Department of **Agriculture and Fisheries**
Biosecurity Queensland

Invasive plant risk assessment

Witchweeds

Striga spp.

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Front cover: An area of corn (maize) that has been severely stunted by *Striga* (in Africa)

Photo: CIMMYT undated, International Maize and Wheat Improvement Center – used with permission under a Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported license)

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Summary

The genus *Striga* comprises at least 30 species (the exact number of species is unclear due to taxonomic uncertainty). Three species, *Striga hermonthica*, *S. asiatica* and *S. gesnerioides*, are among the world's worst weeds. In Africa, these plants reduce the value of grain crop yields by an estimated US$7 billion each year.

Striga are obligate parasites that draw nutrients, water and carbohydrates from the roots of their hosts. Host plants include wheat, corn (maize), sorghum, rice, sugarcane and cowpeas.

Striga are most abundant in dry, infertile soils in semi-arid tropical grasslands and savannahs. In Africa, some of the most marginal cropping lands are located within these habitats. Hence, *Striga* often affects the poorest people.

In the United States, an estimated $250 million has been spent on eradication of *S. asiatica* from the Carolinas.

A single *Striga* plant can produce thousands of seeds that remain viable for over 15 years. Once established, eradication is extremely difficult and control programs are expensive and prolonged.

Based on the evidence presented in this study, it is reasonable to conclude that non-native species of *Striga* pose significant threats to Queensland grain production and exports.

Introduction

Identity and taxonomy

Identity: *Striga* species

Common names: Parasitic witchweeds, witchweeds

Family: Orobanchaceae (also placed in Scrophulariaceae)

There are at least 30 species of *Striga*. The exact number of species is unclear due to taxonomic uncertainty and multiple subspecies. Three species, *S. asiatica* (syn. *S. lutea*), *S. gesneriodes* and *S. hermonthica*, are the most problematic species within the genus and this risk assessment will focus on these.

Mohamed et al. (2001) listed most species within the genus (Table 1). Three species, *S. curviflora*, *S. multiflora* and *S. parviflora*, are native to Australia.

Table 1. List of *Striga* species (Mohamed et al. 2001) Note: list is not complete

***Striga* species**	**Authority**	**Distribution**
S. aequinoctialis	Chev. Ex Hutch. & Dalz.	W. Africa
S. angolensis	K. I. Mohamed & L. J. Musselman	Angola
S. angustifolia	(Don) Saldanha	E. Africa, Asia, Indonesia
S. asiatica syn. *S. lutea* (Asiatic witchweed, red witchweed)	(L.) Kuntz Loureiro	Africa, Arabian peninsula, India, Burma, China, Indonesia, Philippines, Malaysia, New Guinea, USA (introduced)
S. aspera	(Willd.) Benth.	Africa
S. bilabiate	(Thunb.) O. Ktze.	Africa
ssp. *barteri*	(Engl.) Heper	
ssp. *bilabiata*	Kuntze	
ssp. *ledermannii*	(Pilger) Hepper	
ssp. *linearifolia*	(Schum. & Thonn.) Mohamed	
ssp. *rowlandii*	(Engl.) Hepper	
S. brachycalyx	Sckan	Africa
S. chrysantha	A. Raynal	Central Africa
S. dalzielii	Hutch.	W. Africa
S. elegans (elegant witchweed)	Benth.	Angola, Malawi, S. Africa, Zimbabwe
S. forbesii (giant mealie witchweed)	Benth.	Africa, Madagascar

S. gastonii	A. Raynal	Chad and Central African Republic
S. gesnerioides syn. *S. orobanchoides* (cowpea witchweed, tobacco witchweed)	(Willd.) Vatke Benth.	Africa, Arabian peninsula, India, USA (introduced)
S. gracillima	Melch.	Tanzania
S. hallaei	A. Raynal	Gabon, Democratic Republic of Congo
S. hermonthica syn. *S. senegalensis* (purple witchweed)	(Del.) Benth. Benth.	Senegal to Ethiopia, Democratic Republic of Congo and Tanzania, Angola, Namibia
S. hirsuta	Benth.	Madagascar
S. junodii	Schinz	S. Africa, Mozambique
S. klingii	(Engl.) Skan	W. Africa, Nigeria, Ghana, Cameroon, Togo
S. latericea	Vatke	E. Africa, Ethiopia, Somalia
S. lepidagathidis	A. Raynal	Senegal, Guinea, Guinea Bissau.
S. lutea	Lour.	Sudan, Ethiopia
S. macrantha	(Benth.) Benth.	W. Africa, Nigeria, Ivory Coast, Togo
S. passargei	Engl.	W. & C. Africa, Arabian peninsula (?)
S. pinnatifida	Getachew	Ethiopia
S. primuloides	A. Chev.	Ivory Coast, Nigeria
S. pubiflora	Klotzsch	Somalia
S. yemenica	Musselman and Hepper	Ethiopia

Description

Most *Striga* are annual obligate root parasites of grasses and legumes (mainly grasses). Some species only emerge from below ground to produce flowers, spending much of their life underground and out of sight, robbing their host of nutrients and water. Hence, their local African name of 'witchweed'. They are generally seen growing at the base of various host plants.

Morphology varies across the genus. However, most species are only 15–20 cm tall when mature (some species to 60 cm). In general, *Striga* have bright green stems that are square in cross-section and 1–2.5 mm in diameter. The stems are sparsely covered with coarse, short, white, bulbous-based hairs. Leaves are nearly opposite, narrowly lanceolate, about 1–3 cm long with successive leaf pairs perpendicular to one another. Underground stems are round with scale-like leaves and white, but turn blue when exposed to air. The roots are succulent, round, without root hairs, and attached to the root system of hosts. Flowers are small, sessile and axillary. Corolla is two-lipped, tube recurved and shortly hairy. Calyx is up to 6 mm long, ribbed, unequally lobed. Flower colour varies regionally, from red, orange or yellow in Africa to pink, white, yellow or purple in Asia. The fruit is a five-sided capsule with narrow wings. Capsules contain 250–500 tiny dust-like seeds, 0.15–0.2 mm long (CDFA 2006; EPPO 1999; PIER 2008; Rich & Ejeta 2007; Waterhouse & Mitchell 1998).

Key features of the three important species are:

- *S. hermonthica*—large bright purple or pink flowers; grows to 60 cm tall. Stems are hairy, hard and quadrangle-shaped (EPPO 1999; OISAT 2005)
- *S. gesnerioides*— dull pink, purple or creamy white flowers (Figure 1). The stem is at least 30 cm tall and is purplish or brownish in colour, branched, with leaves reduced to scales and the root swollen to a tuber up to 3 cm diameter
- *S. asiatica*—bright red flowers (in some regions white, yellow or pink flowers).

For detailed morphological descriptions and a key of the *Striga* species see Mohamed et al. (2001), Parker & Riches (1993) and Musselman & Hepper (1986).

Figure 1. *S. gesnerioides* growing as a parasite on the roots of a cowpea plant (Photo: Marco Schmidt. Image from Wikimedia Commons under a Creative Commons Attribution ShareAlike 3.0 License)

Reproduction and dispersal

Striga reproduce from seeds. A single plant can produce 25 000 to 200 000 seeds. The minute seeds are dispersed by wind, water, soil movement, human activities or by adhering to the feet, fur or feathers of animals. Seeds remain viable in soil for up to 15 years.

Seeds only germinate in close proximity to the roots of a suitable host. When a host is present, seeds require 1–2 weeks of moisture and temperatures of at least 20 °C (with 25–35 °C being optimal) before they will germinate. Even when conditions are suitable, only a certain percentage of seeds will germinate—the remainder remain dormant. Once a seed germinates, the seedling grows toward the root of the host plant and penetrates the root's outer layers with a specialised structure called a haustorium. Endosperm nutrients within the seed can only sustain the seedlings for 3 to 7 days in the absence of a host (Ramaiah et al. 1991; Worsham 1987). Once attached to the host, the haustorium thickens into a parasitising nodule through which nutrients and water from the host plant pass. After growing for 4–6 weeks underground, the *Striga* plant emerges above ground and produces green leaves which photosynthesise. Some species can remain underground, deriving all their requirements from their host.

Flowering time varies with species and environmental conditions. For example, *S. gesnerioides* flowers as it emerges from underground (Parker and Riches 1993), whereas *S. asiatica* and *S. herminthica* begin to flower about four weeks after emergence (Saunders 1933). Most *Striga* species are self-pollinating, but *S. hermonthica* and *S. aspera* are out-crossers, requiring insects to cross-pollinate. It is highly likely that hybrids of these two species exist in the wild (Aigbokhan et al. 1998).

Symptoms of *Striga* parasitism include stunted growth, wilting and yellowing of leaves. Some host plants, including wheat, corn and sorghum, are very susceptible to *Striga*.

For more information on the *Striga* lifecycle see Ejeta and Gressel (2007).

Origin and distribution

Striga are generally native to semi-arid, tropical areas of Africa, but have been recorded in more than 40 countries (EPPO 1999; Ejeta 2007; Vasey et al. 2005). Three species are native to Australia: *S. curviflora*, *S. multiflora* and *S. parviflora*.

S. asiatica is the most widespread *Striga*. It is native to tropical parts of Asia and Africa, including the Philippines, Cambodia, Indonesia, China, Malaysia, Thailand, Vietnam, Mauritius, India and the Arabian peninsula. *S. asiatica* has been introduced to the United States (Carolinas) (PIER 2008; Wikipedia 2008). Some references erroneously state that *S. asiatica* has been found in Australia (e.g. Parker & Riches 1993).

S. gesnerioides is native to Africa, Arabia and Asia, between 33°10' N and 32°15' S. It has been introduced to the United States (Florida) (Mohamed et al. 2007; Wikipedia 2008).

S. hermonthica is native to semi-arid areas of northern tropical Africa, from Senegal to Ethiopia and the Democratic Republic of Congo, and into south-west Arabia and southern tropical Africa, including Angola, Namibia, Madagascar and Tanzania (Parker & Riches 1993; Wikipedia 2008).

Preferred habitat

Striga generally prefer infertile soils in open grasslands and savannah in semi-arid tropical areas. Their seeds are well adapted to hot, dry conditions, remaining dormant until rain.

While perhaps best suited to dry, tropical areas, *S. asiatica* has been recorded from a range of climate zones, including seasonally dry tropics and subtropics as well as warm temperate regions (generally where it is dry, or at least seasonally dry). *S. hermonthica* and *S. gesnerioides* also prefer hot, arid or semi-arid areas, but the latter has naturalised in Florida, which is subtropical and seasonally wet.

To germinate, *Striga* seeds require temperatures between 25–35 °C. The optimum temperature for germination for *S. hermonthica* and *S. asiatica* is 35 °C (Parker & Riches 1993). *S. asiatica* tolerates lower temperatures than many other *Striga* species and has flourished in temperate regions outside its native range (e.g. the Carolinas in the United States). Its seeds remain viable even after periods of storage at –7°C. Plants reach maturity at a daily mean temperature of 22 °C. Such environmental flexibility might enable this species to expand its geographic and host range (Cochrane & Press 1997). *S. hermonthica* tolerates a range of day/night temperatures between 40/30 °C and 25/15 °C (Mohamed et al. 2007).

The presence of *Striga* is sometimes used as an indicator of poor soil fertility when assessing the potential use of new agricultural land. However, *S. asiatica* can survive and produce seeds in a wide range of soils, including shallow, dry, infertile, sandy, rocky and lateritic soils (Cochrane & Press 1997), as well as alluvial and clay soils (Cochrane & Press 1997).

Many *Striga* species have co-evolved with their hosts and some have narrow host ranges. *S. asiatica* and *S. hermonthica* generally parasitise cereals whereas *S. gesnerioides* parasitises certain legumes (e.g. cowpea). A list of host plants is presented in Table 2.

Table 2. List of host plants affected by *Striga* (Cochrane & Press 1997; EPPO 1999; Vasey et al. 2005)

***Striga* species**	**Host plants**
S. asiatica	Poaceae (grass family), especially the crop plants maize (corn), sorghum, rice and sugarcane, but sometimes wheat, barley, millet and others. Wild plants and weeds of the following genera: *Sorghum*, *Digitaria*, *Paspalum*, *Echinochloa*, *Imperata*, *Pennisetum*, *Cynodon*, *Chrysopogon*, *Elionurus*, *Eleusine*, *Eragrostis*, *Loudetia*, *Hyparrhenia*
S. hermonthica	Poaceae, especially sorghum, but also maize, *Panicum*, *Setaria*, sugarcane and wheat
S. gesnerioides	Tobacco and numerous Poaceae, Fabaceae and Convolvulaceae

There are morphologically and genetically distinct races (varieties) within some species of *Striga*, with each race sometimes having specific hosts. For example, the 'vigna' race of *S. gesnerioides* parasitises cowpeas within a specific geographical region. However, outside that region, it does not affect cowpeas (Riches 2002). Such variability is thought to be a recent evolutionary phenomenon and poses an obstacle to the development of *Striga*-resistant host plants. Moreover, *Striga* species may have the potential to overcome formerly 'resistant' hosts, as has occurred in crop breeding field trials involving *S. gesnerioides* in Africa (Botanga & Timko 2006). Out-crossers such as *S. hermonthica* may display more 'race specificity' to hosts since out-breeding generates broader genetic variability (Safa et al. 1984).

History as a weed elsewhere

Several *Striga* species are major pests of maize, sorghum, wheat and other grain crops in Africa, causing annual losses of up to US$7 billion and adversely affecting over 300 million people. *Striga* have been described as 'one of the most serious biological constraints to food production' over large parts of sub-Saharan Africa, where they affect more than 40 per cent of cereal crops (Ejeta 2007; Scholes & Press 2008; Vasey et al. 2005). Infestation usually causes a substantial reduction of crop yield, often over 70 per cent (Kim 1991) and up to 100 per cent (Figure 2).

Figure 2. An area of corn (maize) that has been severely stunted by *Striga* (in Africa) (Photo: CIMMYT (International Maize and Wheat Improvement Center) undated – used with permission under a Creative Commons Attribution-Noncommercial-Share Alike license)

Striga mostly affects low-income, small-scale farmers in Africa as they are unable to adopt expensive chemical control or use modern agricultural practices. These farmers also tend to rely almost totally on crop species hardest hit by *Striga* (Mohamed et al. 2007).

The *Striga* problem was first recognised in Africa in 1936. Since then, the problem has expanded, mainly due to increasing population and demands placed on cropping land. Traditional cropping practices have been intensified, often to the point where there is continuous cultivation without traditional crop rotation, fallow or intercropping systems. Soil fertility has also declined, providing an ideal environment for *Striga* (Ejeta 2007; Oswald 2005).

S. hermonthica is widely regarded as the most damaging parasitic plant species in the world, and is the most problematic *Striga* in Africa (Parker & Riches 1993). It is a problem in Saudi Arabia, Nigeria, Sudan, Uganda, Cameroon, Niger, Mali, Benin, Togo, Ghana, Ethiopia, Madagascar and Kenya, causing serious damage to crops such as maize, sugarcane, upland rice and finger millet (EPPO 1999; Kim et al. 2002; Musselman & Hepper 1986).

S. asiatica is cited as a serious weed in India, South Africa, the United States, Mauritius, Zimbabwe, Uganda, Pakistan and Zambia (Waterhouse & Mitchell 1998). *S. asiatica* was discovered in the Carolinas (United States) in the 1950s and soon spread over about 175 000 hectares (Parker & Riches 1993). In 1957, the United States Congress decided to eradicate it. Strict quarantine measures and control have since achieved a 99 per cent reduction of the original population (GISD 2006; Musselman 1996) at a total cost of more than US$250 million (currently around US$750 000 per annum) (Carter 1996; Mohamed et al. 2007).

S. gesnerioides is a problem in Nigeria, South Africa, Zimbabwe and Florida in the United States (EPPO 1999). It was discovered in Florida in 1979, parasitising legumes planted to reclaim a mine site. Early control has prevented spread (Musselman 1996). In Africa, *S. gesnerioides* is a significant pest in cowpea crops, with yield losses of 15–100 per cent. Cowpea is an important component of African diets (Boukar et al. 2004).

Other *Striga* with locally significant agricultural impacts include:

- *S. angustifolia*—a serious weed in India, affecting rice, sorghum and sugarcane (Waterhouse & Mitchell 1998)
- *S. aspera*— a significant problem of maize crops in Nigeria, Cameroon, Ivory Coast and Ethiopia, and also of rice crops in the Ivory Coast and Senegal (Parker & Riches 1993)
- *S. latericea*—a cause of damage to sugarcane in Ethiopia and Somalia (Parker & Riches 1993).

Pest potential in Queensland

Current distribution and impact in Queensland and Australia

Of the three species native to Australia (*S. curviflora*, *S. multiflora* and *S. parviflora*) only *S. parviflora* and *S. curviflora* have been recorded to have any impact on crops.

The Queensland Herbarium has the following records of native *Striga* in crops:

Species	Collection location and date	Collector's notes
Striga parviflora	east Bundaberg, 1924	'Parasitic on sugarcane'.
Striga sp.	Mirani (near Mackay), 1948	'Collected in a cane-field recently planted now heavily infested – no plants could be found in surrounding pasture.'
Striga parviflora	Walkamin, between Mareeba and Tolga, 1954	Found growing in a field of maize, and apparently gives an indication of the fertility of the soil since maize growing with this weed is noticeably inferior to maize elsewhere (modified).
Striga parviflora	Bundaberg, Riverview, 1965	'Weed in sugarcane.'
Striga sp.	near Childers, 1973	'Weed infesting about 2 acres of sugar cane causing stunting.'

AQIS (1999) stated that *S. curviflora* and *S. parviflora* were 'major causes of concern' in sugarcane in Queensland, where they are locally referred to as 'cane-killing weed' or witchweed. *S. parviflora* has also been recorded as a weed of corn crops in the Atherton Tableland. In contradiction, Carter et al. (1996) suggested that reports of native *Striga* species affecting sugarcane were isolated, and that there was no evidence of these species affecting economic plants in recent times. The Bureau of Sugar Experiment Stations (1989) suggested that '*Striga* is found, on rare occasions, in cane planted on newly cleared land. Infestations are usually scattered but the parasitised cane can be seriously affected'. Kendrick Cox (Queensland DEEDI, Atherton Tableland, pers. comm. 2008) suggested *Striga* was a problem in corn near Mareeba about 20 to 30 years ago, but there have not been any reports of problems since, nor is it known to be a problem in sugarcane. Ian Martin (corn industry expert, pers. comm. 2008) has never heard of *Striga* being a problem in Queensland corn.

All non-native *Striga* species are declared Class 1 plants in Queensland under the Queensland *Land Protection (Pest and Stock Route Management) Act 2002*.

Potential impact in Queensland

In order to identify areas of Queensland that may be at risk of invasion by *Striga* species, this study reviewed information on the native range of the species and the climatic parameters that appear to limit its distribution. Climate modelling software called CLIMATE (Pheloung 1996) was used to illustrate areas of Australia where climate is similar to climate experienced across the native ranges of three *Striga* species (Figures 3, 4 and 5).

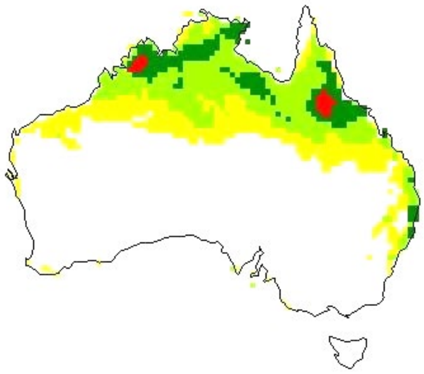

Figure 3. Areas in Australia where climate is similar to climate experienced across the native range of *S. asiatica*. Red indicates areas where climate is most suitable for the species, dark green, light green and yellow are marginally suitable and white is unsuitable

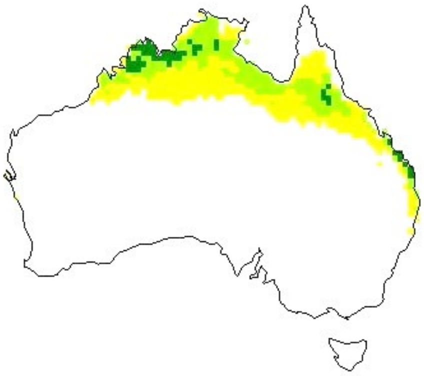

Figure 4. Areas in Australia where climate is similar to climate experienced across the native range of *S. gesneriodes*. Red indicates areas where climate is most suitable for the species, dark green, light green and yellow are marginally suitable and white is unsuitable

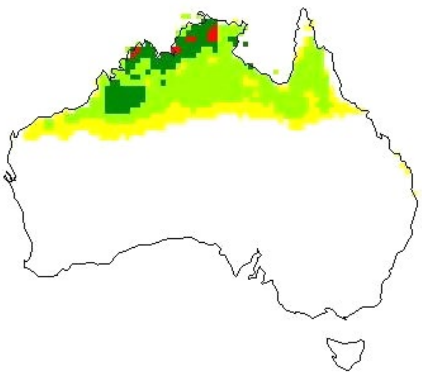

Figure 5. Areas in Australia where climate is similar to climate experienced across the native range of *S. hermonthica*. Red indicates areas where climate is most suitable for the species, dark green, light green and yellow are marginally suitable and white is unsuitable

Based on climate modelling alone, these three *Striga* species appear most likely to survive in dry tropical areas of North Queensland, with the Einasleigh Uplands appearing to be most suitable. Habitats with open tropical savannah, open grassland and grain crops are probably most at risk. While most *Striga* prefer infertile, generally light-textured soils, there is strong evidence that *S. asiatica* can become a problem on clay soils, extending into warm temperate climate zones, as it has done in the United States.

All three species (*S. hermonthica*, *S. gesnerioides* and *S. asiatica*) have a documented history of adapting to new habitats and agro-ecosystems by developing host-specific strains and ecotypes across their ranges. The potential for *Striga* species to hybridise, and potentially select new hosts, is also a risk.

Given that the primary hosts for *Striga* species are grasses, it seems reasonable to predict that grain crops and grasslands of northern and perhaps central Queensland are at risk. According to the Australian Bureau of Statistics (2008), the approximate annual value of some important crops in Queensland are:

- cereals for grain: A$429 million
- sugarcane: A$1121 million
- hay: A$194 million
- legumes for grain: A$43 million.

Perhaps most importantly, detection of non-native *Striga* in Queensland has the potential to affect grain exports, if trading partners impose quarantine restrictions.

If *Striga* species were to establish in Queensland, eradication would likely be expensive and prolonged (at least 15 years) unless detected and contained immediately, as has been the case in the United States. Failure to eradicate *Striga* could result in an ongoing problem. Experience in Africa shows that *Striga* can be managed, using techniques such as herbicide application and the breeding of *Striga*-resistant crop varieties. However, research and application of such control is likely to be expensive and ongoing.

Control

This study does not attempt to summarise the extensive published literature on the control of *Striga*. For such information, refer to Ejeta and Gressel (2007) and Oswald (2005).

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