience Foundation, 2008	
-Tibet (/isc/datasheet/108697)	Present		Native			The Bayscience Foundation, 2008	
-Xinjiang (/isc/datasheet/108696)	Present		Native			The Bayscience Foundation, 2008	
-Yunnan (/isc/datasheet/108698)	Present		Native			The Bayscience Foundation, 2008	
Georgia (Republic of) (/isc/datasheet/108433)	Present		Native		Not invasive	ISSG, 2007	
India (/isc/datasheet/108459)	Present		Native		Invasive	ISSG, 2007	Northwest India
Indonesia (/isc/datasheet/108455)	Present		Native			The Bayscience Foundation, 2008	
Japan (/isc/datasheet/108467)	Present		Native		Invasive	ISSG, 2007	
Laos (/isc/datasheet/108481)						The Bayscience Foundation, 2008	
Pakistan (/isc/datasheet/108537)	Present		Native		Not invasive	ISSG, 2007	
Philippines (/isc/datasheet/108535)	Present		Native			The Bayscience Foundation, 2008	
Taiwan (/isc/datasheet/108590)	Present					GBIF, 2008	
Thailand (/isc/datasheet/108580)	Present					GBIF, 2008	
Turkey (/isc/datasheet/108587)	Present		Native		Not invasive	ISSG, 2007	Present in Northwest Turkey

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Vietnam (/isc/datasheet/108604)	Present		Native		Not invasive	ISSG, 2007	
Africa							
Algeria (/isc/datasheet/108415)	Present		Native		Not invasive	ISSG, 2007	
Angola (/isc/datasheet/108357)	Present		Native		Not invasive	ISSG, 2007	
Botswana (/isc/datasheet/108385)	Present		Native		Not invasive	ISSG, 2007	
Burkina Faso (/isc/datasheet/108371)	Present		Introduced		Invasive	ISSG, IUCN SSC Invasive Species Specialist Group; GBIF, 2008	
Guinea-Bissau (/isc/datasheet/108447)	Present		Native		Not invasive	ISSG, 2007	Present in Cacheu
Malawi (/isc/datasheet/108512)	Present		Native		Not invasive	ISSG, 2007	
Mozambique (/isc/datasheet/108515)	Present		Native		Not invasive	ISSG, 2007	
Namibia (/isc/datasheet/108516)	Present		Native		Not invasive	ISSG, 2007	
Niger (/isc/datasheet/108518)						The Bayscience Foundation, 2008	
Nigeria (/isc/datasheet/108520)	Present					GBIF, 2008	
South Africa (/isc/datasheet/108613)	Present		Native		Not invasive	ISSG, 2007	Present in Natal
Tanzania (/isc/datasheet/108591)	Present		Native		Not invasive	ISSG, 2007	
Tunisia (/isc/datasheet/108584)	Present		Native		Not invasive	ISSG, 2007	
Uganda (/isc/datasheet/108594)	Present		Native		Not invasive	ISSG, 2007	
Zambia (/isc/datasheet/108614)	Present		Native		Not invasive	ISSG, 2007	
Zimbabwe (/isc/datasheet/108616)	Present		Native		Not invasive	ISSG, 2007	
North America							
Canada (/isc/datasheet/108388)	Present						Present based on regional distribution.
-Quebec (/isc/datasheet/108663)	Present		Introduced		Invasive	O'Neill, 2006	
USA (/isc/datasheet/108597)	Present						
-Connecticut (/isc/datasheet/108801)	Present		Introduced	1999	Invasive	O'Neill, 2006	
-Delaware (/isc/datasheet/108803)	Present		Introduced		Invasive	USDA-NRCS, 2008	
-Maryland (/isc/datasheet/108815)	Present		Introduced		Invasive	O'Neill, 2006	
-Massachusetts (/isc/datasheet/108814)	Present					O'Neill, 2006	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-New Jersey (/isc/datasheet/108826)	Present		Introduced		Invasive	USDA-NRCS, 2008	
-New York (/isc/datasheet/108829)	Unconfirmed record					, ; O'Neill, 2006	
-Pennsylvania (/isc/datasheet/108833)	Present		Introduced		Invasive	O'Neill, 2006	
-Vermont (/isc/datasheet/108841)	Present		Introduced		Invasive	O'Neill, 2006	
-Virginia (/isc/datasheet/108840)	Eradicated		Introduced		Invasive	ISSG, 2007	
Europe							
Albania (/isc/datasheet/108354)	Present		Native		Not invasive	ISSG, 2007	
Austria (/isc/datasheet/108361)	Present		Native		Not invasive	ISSG, 2007	
Belarus (/isc/datasheet/108386)	Present		Native		Not invasive	ISSG, 2007	
Belgium (/isc/datasheet/108370)	Present					ISSG, 2007	
Bosnia-Hercegovina (/isc/datasheet/108367)	Present		Native		Not invasive	ISSG, 2007	
Bulgaria (/isc/datasheet/108372)	Present		Native		Not invasive	ISSG, 2007	
Czech Republic (/isc/datasheet/108409)	Present		Native		Not invasive	ISSG, 2007	
Denmark (/isc/datasheet/108412)	Present					GBIF, 2008	
Finland (/isc/datasheet/108424)	Present					GBIF, 2008	
France (/isc/datasheet/108429)	Present		Native		Not invasive	ISSG, 2007	
Germany (/isc/datasheet/108410)	Present		Native		Not invasive	ISSG, 2007	
Greece (/isc/datasheet/108443)	Present		Native		Not invasive	ISSG, 2007	
Hungary (/isc/datasheet/108454)	Present		Native		Not invasive	ISSG, 2007	
Italy (/isc/datasheet/108464)	Unconfirmed record					, ; ISSG, 2007	
Latvia (/isc/datasheet/108491)	Present		Native			GBIF, 2008	
Netherlands (/isc/datasheet/108522)	Present					GBIF, 2008	
Poland (/isc/datasheet/108538)	Present					ISSG, 2007	
Romania (/isc/datasheet/108548)	Present		Native		Not invasive	ISSG, 2007	
Russian Federation (/isc/datasheet/108550)	Present		Native			The Bayscience Foundation, 2008	
Sweden (/isc/datasheet/108556)	Present					GBIF, 2008	
Switzerland (/isc/datasheet/108393)	Present		Native		Not invasive	ISSG, 2007	
Ukraine (/isc/datasheet/108592)	Present		Native		Not invasive	ISSG, 2007	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Oceania							
Australia (/isc/datasheet/108362)	Present		Introduced			ISSG, 2007	

Introductions

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Introduced to	Introduced from	Year	Reason	Introduced by	Established in wild through		References	Notes
					Natural reproduction	Continuous restocking		
Connecticut		1999						
Massachusetts	Europe	1879	Aquaculture (pathway cause) (/isc/datasheet/109023) , Botanical gardens and zoos (pathway cause) (/isc/datasheet/109025)				Les and Mehrhoff (1999)	
New York		1884	Aquaculture (pathway cause) (/isc/datasheet/109023) , Botanical gardens and zoos (pathway cause) (/isc/datasheet/109025)					
Vermont		1940s	Hitchhiker (pathway cause) (/isc/datasheet/109037)				Les and Mehrhoff (1999)	

Risk of Introduction

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T. natans has largely been spread as a result of intentional plantings. There have been many reports of escape from cultivation, and the species was originally introduced as an ornamental (Les and Mehrhoff, 1999). *T. natans* remains well-established in the North Eastern United States to this day (Hummel and Kiviat, 2004). The plant annually produces nuts that sink to the sediment and germinate. The rough spines of the fruit make it generally unpalatable to wildlife, reducing the likelihood of the species being spread this way. Instead, seeds disperse passively, being carried by water currents as they drop to the sediment surface (Boylen et al., 2006). The spines of the fruit also allow it to spread over longer distances as a hitchhiker, when it clings to boats and gear (Hummel and Kiviat, 2004).

Habitat

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T. natans is found world-wide in full sun and low-energy, nutrient-rich fresh waters (Hummel and Kiviat, 2004). It is commonly found in waters with alkalinity ranging from 12 to 128 mg/L of calcium carbonate (O'Neill, 2006), and dislikes calcium-rich waters (PFAF, 2000). Mixed reports exist on the depths of water typically inhabited by *T. natans*. Some sources report the plant can grow in water up to 5 m deep (Pemberton, 2002), others report that *T. natans* can be found in depths ranging from 0.3 to 3.6 m (Hummel and Kiviat, 2004), whereas others report a maximum depth of 0.6 m (PFAF, 2000). Hummel and Kiviat (2004) report that the species is found most abundantly in water around 2 m deep and in soft substrate. It also prefers slightly acidic water (PFAF, 2000), although germination can occur in water with pH ranging from 4.2 to 8.3 (Hummel and Kiviat, 2004). The species is disturbance-tolerant; it has been shown that sewage inputs create favourable conditions of increased alkalinity for the plant, and that increased nitrogen is correlated with increased petiole and fruit biomass. *T. natans* does not tolerate salinity; its seeds will not germinate when NaCl concentrations exceed 0.1% (Hummel and Kiviat, 2004).

Habitat List

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Category	Habitat	Presence	Status
Freshwater	Irrigation channels	Present, no further details	Harmful (pest or invasive)
	Irrigation channels	Present, no further details	Productive/non-natural
	Lakes	Principal habitat	Harmful (pest or invasive)
	Lakes	Principal habitat	Productive/non-natural
	Ponds	Principal habitat	Harmful (pest or invasive)
	Ponds	Principal habitat	Productive/non-natural
	Reservoirs	Principal habitat	Harmful (pest or invasive)
	Reservoirs	Principal habitat	Productive/non-natural
	Rivers / streams	Principal habitat	Harmful (pest or invasive)
	Rivers / streams	Principal habitat	Productive/non-natural

Hosts/Species Affected

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Where conditions are favourable, *T. natans* can cover almost 100% of the water surface and shade up to 95% of sunlight (Hummel and Kiviat, 2004). Thus, the effects of the species on native vegetation in its adventive range are significant. Water chestnut is considered an invasive, destructive species, and has been implicated in the loss of many other plant and animal species. In the Hudson River, for instance, the plant has replaced water celery (*Vallisneria americana*), clasping pondweed (*Potamogeton perfoliatus* .) nonindigenous Eurasian watermilfoil (*Myriophyllum spicatum* .). However, the shelter created by the rosettes is beneficial for duckweeds (*Lemna minor* , *Spirodela polyrhiza*. and *Wolffia* spp.) and filamentous algae. Other emergent species that grow above the waterline, including cattail (*Typha angustifolia*), pickerelweed (*Pontederia cordata*), and spatterdock (*Nuphar advena*) are unaffected by the presence of *T. natans* (Hummel and Kiviat, 2004).

Host Plants and Other Plants Affected

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Plant name	Family	Context
Myriophyllum spicatum (spiked watermilfoil) (/isc/datasheet/34941)	Haloragidaceae	Wild host
Potamogeton perfoliatus (/isc/datasheet/43669)	Potamogetonaceae	Wild host
Vallisneria americana (Vallisneria) (/isc/datasheet/56571)	Hydrocharitaceae	Wild host

Growth Stages

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Flowering stage, Fruiting stage, Pre-emergence, Seedling stage, Vegetative growing stage

Biology and Ecology

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Genetics

The taxonomy of the genus *Trapa* is confusing, it has been varyingly considered as part of one polymorphic group, or as a genus with approximately 20 species. Enzyme electrophoresis indicates, for example, three distinct lineages in the Japanese *Trapa*. The analysis indicates that two varieties of *Trapa* have different chromosome numbers (2n = 96 and 2n = 48). However, the authors recognize that despite the distinct genetic differences, the species *T. natans* and *T. bispinosa* may be a polymorphism of the same single species (Takano and Kadono, 2005). A different study identified genotypic variation as an important factor affecting organogenesis in more than 18 different *T. natans* genotypes drawn from all over the world (Aminul Hoque et al., 2007). However, the current tendency is to consider the family Trapaceae as a single monogeneric group containing two species that exhibit high genetic and morphological variation. Missouri Botanical Garden (2010) refers to a study showing chromosome numbers of 44, 46, 48, 90 and 96-97).

Reproductive Biology

T. natans is an annual species that produces single, bisexual flowers on stalks produced from the centre of the floating rosettes. The flower has a two-chambered ovary, four stamens, four petals, and four sepals that eventually become the spines of the fruit (GBIF, 2008). The flowers are generally pollinated by insects, but self-pollination may occur before the flower opens (Hummel and Kiviat, 2004). Once fertilized, the flower stalks droop downward, allowing the ovary to develop underwater into a nut-like barbed fruit (GBIF, 2008). The seed has two unequal cotyledons, one of which is large and starchy. Each seed produces 10 to 15 rosettes, and each rosette can give rise to up to 20 seeds (O'Neill, 2006). Seeds can remain dormant in the sediments for up to 10 years but do not tolerate dessication (Hummel and Kiviat, 2004). Vegetative reproduction is also very important to the growth and spread of the plant. The plant produces ramets that can break off and move away from the rest of the clone and survive to produce seeds. This attribute allows for extremely rapid clonal expansion, for example, a 10-fold increase was documented in 1 year in Lake Champlain (Groth et al., 1996). In fact, it has been suggested that this annual plant might act as a perennial in parts of its exotic range, mainly through rapid proliferation from clonal fragments year to year (Groth et al., 1996).

Physiology and Phenology

In spring (May in the Northeastern USA), stems bearing leaf rosettes elongate toward the surface of the water. The rosettes flourish and remain green until autumn. The plant begins to flower in early summer, and can continue to flower through to autumn (June to September in its North American range). The fruits mature mid-summer through autumn, after which they sink to the sediment when the plant begins to senesce. The plant quickly decomposes, but the seeds can stay dormant for up to 10 years. The nut overwinters in the sediment, but when water temperature rises to 12 ºC, the terminal pore begins to rot, and around 1 month later, the seed germinates (Hummel and Kiviat, 2004).

Associations

T. natans is an extremely widespread species and its worldwide distribution means it has a great many associates.

Environmental Requirements

In its alien range, *T. natans* can grow in any freshwater setting (Swearingen et al., 2002) and is found typically in water from 0.3 to 3.6 m deep (Hummel and Kiviat, 2004). It is restricted to low-energy systems and favours nutrient-rich waters with pH from 6.7 to 8.2 and alkalinity from 12 to 128 mg/L calcium carbonate (O'Neill, 2006).

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Climate

Climate	Status	Description	Remark
A - Tropical/Megathermal climate	Tolerated	Average temp. of coolest month > 18°C, > 1500mm precipitation annually	
Am - Tropical monsoon climate	Tolerated	Tropical monsoon climate (< 60mm precipitation driest month but > (100 - [total annual precipitation(mm}/25]))	
Aw - Tropical wet and dry savanna climate	Tolerated	< 60mm precipitation driest month (in winter) and < (100 - [total annual precipitation{mm}/25])	
B - Dry (arid and semi-arid)	Tolerated	< 860mm precipitation annually	
C - Temperate/Mesothermal climate	Preferred	Average temp. of coldest month > 0°C and < 18°C, mean warmest month > 10°C	
Cf - Warm temperate climate, wet all year	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, wet all year	
Cs - Warm temperate climate with dry summer	Preferred	Warm average temp. > 10°C, Cold average temp. > 0°C, dry summers	
Cw - Warm temperate climate with dry winter	Preferred	Warm temperate climate with dry winter (Warm average temp. > 10°C, Cold average temp. > 0°C, dry winters)	
D - Continental/Microthermal climate	Tolerated	Continental/Microthermal climate (Average temp. of coldest month < 0°C, mean warmest month > 10°C)	
Ds - Continental climate with dry summer	Tolerated	Continental climate with dry summer (Warm average temp. > 10°C, coldest month < 0°C, dry summers)	

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Soil Tolerances

Soil drainage

seasonally waterlogged

Soil reaction

acid
alkaline
neutral

Soil texture

heavy
light
medium

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Aix sponsa (/isc/datasheet/95160)	Herbivore					
Anser fabalis (/isc/datasheet/94088)	Herbivore					
Athelia rolfsii (/isc/datasheet/49155)	Pathogen	Whole plant	not specific			
Bagous (/isc/datasheet/8295)	Herbivore					
Bagous rufimanus (/isc/datasheet/108228)	Herbivore	Fruits/pods/Stems	not specific			
Bagous tersus (/isc/datasheet/108226)	Herbivore	Leaves				
Bagous trapae (/isc/datasheet/108227)	Herbivore	Stems				
Bagous vicinus (/isc/datasheet/8300)	Herbivore					
Bipolaris tetramera (/isc/datasheet/108222)	Pathogen	Leaves				
Botryotinia fuckeliana (/isc/datasheet/9611)	Pathogen	Whole plant	not specific			
Castor canadensis (/isc/datasheet/90583)	Herbivore	Fruits/pods/Leaves				
Cercospora (/isc/datasheet/12178)	Pathogen	Leaves	not specific			
Chironomus (/isc/datasheet/13020)	Herbivore	Leaves				
Galerucella birmanica (/isc/datasheet/24794)	Herbivore	Leaves				
Galerucella nymphaeae (/isc/datasheet/24801)	Herbivore	Leaves	not specific			
Galerucella singhara (/isc/datasheet/108232)	Herbivore	Leaves				
Lymnaea auricularia (/isc/datasheet/75927)	Herbivore	Leaves	not specific			
Macrosteles purpurata (/isc/datasheet/108229)	Herbivore	Leaves	not specific			
Nanophyes (/isc/datasheet/35697)	Herbivore	Leaves				
Nanophyes japonica (/isc/datasheet/108230)	Herbivore	Leaves				
Nanophyes rufipes (/isc/datasheet/108225)	Herbivore					
Nymphula (/isc/datasheet/36764)	Herbivore	Leaves				
Nymphula crisonalis (/isc/datasheet/108223)	Herbivore	Leaves				
Nymphula gangeticalis (/isc/datasheet/108224)	Herbivore	Leaves				
Nymphula interruptalis (/isc/datasheet/108221)	Herbivore	Inflorescence/Leaves	not specific			
Nymphula responsalis (/isc/datasheet/36766)	Herbivore	Inflorescence/Leaves	not specific			
Odocoileus virginianus (/isc/datasheet/72770)	Herbivore	Leaves				
Ondatra zibethicus (/isc/datasheet/71816)	Herbivore					
Parapoynx vittalis (/isc/datasheet/108231)	Herbivore	Leaves	not specific			

Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Rattus norvegicus (/isc/datasheet/46829)	Herbivore					
Rhopalosiphum nymphaeae (/isc/datasheet/47320)	Herbivore	Leaves	not specific			
Sciurus carolinensis (/isc/datasheet/49075)	Herbivore	Fruits/pods/Leaves				
Sclerotium hydrophilum (/isc/datasheet/49150)	Pathogen	Leaves				
Spodoptera litura (/isc/datasheet/44520)	Herbivore	Leaves	not specific			
Tamias striatus (/isc/datasheet/62791)	Herbivore					
Tamiasciurus hudsonicus (/isc/datasheet/52698)	Herbivore					

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Notes on Natural Enemies

Many natural enemies in the native range of *T. natans* have been documented by Pemberton (1999). The plant is native to the Old World, and many enemies (insects, fungi, viruses) are found throughout its native range. Of the currently explored enemies, he reports that the most common and damaging species in Asia is the weevil *Galerucella birmanica* which causes complete defoliation of entire populations and is also somewhat host-specific (oligophagous). Hummel and Kiviat (2004) report observations on natural enemies in the plant's alien range. *T. natans* is productive and is occasionally a nuisance in its native range, therefore, natural enemies are extremely important to keep populations in check. A major reason behind why the plant is so problematic in its introduced range is precisely because of release from predation (O'Neill, 2006).

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Means of Movement and Dispersal

Natural Dispersal

T. natans disperses primarily through water flow. The nuts are 20% heavier than the surrounding water, and as the nuts sink downward, water currents carry them a short distance away from the parent plant. Additionally, when ramets break, groups of rosettes can detach from the clone and float a long distance to establish a new population much further away from the parent plant (Hummel and Kiviat, 2004).

Vector Transmission

Humans may be the primary vector of transmission. *T. natans* has been historically valued as an ornamental; its escape from ornamental and botanical gardens that probably explains the invasion of the plant in the New World (Les and Mehrhoff, 1999). Although still available from online distributors, current educational efforts aim to decrease the probability that this plant will be intentionally introduced, and hopefully cut down on accidental release in areas where this plant has been declared a noxious weed. Les and Mehrhoff (1999) report observations of nuts attached to the feathers of geese, although they hypothesize that due to the size and weight of the nuts (6 g), it is unlikely that they would remain attached during prolonged flight, so although waterfowl may be a possible vector of transmission, dispersal in this manner probably only occurs over short distances.

Accidental Introduction

Humans can serve as a transmissive vector: the nuts have spines that allow the seed to move as a hitchhiker on boats and attached equipment (Les and Mehrhoff, 1999). This factor has contributed to the spread of *T. natans* in its alien range from the Hudson River to Lake Champlain via interconnected waterways (Les and Mehrhoff, 1999).

Intentional Introduction

T. natans was intentionally introduced into its alien range around the end of the nineteenth century (Les and Mehrhoff, 1999). The species remains an attractive water garden plant as well as a valuable food crop, and it is possible that intentional introduction will help expand this species' range further.

Pathway Causes

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Cause	Notes	Long Distance	Local	References
Aquaculture (/isc/datasheet/109023)		Yes	Yes	O'Neill, 2006
Botanical gardens and zoos (/isc/datasheet/109025)		Yes	Yes	O'Neill, 2006
Escape from confinement or garden escape (/isc/datasheet/109030)			Yes	O'Neill, 2006
Hitchhiker (/isc/datasheet/109037)		Yes	Yes	Les and Mehrhoff, 1999
Horticulture (/isc/datasheet/109038)		Yes	Yes	Hummel and Kiviat, 2004
Intentional release (/isc/datasheet/109041)		Yes	Yes	Les and Mehrhoff, 1999
Interbasin transfers (/isc/datasheet/109042)			Yes	GBIF, 2008
Interconnected waterways (/isc/datasheet/109043)			Yes	
Internet sales (/isc/datasheet/109044)		Yes	Yes	
Ornamental purposes (/isc/datasheet/109051)		Yes	Yes	Hummel and Kiviat, 2004

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Aquaculture stock (/isc/datasheet/109062)		Yes	Yes	Hummel and Kiviat, 2004
Floating vegetation and debris (/isc/datasheet/109069)			Yes	GBIF, 2008
Machinery and equipment (/isc/datasheet/109075)		Yes	Yes	Hummel and Kiviat, 2004
Ship structures above the water line (/isc/datasheet/109082)		Yes	Yes	Hummel and Kiviat, 2004
Water (/isc/datasheet/109085)			Yes	GBIF, 2008

Impact Summary

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Category	Impact
Cultural/amenity	Positive and negative
Economic/livelihood	Positive and negative
Environment (generally)	Positive and negative
Human health	Positive and negative

Economic Impact

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T. natans is an economic asset in its native range as it is an important food crop and a staple in many areas. However, in its introduced range, the plant is a significant nuisance. The economic cost of *T. natans* in the northeastern United States is not well documented (Pemberton, 2002), but we do know that from 1982 to 2001, $4.3 million dollars were spent on the control of *T. natans* in the Lake Champlain basin alone (Naylor, 2003). The largest control program, which takes place in Vermont, USA, was estimated to cost $500,000 in the year 2000 (Pemberton, 2002).

Environmental Impact

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Impact on Habitat

T. natans can have severe impacts on the environment. When compared to areas vegetated by native species, areas under *T. natans* beds experienced higher variation in (varying) dissolved oxygen (DO) levels. In a study on the Hudson River, dangerously low DO values (below 5 mg/L) occurred 51% of the time, and levels below 2.5 mg/L occurred 30% of the time, while DO below 5 mg/L *never* occurred in native *Vallisneria* beds (Caraco and Cole, 2002). These observed low levels can be lethal to fish, and consequently cause the migration of small fish from under the canopy to the edges of the beds, which in turn can cause the congregation of game fish at the edges of the beds (O'Neill, 2006).

Where the plant is very abundant, up to 50 rosettes can grow within 1 square metre, covering the water with up to three layers of leaves (Pemberton, 2002). The high density growth of which *T. natans* is capable can result in a decrease in light penetration. In one study that occurred in the Hudson River, only 0.5% of incident light reached a depth of 0.2 metres underneath large beds of *T. natans* (Caraco and Cole, 2002). Yet other studies report the species' general ability to intercept 95% of incident light (Hummel and Kiviat, 2004).

Impact on Biodiversity

Due to the species' ability to shade out other submersed vegetation, it is generally considered a threat to biodiversity in its introduced range. The species also has an effect on epiphyton communities. In its native range, epiphyton development was shown to be significantly higher on submerged plants than on *T. natans*, while taxonomic composition of epiphytic algae, but not macroinvertebrates, was higher on *T. natans* (Cattaneo et al., 1998).

Social Impact

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This plant can cause substantial nuisance to recreational users by impeding navigation and tangling fishing line. This species has little nutritional benefit for fish or waterfowl, and can have detrimental effect on native game species that utilize the area. Additionally, the sharp spines present on the nuts can result in puncture wounds to swimmers (O'Neill, 2006). The plant may have played a role in the drowning deaths of a woman and two children in 2001 on the Hudson River (Hummel and Kiviat, 2004). Some people eat the chestnuts raw and ingest the giant intestinal fluke *Fasciolopsis buski* that is known to cause fasciolopsiasis, and the beds are known to be good breeding grounds for mosquitoes (Hummel and Kiviat, 2004). However, there is evidence that the *T. natans* nuts have been consumed by humans as early as 8000 BC. Currently the nut is valued worldwide for both its nutritional value as well as its medicinal properties.

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Risk and Impact Factors

Invasiveness

Invasive in its native range
Proved invasive outside its native range
Has a broad native range
Reproduces asexually

Impact outcomes

Negatively impacts livelihoods

Likelihood of entry/control

Highly likely to be transported internationally deliberately
Difficult to identify/detect as a commodity contaminant

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Uses

Economic Value

T. natans has long been consumed by humans across the globe (Hummel and Kiviat, 2004). The nuts have a high moisture content and are valued for quenching thirst as well as being used as a source of flour that forms the base for many different food products (Hummel and Kiviat, 2004). Nuts are composed of 15% protein, 7.5% fat, 52% starch, 3% sugar and 22.5% water (Hummel and Kiviat, 2004). Singhara nut plants (related subspecies) are highly productive and are capable of high yields (typically 260-370 g/m2 and up to 550 g/m2) (Hummel and Kiviat, 2004). As well as being an important food source, the nut has also been recommended for use as paper pulp, fertilizer, fish food, compost and biofuel (Hummel and Kiviat, 2004).

Social Benefit

The plant is used medicinally to treat rabies, poisonous animal bites, diarrhea, amoebic dysentery and other complications (Hummel and Kiviat, 2004).*T. natans* has also been used in a herbal mixture that has proven to provide relief from the symptoms associated with recurrent herpes genitalis and labialis (Hijikata et al., 2007).The rind of the fruit has been discovered to have antibacterial activity, and is primarily effective against gram negative bacteria (Parekh and Chanda, 2007).

Environmental Services

While being widely reported as productive, and as a nuisance in its invasive range, *T. natans* is capable of some environmental services. The plant is able to fix a large quantity of nitrogen and phosphorus (Marion and Paillisson, 2003). This attribute conveys a certain amount of potential for the plant to be used as a tool to reduce eutrophication, however, the vegetation must be removed annually prior to its decay and subsequent release of sequestered nutrients (Hummell and Kiviat, 2004). Water chestnut may also be used in environmental reclamation, as it is capable of accumulating heavy metals, although not at levels as high as other species commonly used in this capacity (Hummel and Kiviat, 2004).

Uses List

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Animal feed, fodder, forage

Fishmeal

Environmental

Landscape improvement
Revegetation
Wildlife habitat

Fuels

Biofuels

General

Botanical garden/zoo
Ritual uses
Sociocultural value

Human food and beverage

Flour/starch
Nuts
Sugar

Materials

Chemicals
Essential oils
Fertilizer
Fibre

Medicinal, pharmaceutical

Source of medicine/pharmaceutical
Traditional/folklore

Detection and Inspection

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The distinct floating rosette makes this aquatic species easier than most to detect soon after invasion.

Similarities to Other Species/Conditions

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T. natans is unlikely to be readily confused with native plants in its adventive range. The distinctive floating rosette of leathery green leaves and the production of large horned nuts means it is highly morphologically distinct from other floating-leaf species. The two most commonly recognized varieties are distinguished based on the number of spines. The Eurasian/European varieties always have four spines, whereas the Asian varieties (*Trapa natans* var. *bispinosa*) have two spines.

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Prevention and Control

Prevention

Since *T. natans* remains valued for its nutritional and cultural uses, and since it is still a plant of botanical interest, educational programs must be directed to educate the public about the dangers this plant poses outside of its native range. Teaching users how to clean equipment in a way that decreases the chance of transmission is one way to lessen the impact of human-mediated transport. Several of the United States have legislated the regulation of the purchase, transportation, and introduction of this species.

Rapid response

It is much easier and more effective to attempt to control this plant early in its introduction timeline. Small populations are effectively controlled by hand pulling, preferably prior to the production of the propagating nuts. If the infestation is allowed to persist, it will probably grow quickly. It has been reported that this species is capable of increasing its biomass by ten times in a single year (Groth et al., 1996). Large infestations must be controlled by mechanical harvesters or herbicides and can be quite costly (O’Neill, 2006).

Public awareness

Numerous educational campaigns have been directed at informing the public about the danger of aquatic invasive species in states of the USA in which *T. natans* is particularly problematic commonly distribute informational materials about its identity as well as instructions on how to report new invasions. Other educational campaigns have been directed toward informing the public about how to clean equipment in order to prevent the movement of invasive species.

Eradication

It has been reported that this species was eradicated from the state of Virginia, USA (ISSG, 2007).

Control

Cultural control and sanitary measures

Nuts, though large and not as portable as propagules of other aquatic invasive species can remain dormant for up to 10 years, so it is extremely important to decrease the instances of accidental introduction by addressing humans as vectors. Additionally, since the plant is capable of producing ramets and engaging in vegetative clonal expansion via plant fragments, establishing guidelines on how to properly clean equipment, dispose of water, and identify target plants will probably decrease instances of accidental transportation and release.

Physical/mechanical control

Since the seeds of *T. natans* can remain dormant for up to 10 years, annual control efforts for at least that long must be undertaken in order for there to be a chance of eradication (O’Neill, 2006). Large beds must be mechanically harvested, but this will provide relief for only one growing season (O’Neill, 2006). Smaller areas of infestation can be addressed with hand pulling, although care must be exercised that all parts of the plant be removed, lest fragments remain to mature and produce fruits (Hummel and Kiviat, 2004). Ultrasound has also been proposed as a possible method of control. After treatment of the stem with ultrasound for 10 seconds, a mortality rate of 97.6% was reported (Wu, 2007).

Movement control

Plants can spread locally as nuts and fragments drift in water currents, but most attention should be given to addressing forms of human-mediated transport. A number of the United States have enacted legislation limiting the introduction, sale, transportation and trafficking of the species in an attempt to limit the rate of accidental or intentional introduction (USDA-NRCS, 2008).

Biological control

Much attention has been given to discovering methods of biological control. Grass carp *Ctenopharyngodon idella* has been used to control water chestnut (Hummel and Kiviat, 2004). However, grass carp are non-selective herbivores that will almost certainly harm native species. Much research has been forwarded on the use of herbivorous insects from the plant's native range (Pemberton, 1999). Of the explored species, the leaf beetle *Galerucella birmanica* has shown the most promise. Although concerns regarding its specificity were forwarded early on in the research process, it has since been shown that although capable of completing its life cycle using native *Brasenia schreberi*, *G. birmanica* exhibits a strong preference in the laboratory and in the field for *T. natans*, with only occasional "spill-over" of beetles onto *B. schreberi* (Ding et al., 2006).

Chemical control

Some control of water chestnut has been documented with subsurface applications of triclopyr and 2,4-D amine. However, the maximum control achieved was only 66% (Poovey and Getsinger, 2007). Due to its limited efficacy, if chemical control is used, it should be accompanied by other forms of physical control and removal.

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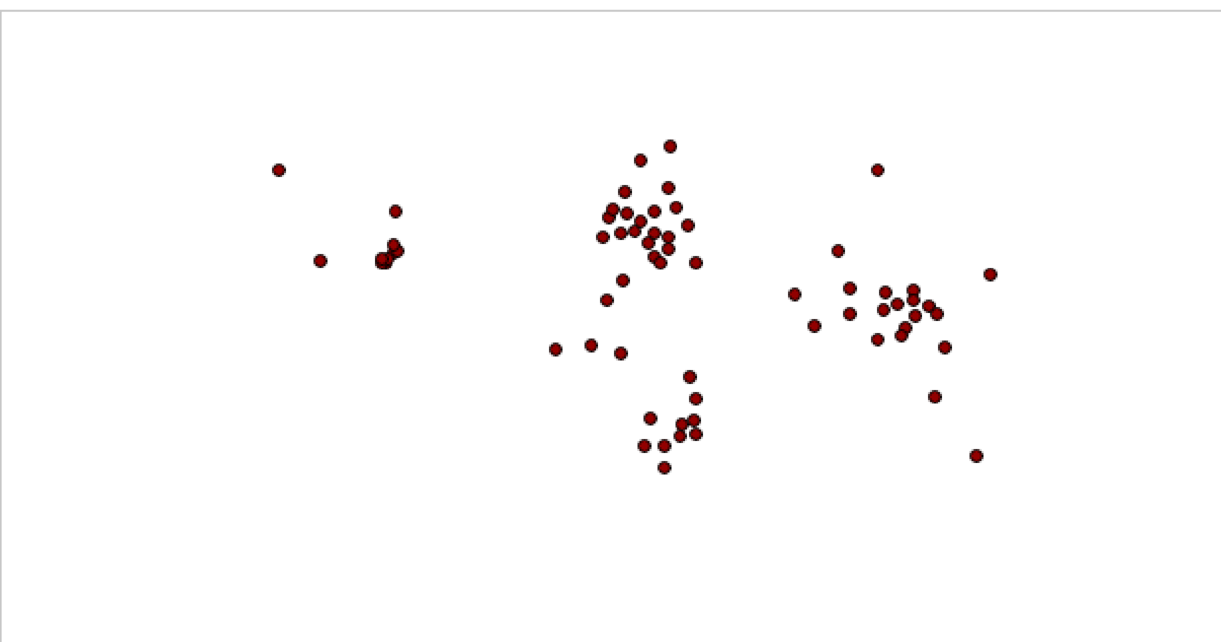
World Map

Analyzed by: Density

Present, no further details



Africa

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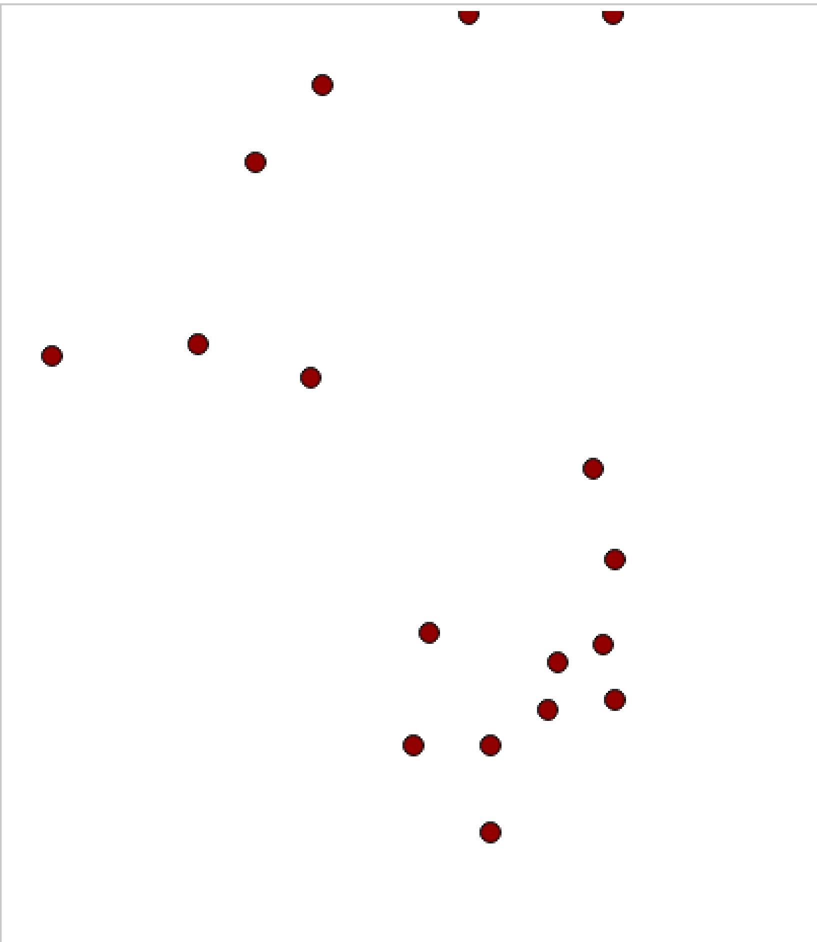

Asia

Europe

Pacific

North America

Central America

South America

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