Biological control initiatives against the invasive Oriental legume, *Caesalpinia decapetala* (Roth) Alston (Mauritius thorn), in South Africa

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Caesalpinia decapetala (Roth) Alston, a woody legume reported to be of Oriental origin, is an aggressive invader of riverine habitats, forest margins and clearings, grasslands and commercial plantations in South Africa. Mechanical and chemical control methods are impractical and ineffective, and herbicides are often undesirable because of the risk of water pollution. Biological control could therefore play an important part in the suppression of this weed. Mauritius thorn is cultivated as a barrier plant in South Africa but many indigenous plants can be used for this purpose, so no conflicts of interest are envisaged. Preliminary surveys for natural enemies in India revealed a depauperate insect fauna, suggesting that future surveys should focus on other Asian regions. Two insect species have been introduced from India into quarantine in South Africa. Oviposition choice-tests in quarantine demonstrated that the seed-feeding beetle *Sulcobruchus bakeri* Kingsolver (Bruchidae) has a strong preference for ovipositing on *C. decapetala* seeds. *Sulcobruchus bakeri* was cleared for release in South Africa in February 1999. A culture of the leaf-mining moth *Acrocercops hyphantica* Meyr. (Gracillariidae) was established in quarantine in November 1998. Biology studies and host-range tests on *A. hyphantica* are in progress.

Key words: biological weed control, *Caesalpinia decapetala*, seed-feeder, *Sulcobruchus bakeri*.

The genus *Caesalpinia* L. (Caesalpiniaceae) contains about 100 species of shrubs and trees that have tropical and subtropical distributions (Polhill & Vidal 1981). Worldwide, five *Caesalpinia* species are considered to be weeds, namely *C. bonduc* (L.) Roxb. in Jamaica, Hawaii and continental U.S.A., *C. coriaria* Willd. in Jamaica, *C. crista* L. in Hawaii, *C. gilliesii* (Hook.) Wall. in Argentina, U.S.A. and Israel (Holm *et al.* 1991) and *C. decapetala* (Roth) Alston in Australia (Auld & Medd 1987; Trounce 1995), Kenya, Zimbabwe, South Africa (Holm *et al.* 1991; Henderson 1995) and Raoul Island (New Zealand) (Devine 1977). *Caesalpinia decapetala* has also become naturalized in East Africa (Ross 1977), West Africa and Jamaica (Adams 1972), and is widely cultivated in both hemispheres as an ornamental and barrier plant (Isely 1975).

The date of the first introduction of *C. decapetala* (Fig. 1) into South Africa, and the country from which it was introduced, are unknown. Specimens of *C. decapetala* were first recorded in Durban (KwaZulu-Natal Province) in 1888 and two specimens, collected in 1899, are lodged in the herbarium of the National Botanical Institute in Pretoria. One was collected at Egossa (31.37S 29.32E), East Pondoland (now Eastern Cape Province), and the other in Maagne Village, Shiluvane (24.05S 30.15E) (Northern Province). The great distance between these localities (±1000 km) indicates that Mauritius thorn may already have been widely established in South Africa by 1899. It was soon to become widespread, because the Conservator of Forests for the Transvaal is believed to have distributed some 500 000 seedlings of several alien tree species, including Mauritius thorn, annually, between 1904 and 1908 (Wells *et al.* 1986). Although its invasiveness has been recognized since the 1960s, *C. decapetala* was only declared a weed in South Africa in 1983.

In this review, we focus on the initiation of a biological control programme against *C. decapetala* in South Africa. The available literature on the taxonomy and distribution of the weed is reviewed, as this has determined where surveys for natural enemies have been conducted. We also consider the harmful and useful attributes of the weed in South Africa and discuss options for its control.

TAXONOMY OF *C. DECAPETALA*

Caesalpinia decapetala is synonymous with the following commonly encountered names: *Reichardia decapetala* Roth, *Caesalpinia sepiaria* Roxb., *Caesalpinia sepiaria* var. *japonica* (Sieb. & Zucc.)

Fig. 1
Caesalpinia decapetala.
(Drawn by B. Connell, National Botanical Institute, Pretoria.)

Makino and *Caesalpinia japonica* Sieb. & Zucc. While *C. decapetala* is commonly called 'Mauritius thorn' in South Africa, it is referred to as 'Mysore thorn' in India. Other common names include 'kurudu gejjuga' in Karnataka State, South India (Saldanha & Singh 1984), 'wait a while' and 'Mysore thorn' in Australia (Auld & Medd 1987) and 'setjang lemboet', apparently a Javanese name for *C. sepiaria* in Indonesia (Miquel 1860).

Caesalpinia decapetala has been recorded throughout most of the Oriental biogeographical region (*sensu* Wallace 1876). A wide range of morphological variability is evident in herbarium specimens collected within, as well as between, parts of the Oriental Region. For example, several forms of *C. decapetala* that differ in the size of their leaflets and the degree of hairiness on their stems and leaf-rachides, are evident in specimens from India (A. Nicholas, pers. comm.; S. Neser, unpubl.). Variation in the morphology of *C. decapetala* from different parts of the Oriental Region was reported by Isely (1975), who suggested that two varieties of *C. decapetala* should be recognized in plants that have become naturalized in the United States. These were *C. decapetala* var. *decapetala,* with closely puberulent raceme-axes and 7–12 pairs of leaflets, originating in tropical Asia, and *C. decapetala* var. *japonica* (Sieb. & Zucc.) Isely, with glabrate-glaucous to puberulent raceme-axes and 4–7 pairs of leaflets, originating in China and

Japan. These intraspecific morphological differences were believed to have been verified by the discovery that the two varieties had different genomes. Bir & Kumari (1973, cited by Isely 1975) recorded 12 chromosomes in the haploid condition of *C. decapetala* var. *decapetala* (then known as *C. sepiaria*), while Sakai (1951, cited by Isely 1975), recorded 22 chromosomes in diploid *C. decapetala* var. *japonica* cells (then known as *C. japonica*).

DISTRIBUTION OF *C. DECAPETALA* IN THE ORIENTAL REGION

Many herbarium specimens have been collected in India, where *C. decapetala* is widespread. The plant is abundant in the western Ghats mountains and in the interior of Karnataka State (Saldanha & Singh 1984). Specimens collected in nine other Indian States, from Tamil Nadu in the south to the Himalayan region in the north, are lodged in the herbarium of the Old East India Company Botanic Garden in Calcutta (S. Neser, unpubl.), some of which are referred to in the botanical literature (Roxburgh 1874; Hooker 1897). This ubiquity may be ascribed to the cultivation of *C. decapetala* as protective, thorny hedges around crops, not only in India, but probably throughout its range of distribution. Considering that *C. decapetala* seeds appear to be dispersed by water in nature, the cause of the species' wide distribution seems likely to be anthropogenic.

Caesalpinia decapetala occurs in Iraq, Pakistan, Sri Lanka, Bangladesh, Burma, Nepal, Bhutan, China, Korea, Taiwan and Japan (Ohwi 1965; Hattink 1974; Saldanha & Singh 1984; Watanabe 1985; Polunin & Stainton 1990; Huang & Huang 1991; Lock & Simpson 1991; Sanjappa 1992). According to Hattink (1974), records of *C. decapetala* from Indochina were unconfirmed, but Vidal *et al.* (1980, cited by Hou *et al.* 1996) listed one specimen from Laos and several from North and South Vietnam. Vidal (1984, cited by Hou *et al.* 1996) also reported that two *C. decapetala* specimens had originated from Thailand.

According to Auld & Medd (1987), *C. decapetala* was introduced into Australia from Indonesia. In a comprehensive revision of the genus *Caesalpinia* in Malesia (Malaysia, the Philippines and Indonesia) and the Solomon Islands, Hattink (1974) reported the following distribution of *C. decapetala* in Malesia: peninsular Malaysia, northern and western Sumatra, west to east Java, Philippines (Luzon), the southwestern peninsula of Celebes and the Lesser Sunda Islands (Lombok, Flores, Timor).

NATIVE DISTRIBUTION RANGE OF *C. DECAPETALA*

The number of indigenous *Caesalpinia* species increases markedly from west Asia, where only one species (*C. erianthera* Chiov.) occurs in Iraq (Lock & Simpson 1991), through India where 11 species are found (Sanjappa 1992), to countries further east in Asia. Thirteen and 19 species are indigenous to Indochina and Malesia, respectively (Hattink 1974). China is reported to harbour 17 *Caesalpinia* species (Zarucchi *et al.*, in prep.), but the number of indigenous species appears to be unknown. The centre of speciation of the genus in Asia is therefore difficult to pinpoint. In any event, the contention that the genus *Caesalpinia* is not a monophyletic group (Polhill & Vidal 1981) would detract from any conclusion about the origin of *C. decapetala* based on species richness. A reclassification of the genus has not been attempted since the work of Hattink (1974).

In a review of Malesian *Caesalpinia* species, Hattink (1974) regarded *C. decapetala* as 'most remarkable' because it was the only species that occurred mostly on mountains up to an altitude of 1700 m. Hattink (1974) suggested that hedge plantings at low altitudes in Malesia had been the origin of populations which had run wild, implying that he considered montane plants to be indigenous. Hattink (1974) also reported that 12 collections of *C. decapetala* had been made from plants growing between 900 m and 1350 m in northern Sumatra, and that flowering specimens had been collected at Pajakumbuh (Payakumbuh) (500 m) in northwestern Sumatra. Hattink's review mentioned 28 collections, mostly from montane areas, that were made from west to east Java in 1912, as well as herbarium specimens from Luzon, Celebes, Lombok, Flores and Timor that were similarly collected at altitudes of 1000–1400 m. The occurrence of *C. decapetala* in Malesia is currently being investigated.

DISTRIBUTION AND EFFECT OF *C. DECAPETALA* IN SOUTH AFRICA

In South Africa, Mauritius thorn infestations are restricted to the moist, eastern parts of the country, from the Northern Province southward through Mpumalanga, Swaziland and KwaZulu-Natal to the Eastern Cape Province (Fig. 2). Infestations are estimated to occur over some 1.3 million ha, of which 24 000 ha are infested by Mauritius thorn alone (Versfeld *et al.* 1998). In South Africa, *C. decapetala* invades riverine habitats, forest margins and clearings, savanna and timber plantations, where

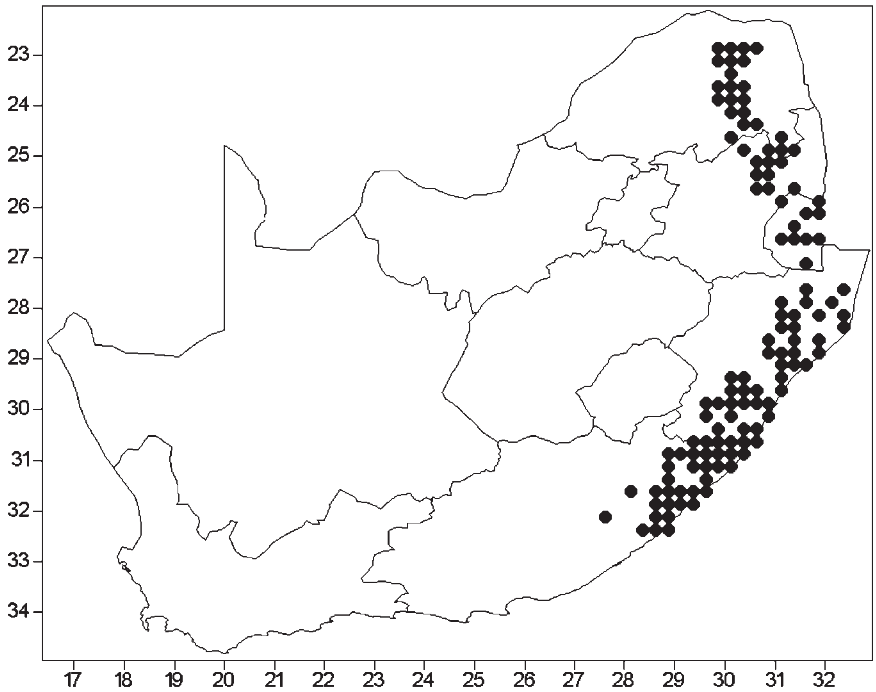

Fig. 2
Distribution of *Caesalpinia decapetala* in South Africa.
(Drawn by L. Henderson, Plant Protection Research Institute, Pretoria.)

it obstructs plantation operations and increases the risk of fire. In indigenous, subtropical forests, dense *C. decapetala* stands shade out understoreys and cause trees to collapse (Geldenhuys *et al.* 1986). Infestations that scramble over riparian vegetation are believed to greatly accelerate water loss by evapo-transpiration (Versfeld *et al.* 1998).

USEFUL ATTRIBUTES OF *C. DECAPETALA*

The cultivation of *C. decapetala* in thorny hedges to protect crops from grazing livestock and wildlife appears to be widespread. The practice is reported from South Africa and its neighbouring countries (Henderson 1987), as well as from India, Taiwan (Saldanha & Singh 1984; Huang & Huang 1991) and Java (Backer & Bakhuizen van den Brink 1963). Many indigenous South African plants may be used as effective barriers instead of Mauritius thorn. Henderson (1987) listed 105 indigenous plant species that could replace invasive, alien species as barriers in South Africa. These included species that have already been used successfully, such as *Acacia ataxacantha* DC., *Carissa macrocarpa* (Eckl.) A. DC., *Dovyalis caffra* (Hook. f. & Harv.) Hook. f. and *Flacourtia indica* (Burm. f.) Merr. These alternatives suggest that there should be no conflicts of interest relating to biological control.

CHEMICAL AND MECHANICAL CONTROL OF *C. DECAPETALA*

The herbicides glyphosate, glyphosate trimesium and triclopyr are registered for use against *C. decapetala* in South Africa (Vermeulen *et al.* 1996). In some situations, control may be achieved by a combination of chemical and mechanical means (Bromilow 1995) in which herbicides are applied to young plants and to the regrowth of mature plants that have been slashed. West (1996) reported on the successful chemical and mechanical control of *C. decapetala* on Raoul Island over a period of two decades.

Conventional control methods are, however, mostly impractical because infestations on steep river banks are inaccessible and foliar applications of herbicides have to be replaced by slashing when weed foliage scrambles along high riparian, forest and plantation canopies. Because infestations also spread vegetatively (trailing branches are reported to root where they touch the ground and slashed plants coppice readily) (Bromilow 1995), and because regeneration from seed-banks may

Table 1

Phytophagous insect species collected on *Caesalpinia decapetala* in India.

Family	Insect species	Feeding damage	Status
Alydidae	Unidentified species[1]	Pods or seeds	Uncertain
Bruchidae	*Caryedon serratus* (Olivier)[2]	Seeds	Polyphagous
	Spermophagus sp.[1]	Seeds	Uncertain
	Sulcobruchus bakeri Kingsolver[1,2]	Seeds	Cleared for release
Cerambycidae	7 unidentified species[1]	Stem-borers (?secondary)	Uncertain
Chrysomelidae	*Aetheomorpha suturata* Jacoby[1]	Petals	Uncertain
	Chaloenosoma metallicum Jacoby[2]	Leaves	Uncertain
	Dactylispa ? *severinii* (Guestro)[2]	Petals	Uncertain
	Luperomorpha vittata Duvivier[2]	Petals	Uncertain
Coreidae	*Cletus* sp.[2]	Pods	Uncertain
Curculionidae	*Amorphoidea* sp. 1[2]	Flowerbuds	Potential agent
	Amorphoidea sp. 2[2]	Flowerbuds	Potential agent
	Endaeus sp. nr *butae* Marshall[2]	Flowerbuds	Potential agent
Geometridae	*Pingasa* sp.[2]	Flowers	Uncertain
Gracillariidae	*Acrocercops hyphantica* Meyr.[1,2]	Leaf-miner	Introduced
	Stomphastis chalybacma Meyr.[1]	Flowerbuds	Oligophagous
Lycaenidae	*Rapala* sp.[2]	Flowerbuds and petals	Uncertain
Margarodidae	*Icerya purchasi* Maskell[1]	Leaves and stems	Polyphagous
Membracidae	*Gargara* sp.[2]	Stems	Uncertain
	Leptocentrus basilewskyi Capener[2]	Stems	Uncertain
Noctuidae	*Autoba versicolor* Walker[2]	Primary stem-borer	?Potential agent
	Lacera noctilio Fabr.[1]	Leaves	Prob. polyphagous
Pieridae	*Eurema andersoni ormistoni* Watkins[2]	Leaves	Uncertain
Plataspidae	*Coptosoma* sp.[2]	Flowerbuds	Uncertain
Pyralidae	*Thylacoptilla maculella* (Ragonot)[2]	Young growth	?Oligophagous
Thripidae	*Thrips elixicornis* Hood[2]	Flowers	Uncertain
Tortricidae	*Cryptophlebia* sp.[1]	Flowers and immature pods	Uncertain

1: collected by the authors.
2: collected by Manjunath *et al.* (1992).

persist at high rates, follow-up slashing and herbicide applications are required frequently. Follow-up treatments are, however, severely hampered by brushwood thorns that remain after successful initial control (P.L. Campbell, pers. comm.). Foliar applications of herbicides are inappropriate along streams, and for mechanical control to be effective, entire rootstocks must be excavated at great cost (Bromilow 1995).

BIOLOGICAL CONTROL OF *C. DECAPETALA*

Surveys for natural enemies

Despite the resilience of *C. decapetala* to conventional control methods, and the early recognition of its suitability for biological control in 1971 (Neser & Annecke 1973), surveys for natural enemies only began in the 1990s. The first of these, from October 1991 to March 1992, was conducted in India by Bio-Control Research Laboratories (BCRL), a division of Pest Control (India) Limited, under contract to the Plant Protection Research Institute (PPRI) (Manjunath *et al.* 1992). Surveys were carried out in Bangalore (12.58N 77.35E) and the Districts of Chickmagalur, Hassan and Shimoga (all in Karnataka State), in Trivandrum District (Kerala State) and in Pune District (Maharashtra State). Forty-one insect species, mostly Lepidoptera and Coleoptera, were collected on *C. decapetala* in the BCRL surveys.

The second survey in India was conducted by the authors in November 1997 and included Bangalore and Jabalpur (23.10N 79.59E) in Madhya Pradesh State. No new insect species were discovered in Jabalpur, and Bangalore remains the primary source of insects that are considered to have potential as biocontrol agents. The phytophagous insect fauna associated with *C. decapetala* in India is listed in Table 1. The Indian fauna is, however, considered to be depauperate because certain guilds are poorly represented (*e.g.* primary stem-borers) while others are absent (*e.g.* gall-formers). Future surveys should therefore be undertaken elsewhere in Asia. On the basis of herbarium records, Malesia and the Himalayan region have as much potential as sources of natural enemies as India.

Natural enemies introduced into quarantine

The prodigious seeding capability of *C. decapetala,* its potential for regeneration from seed-banks and the possibility that seeds may be widely dispersed by streams, pointed to the seeds as priority targets for introduced natural enemies. In 1996, one of the insects identified by the BCRL surveys, the seed-feeding beetle *Sulcobruchus bakeri* Kingsolver (Bruchidae), was introduced into quarantine in South Africa for evaluation as a candidate agent. *Sulcobruchus bakeri* is a small (±4 mm long), black seed-weevil with fine, grey setae. The adults are diurnally active, positively phototactic and fly readily. *Sulcobruchus bakeri* was first recorded from a malaise trap in the Cuernos Mountains, Philippines, in 1961 (Kingsolver 1984), but the association of *S. bakeri* larvae with *C. decapetala* seeds was only confirmed in October 1996, when adults emerged from *C. decapetala* seeds collected in India by PPRI scientists. *S. bakeri* has not been associated with any other hosts. The known host associations of the other four *Sulcobruchus* species are reported in Arora (1977), Watanabe (1985) and Signal (1987).

A second agent, the leaf-mining moth *Acrocercops hyphantica* Meyr. (Gracillariidae), was introduced from India in November 1998.

Introduction and culturing of *S. bakeri*

The quarantine culture of *S. bakeri* was initiated from beetles that emerged from *C. decapetala* seeds that were collected at four localities in India during October 1996. These include Byatrayanapura near Bangalore (12.58N 77.35E) in Karnataka State, near the Nira River (18.09N 74.02E), near Pune (18.34N 73.58E) and at Wai (17.57N 73.57E), all in Maharashtra State. A genetically heterogeneous culture was produced by systematically combining insects from all four localities. This process was begun with progeny reared from eggs deposited by females that had been confined with single males.

Biology and oviposition preference of *S. bakeri*

Females of *S. bakeri* each laid 3–6 eggs per day during the period of oviposition, which ranged from 20–30 days. Eggs were deposited singly and directly onto the seed coats of *C. decapetala* seeds. Females deposited between 73 and 111 eggs during their life-times. Adults lived for up to 65 days following their emergence from seeds. The eggs hatched after about eight days and development of the immature stages (hatching to adult emergence) averaged around 35 days at 28 °C. The larvae were relatively immobile and were never observed transferring between seeds. Pupation always occurred in the seeds. Although some seeds contained up to nine adult emergence holes, usually five or six beetles emerged from seeds on which multiple oviposition had occurred (Coetzer, in prep.)

Test plants were selected according to the phylogenetic testing method of Wapshere (1974). The seeds of nine species of economically important legumes, 26 species of indigenous legumes and five species of introduced, ornamental legumes were offered, along with *C. decapetala* seeds, to separately confined pairs of beetles in oviposition choice tests. *Sulcobruchus bakeri* displayed a strong preference for ovipositing on the seeds of *C. decapetala* (Coetzer, in prep.). As a result, the release of *S. bakeri* in South Africa was approved by the regulatory authorities in February 1999.

Acrocercops hyphantica

This leaf-mining gracillariid moth was collected at Byatrayanapura (12.58N 77.35E) in India and introduced into quarantine in South Africa in late 1998. Larvae of *A. hyphantica* cause blotch mines in the leaflets of *C. decapetala,* causing them to die. A single larva is able to consume the tissue between the adaxial and abaxial epidermises of 3–4 leaflets before it pupates in a cocoon spun on the upper surface of an undamaged leaflet. Fletcher (1933) reported that *A. hyphantica* mines the leaflets of *Caesalpinia bonducella* (= *C. bonduc*) in India. Results of preliminary host-specificity tests suggest that *A. hyphantica* may have a limited host-range and may thus be suitable for release in South Africa (Coetzer, unpubl.).

Other potential agents

Collections in India revealed several other insect species that have potential as candidate agents (Table 1). In particular, species that prevent pod set are receiving high priority. Three weevil species, including *Endaeus* sp. nr *buteae* Marshall and two unidentified species of *Amorphoidea* (Curculionidae), were reared from *C. decapetala* flowerbuds collected at Bangalore. Damage by these weevils is thought to be the cause of inflorescences in India developing fewer pods than those in South Africa (Neser, unpubl.).

CONCLUSIONS

Although *S. bakeri* is expected to decrease the numbers of seeds available for regeneration in *C. decapetala* infestations, the bruchids will not affect the density of old, established infestations. To realize the full potential of biological control, insects and pathogens that damage the vegetative tissue of *C. decapetala* should also be utilized. The objective is to establish a suite of natural enemies that attack different parts of *C. decapetala* so as to maximize the stress on weed populations and decrease their reproductive potential. Immediate priorities include releases and establishment of *S. bakeri* throughout the range of *C. decapetala* in South Africa and evaluation of the host-range of the leaf-mining moth *A. hyphantica.* Confirmation of the identities of the bud-feeding curculionids, followed by their introduction into quarantine and evaluation, will also be given priority. New surveys for natural enemies will focus on unexplored parts of the native range of distribution of *C. decapetala,* and literature surveys will be continued to clarify the status of *C. decapetala* in Malesia and the Himalayan region.

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