Prospective agents for the biological control of *Cardiospermum grandiflorum* Sw. (Sapindaceae) in South Africa

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Balloon vine, *Cardiospermum grandiflorum* Sw. (Sapindaceae), originally from South and Central America and now invasive in South Africa, was one of five incipient or 'emerging weeds' targeted for biological control in 2003. In search of potential biological control agents, exploratory surveys were conducted in northern Argentina from 2005 to 2009. The surveys, which included plant species in the genus *Cardiospermum* and other native Sapindaceae, were aimed at determining the distribution and field host ranges of the natural enemies associated with *C. grandiflorum.* Eight phytophagous insect and two fungal pathogen species were associated with *C. grandiflorum,* four of which were introduced into quarantine in South Africa for further host-specificity testing. Based on the nature of the potential agents' damage, field distribution, abundance, field host range and the results of preliminary host-specificity tests, the seed-feeding weevil *Cissoanthonomus tuberculipennis* Hustache (Coleoptera: Curculionidae) and the fruit-galling midge *Contarinia* sp. (Diptera: Cecidomyiidae) were deemed to be the most promising insect agents. Also promising was the rust fungus *Puccinia arechavaletae* Speg. (Pucciniales: Pucciniaceae) which caused severe disease symptoms on South African *C. grandiflorum.* However, feeding on two congeners of *C. grandiflorum,* whose exact country of origin is disputed, has limited the number of agents that are suitable for release. To resolve this problem, phylogenetic studies are currently under way to verify the contention that both non-target *Cardiospermum* species are native to South America and not to Africa. If that proves to be true, then these and other agents would qualify for release against *C. grandiflorum* in South Africa. Although this is a very recent programme, prospects for success seem good.

Key words: balloon vine, phylogenetic relationships, host range, native distribution, emerging weeds.

INTRODUCTION

Balloon vine, *Cardiospermum grandiflorum* Sw. (Sapindaceae), is a perennial, slightly-woody climber of South and Central American origin that has become naturalized in tropical and subtropical Africa and Asia, following its introduction as an ornamental creeper (Cowan 1983; Moranes 1990). The increasing infestations of *C. grandiflorum* in riparian and suburban areas during the past 15 years has been a concern in South Africa, hence the initiation of a biological control programme against this weedy creeper in 2003.

The Sapindaceae, or soapberry family, contains more than 2000 species from 150 genera, comprising mostly trees and shrubs, but rarely herbs, that are widely distributed throughout the warm subtropics and tropics (Ferrucci 1991). The genus *Cardiospermum* consists of approximately 16 species with a pantropical New and Old World distribution (Exell 1966; Davies & Verdcourt 1998; Ferrucci 2000; Hyde & Wursten 2009). *Cardiospermum grandiflorum* grows well in damp situations, especially along forest margins, watercourses and urban open spaces in subtropical regions. The leaves are widely spaced, usually biternate, while the leaflets are pinnately lobed (Fig. 1). It has an extensive system of tendrils which twirl around supporting structures and other plants, and may climb to over 10 m in height. Infestations form large, dense smothering-curtains of tangled stems, outcompeting underlying plants for sunlight. *Cardiospermum grandiflorum* flowers throughout the year, and each flower produces a membranous and inflated fruit containing three angled capsules. Three seeds, each with a white heart-shaped aril, are formed in each of the three chambers. Although the plant re-grows from root fragments, fruit

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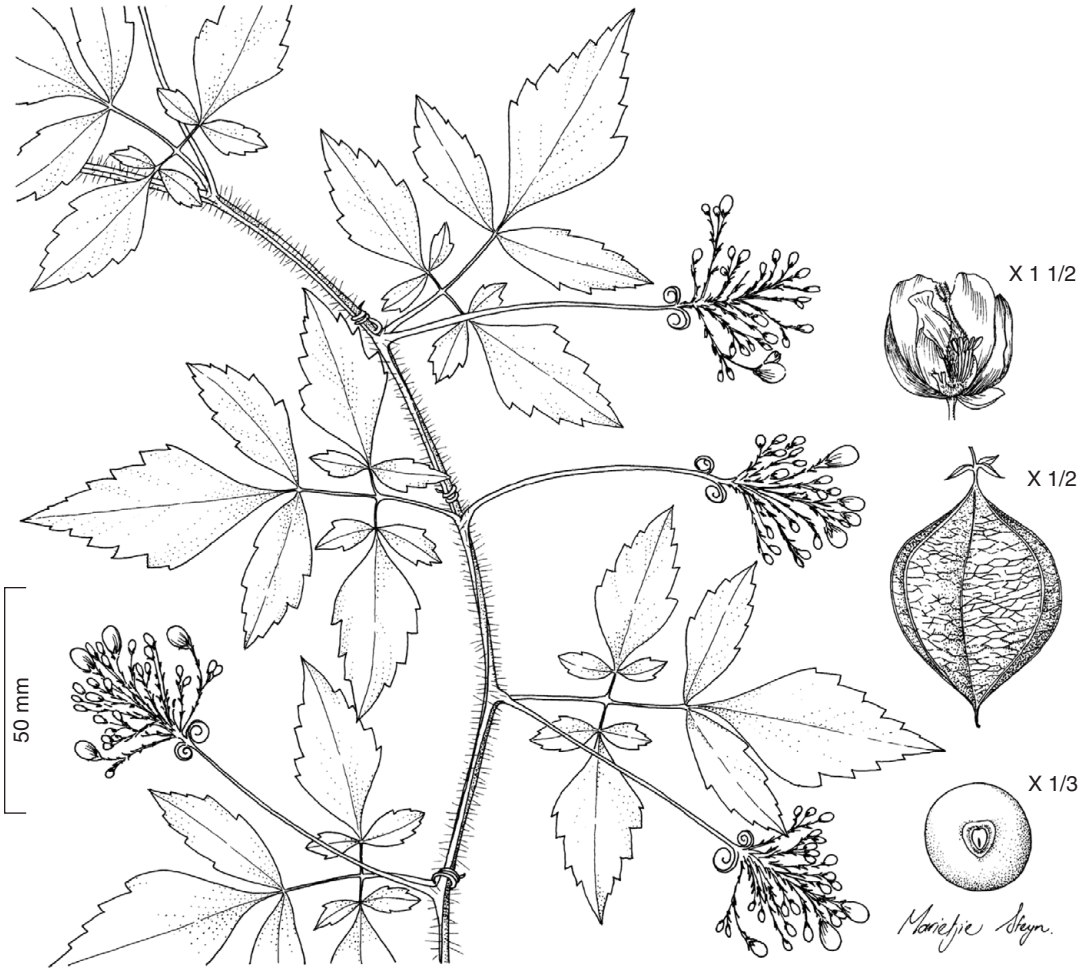

Fig. 1. *Cardiospermum grandiflorum.* (Drawn by M. Steyn; first published in Henderson (1995), South African National Biodiversity Institute, Pretoria.)

capsules with seeds are carried by wind and float freely on water, dispersing the plant along waterways (Henderson 2001).

In the Americas, the Neotropical native-range distribution of *C. grandiflorum* extends from southern Mexico to Brazil (Cowan 1983; Ferrucci 1991). The plant has become invasive in many parts of the world, particularly in Australia, the Cook Islands, Hawaii, New Zealand and South Africa (Henderson 2001; Meyer 2000; Carroll *et al.* 2005; USDA-NRCS 2009). *Cardiospermum grandiflorum* is still planted as an ornamental creeper in many warm areas of the world (Carroll *et al.* 2005), suggesting that it may have escaped horticultural plantations in countries where it has become invasive. Although *C. grandiflorum* was introduced in 1912 to South Africa (Henderson 2006), massive infestations of this climber have only been reported in the eastern low altitude regions of Mpumalanga and KwaZulu-Natal provinces since 2000 (Olckers 2004), suggesting that it may have been a sleeper-weed in South Africa for over 80 years. Similarly, a study by Carroll *et al.* (2005) showed that *C. grandiflorum* was a sleeper-weed for over 80 years in Australia following its introduction in the 1920s to that country. Although considered to be in the early stages of invasion in South Africa (Fig. 2), the Department of Agriculture, Fish and Forestry (DAFF) has acknowledged its potential threat to the ecosystem, thus declaring it a Category 1 weed (Henderson 2001). The magnitude of invasion by *C. grandiflorum* in recent

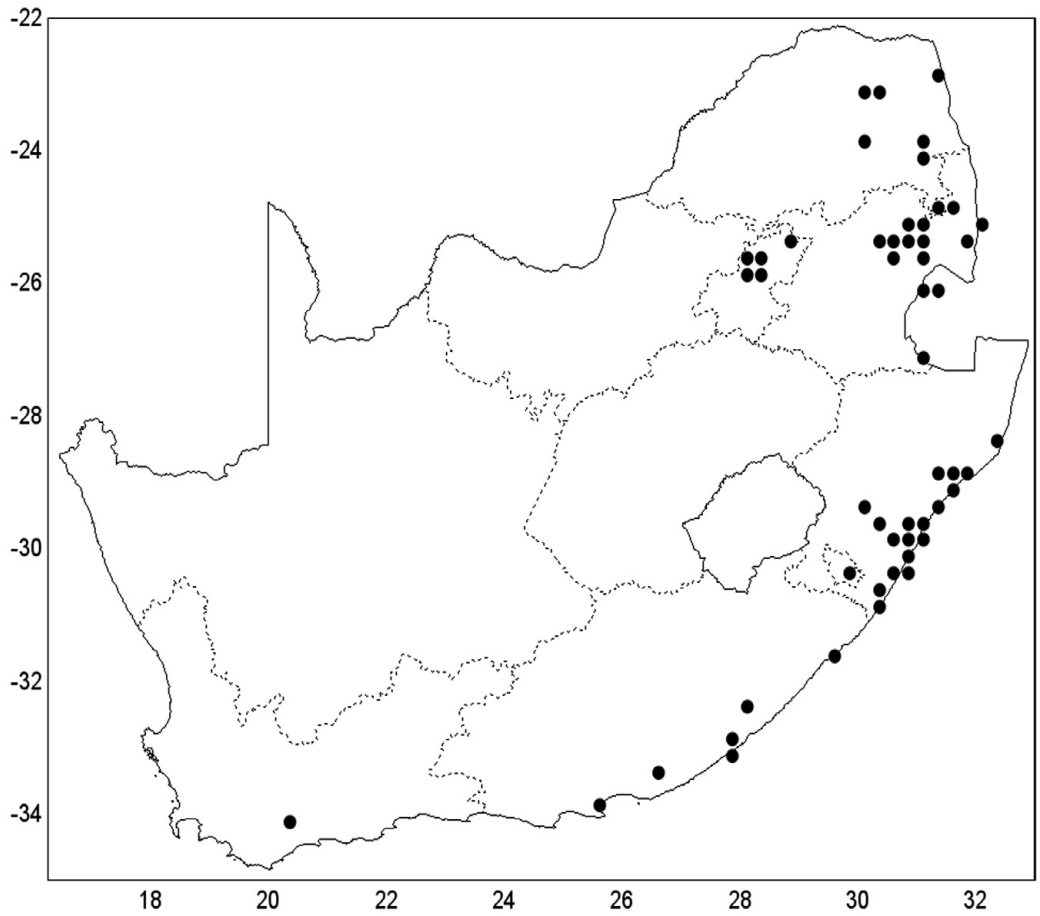

Fig. 2. Distribution of *Cardiospermum grandiflorum* in southern Africa. (Drawn by L. Henderson; data source: SAPIA database, ARC-Plant Protection Research Institute, Pretoria.)

years has been increasingly severe and threatening to biodiversity along the coastal regions of KwaZulu-Natal (KZN).

Mechanical control of *C. grandiflorum* is extremely difficult and costly as dead plant material has to be removed to restore exposure of the understorey to sunlight. Chemical control is similarly problematic because of non-target damage to underlying vegetation. Biological control is thus considered the only feasible option to curb the invasion of this vine in South Africa. Accordingly, *C. grandiflorum* was among five incipient, 'emerging weed' species targeted for biological control in 2003 by the Agricultural Research Council's Plant Protection Research Institute, through funding from the *Working for Water* Programme of the Department of Water Affairs (Olckers 2004). The South African biological control programme against *C. grandiflorum,* since its inception in 2003, is reviewed here.

BIOLOGICAL CONTROL

Surveys for natural enemies

In search of potential biological control agents, extensive exploratory surveys on *C. grandiflorum* and other selected Sapindaceae were conducted at 40 sites in Argentina from 2005 to 2009 (Mc Kay *et al.* 2010). The sites were concentrated in northern Argentina within the range of *C. grandiflorum* and other closely related Sapindaceae (Fig. 3). Field surveys showed that seed-feeding insects were the most common and damaging agents, and probably the key factors that regulate the abundance and spread of *C. grandiflorum* in its native range (Mc Kay *et al.* 2010), and were there-

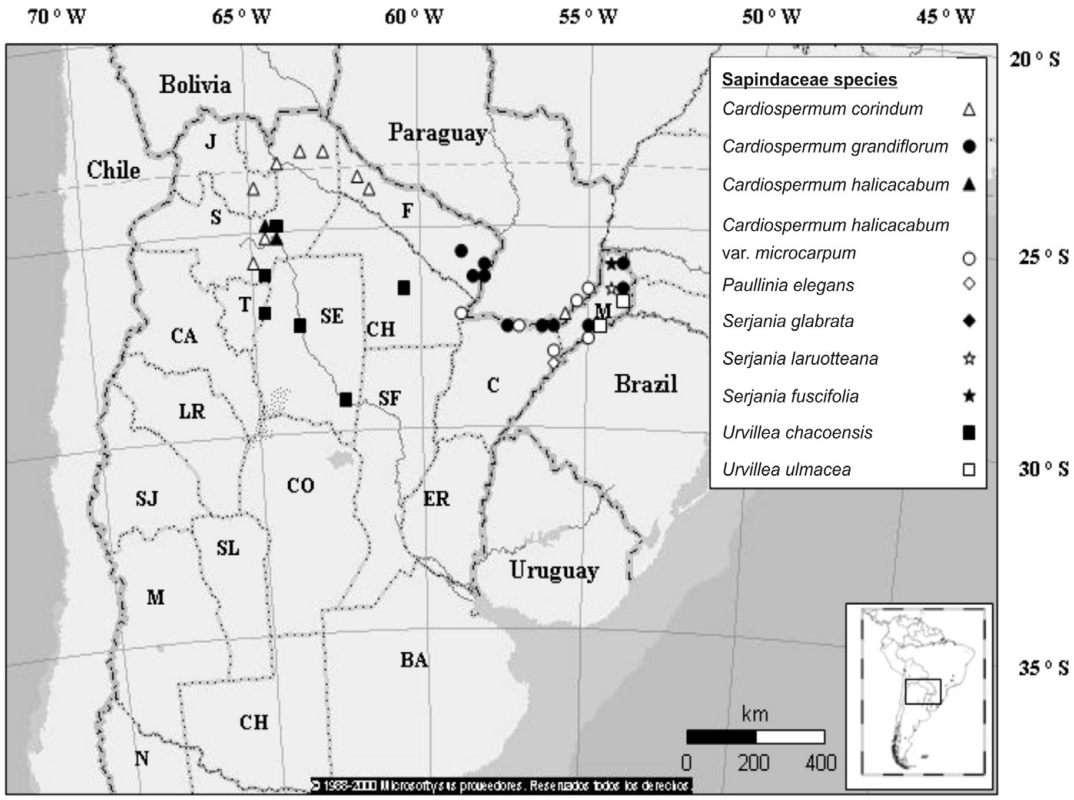

Fig. 3. Localities in northern Argentina where surveys for natural enemies of *Cardiospermum grandiflorum* and other Sapindaceae were undertaken from 2005 to 2009. (CH, Chaco; C, Corrientes; F, Formosa; J, Jujuy; M, Misiones; S, Salta; SE, Santiago del Estero; T, Tucumán). (First published in Mc Kay *et al.* 2010.)

fore prioritized as candidate biological control agents. Since the inception of the biological control programme against *C. grandiflorum,* eight insect species and two fungal pathogen species have been recorded on *C. grandiflorum* in its native South American range, four of which have been subjected to host-specificity testing in South Africa (Table 1). Of the three insect species tested, two displayed wide host ranges and were rejected because they were capable of feeding and developing on other cosmopolitan *Cardiospermum* species, particularly *Cardiospermum halicacabum* (Kunth) Blume and *Cardiospermum corindum* L. However, preliminary results of pre-release studies have shown that three agents, two insects and one pathogen, may be suitable for release against *C. grandiflorum.* The biology, host range and current status of the natural enemies collected so far on *C. grandiflorum* are reviewed below in descending order of their perceived level of suitability as biological control agents.

Cissoanthonomus tuberculipennis Hustache (Coleoptera: Curculionidae)

The seed-feeding weevil *C. tuberculipennis* has been recorded on *C. grandiflorum* throughout its range in Argentina, and is particularly abundant in the northeastern Misiones province. Adult weevils are light brown to grey in colour, and are 4–5 mm in length. Adults have prominent tubercles on the elytra, with greatly enlarged fore-femora and a strong ventral spine. Adults feed on the flower buds and open flowers, and occasionally on the leaves and shoot tips. Eggs are inserted into the young green fruits and the emerging larvae feed on the seeds inside the developing fruit. Larvae are highly damaging, with one to two larvae capable of destroying all of the seeds within a single fruit capsule. Pupation occurs inside the fruit capsule, and the newly emerged adults often remain inside the capsule for some days prior to emergence.

Preliminary results of paired- and no-choice

Table 1. Natural enemies recorded on *Cardiospermum grandiflorum* in Misiones, Argentina.

Order: Family	Natural enemy	Date imported/ recorded	Main feeding guild	Status
Coleoptera: Curculionidae	*Cissoanthonomus tuberculipennis*	2007	Seed feeder	Host-specificity tests in progress; agent promising
Diptera: Cecidomyiidae	*Contarinia* sp.	2009	Flower-bud galler	Culturing unsuccessful; agent promising
Hymenoptera: Eulophidae	*Lisseurytomella flava*	2005	Seed feeder	Culturing unsuccessful
Lepidoptera: Pyralidae	*Moodnopsis* sp. nr *perangusta*	2007	Seed feeder	Not imported
Lepidoptera: Pyralidae	*Apocera zographica*	2007	Leaf tier and chewer	Not imported
Lepidoptera: Tortricidae	*Platynota xylophaea*	2007	Leaf tier and chewer	Not imported
Hemiptera: Tingidae	*Gargaphia* sp.	2005	Leaf sucker	Not host-specific, rejected
Lepidoptera: Lycaenidae	*Chlorostrymon simaethis sarita*	2005	Seed feeder	Not host-specific, rejected
Uredinales: Pucciniaceae	*Puccinia arechavaletae*	2005	Leaf rust	Host-specificity tests completed; agent promising
Phyllachorales: Phyllachoraceae	*Phyllachora rimulosa*	2008	Stem/petiole/leaf rust	Culturing unsuccessful

tests conducted in South Africa have indicated that the weevil is only able to lay eggs and to develop in the seeds of *C. grandiflorum.* These results are consistent with surveys and studies conducted in the native range which have also shown that *C. tuberculipennis* is monophagous and specific to *C. grandiflorum* (Clark 2006; Clark *et al.* 2007; Mc Kay *et al.* 2010). Other biological attributes of *C. tuberculipennis,* including long-lived adults (2–4 months) and a short life cycle (40–45 days from egg to adult), suggest that this weevil has great potential as a biological control agent against *C. grandiflorum.*

Contarinia sp.
(Diptera: Cecidomyiidae)

The gall-forming midge *Contarinia* sp., though less abundant than *C. tuberculipennis* in its native range, is highly damaging to the young fruits of *C. grandiflorum.* Adults oviposit on the young fruits and larval feeding transforms these into galls, resulting in fruit deformation and the destruction of seeds. Fully matured orange-red larvae exit the galls and drop onto the ground to pupate in the leaf litter. Adult emergence was recorded 2–3 weeks after the emergence of larvae from the galls.

Owing to high levels of parasitism by several wasp species (*e.g. Oomyzus sokolowskii* (Kurdjumov) (Eulophidae), *Idiomacromerus* sp. (Torymidae) and *Torymus* sp. (Torymidae)) in South America, few adults emerge from field-collected galls, thereby limiting the number required to establish laboratory cultures. However, extensive field surveys and open-field experiments conducted in the native range revealed that *C. grandiflorum* is the only host of *Contarinia* sp. (Mc Kay *et al.* 2010). Since there are no host records of gall midges associated with either Sapindaceae or *Cardiospermum* species in North and South America (Gagné 1989), this gives some indication of the extreme specialization of *Contarinia* sp. In the light of its apparently narrow field host-range and potential impact on the reproductive capacity of *C. grandiflorum, Contarinia* sp. appears to have great potential as a biological control agent for

C. grandiflorum in South Africa, and further attempts to develop effective rearing techniques that permit quarantine cultures and enable host-specificity testing of this midge, are a priority.

Puccinia arechavaletae Speg.
(Pucciniales: Pucciniaceae)

Many destructive pathogens have been recorded on *C. grandiflorum* in its native distribution (Farr & Rossman 2009). During exploratory field surveys conducted in northern Argentina from 2005 to 2009, the rust fungus, *P. arechavaletae,* was found to cause conspicuous and damaging disease symptoms on *C. grandiflorum,* and an isolate of the rust was collected for further tests in South Africa (Mc Kay *et al.* 2010). Studies showed that optimum production of basidiospores occurs at 20°C, under conditions of high relative humidity (above 90 %), and in the presence of free water. The fragile basidiospores germinated over a wide temperature range but were particularly vulnerable to desiccation. *Puccinia arechavaletae* is an autoecious microcyclic rust (Hennen *et al.* 2005), and the production of basidiospores is therefore a crucial phase in its life cycle, as it is the primary means of dispersal.

The rust proved to be highly pathogenic on South African *C. grandiflorum,* causing severe detrimental effects to plant growth and vigour. Host-specificity tests demonstrated that *P. arechavaletae* has a narrow host range, only infecting and causing disease symptoms on two, supposedly South African, *Cardiospermum* congeners (*C. corindum* and *C. halicacabum* var. *halicacabum*) under laboratory conditions. To resolve the issue of non-target effects of *P. arechavaletae* on other *Cardiospermum* species, potential distributions of the rust in South Africa and South America were determined by climatic modelling software, and validated by extensive field surveys conducted in the native range of *C. grandiflorum.* These studies showed that *P. arechavaletae* would only persist in the wetter areas of South Africa where *C. grandiflorum* is a problem, but not in the drier northern parts of the country where *C. corindum* occurs. Since *P. arechavaletae* has a narrow host-range and climatic modelling has shown that *C. corindum* is not at risk, release of this fungus against *C. gradiflorum* in South Africa seems justified, particularly when considered in conjunction with the disputed native status of the two non-target species (see below).

Moodnopsis n. sp. near *perangusta* Dyar
(Lepidoptera: Pyralidae)

An undescribed species of *Moodnopsis* that is closely related to *M. perangusta* was recorded for the first time on *C. grandiflorum* by Mc Kay *et al.* (2010), and it is not known to occur on any other plant species (Robinson *et al.* 2009). Adult moths oviposit on the fruits of *C. grandiflorum* and a single larva of *Moodnopsis* n. sp. is capable of destroying all three seeds within a fruit capsule before pupating. A silk-cocoon-covered pupa remains attached to the inner wall of the fruit capsule until adult emergence from the dry mature fruit. Although surveys indicated that *C. grandiflorum* was the only natural host of *Moodnopsis* n. sp. (Mc Kay *et al.* 2010), larvae of this moth were recently found inside young fruits of *C. corindum* in an open-field experiment currently in progress in Argentina (F. Mc Kay *et al.,* unpubl.). In the event that the most promising seed-feeding agent, the seed weevil *C. tuberculipennis,* fails to establish or is ineffective in controlling *C. grandiflorum* in South Africa, host-specificity tests on *Moodnopsis* n. sp. may be considered, despite its apparent ability to develop on *C. corindum.*

Lisseurytomella flava (Ashmead)
(Hymenoptera: Eulophidae)

Besides *C. grandiflorum,* this seed-feeding wasp has also been recorded on other *Cardiospermum* species as well as other Sapindaceae. Adult wasps oviposit on young fruits, and larvae feed on the seeds until pupation. Larvae cause deformation of the seeds and possibly limit their viability. Five to thirty larvae per fruit have been recorded on *C. grandiflorum* in the field (Mc Kay *et al.* 2010). Since *L. flava* has also been recorded on sapindaceous species outside of the genus *Cardiospermum* (*e.g. Urvillea* sp.), its suitability as a biological control agent for *C. grandiflorum* in South Africa is very doubtful. The wasp was imported into quarantine in 2005 but attempts to culture it in the laboratory have not been successful. It is thus unlikely that this insect will be considered for further tests.

Chlorostrymon simaethis sarita (Skinner)
(Lepidoptera: Lycaenidae)

Chlorostrymon simaethis sarita, commonly known as 'the hairstreak moth', occurs throughout Central and South America, from Mexico to Argentina (Nicolay 1980). Eggs are laid singly on the outside of *C. grandiflorum* fruits, and the newly-hatched

larvae bore through the fruit membrane to feed on the seeds. Larvae of *C. simaethis sarita* are highly cannibalistic, and they are voracious, capable of destroying all three seeds within the fruit capsule prior to pupation. The larva exits the empty fruit capsule to pupate in the leaf litter. Following importation into South Africa in 2005, host-specificity tests demonstrated that *C. simaethis sarita* was unsuitable for release. Although the butterfly is highly damaging to *C. grandiflorum* seeds, larvae were found to develop on other species of *Cardiospermum* and on *Urvillea* species (Mc Kay *et al.* 2010). Furthermore, laboratory studies showed that *C. simaethis sarita* was equally damaging to non-target *Cardiospermum* species such as *C. halicacabum* and *C. corindum.* Pratt & Ballmer (1991) also recorded *C. simaethis sarita* on a wide variety of plant species, including some in the family Fabaceae. Due to this broad host range, further work on this insect was terminated and the cultures were destroyed.

Gargaphia sp. (Hemiptera: Tingidae)

An unidentified species of *Gargaphia* is one of the most common and damaging natural enemies of *C. grandiflorum,* occurring along the entire range of the target weed in Argentina (Mc Kay *et al.* 2010). Owing to severe drought during field surveys in 2005, *C. grandiflorum* fruits and seed-feeding agents were extremely rare, allowing the opportunity to collect and introduce a leaf-sucking bug *Gargaphia* sp. into South African quarantine. Females deposit egg batches on the undersides of leaves and the sap-sucking nymphs and adults feed mainly on the leaves, and occasionally on green stems, causing severe chlorosis. *Gargaphia* sp. has a short generation time, taking approximately 30 days to develop from egg to adulthood. Although Mc Kay *et al.* (2010) consistently found *Gargaphia* sp. on *C. grandiflorum* during field surveys conducted over a five-year period, paired-choice tests conducted in South Africa indicated that the lace bug accepts both the common bean *Phaseolus vulgaris* L. (Fabaceae) and *Cardiospemum* species, including *C. grandiflorum,* for oviposition and development to adulthood. Owing to its apparently broad physiological host range, the tingid was deemed unsuitable for release. Although previous taxonomic investigation had indicated that there are two species of *Gargaphia* on *C. grandiflorum* (F. Mc Kay, pers. comm.), several attempts to collect the second species have been unsuccessful and further pre-release studies are thus required to determine its suitability for release.

Apocera zographica (Dyar)
(Lepidoptera: Pyralidae) and
Platynota xylophaea (Meyrick)
(Lepidoptera: Tortricidae)

Both moth species, *A. zographica* and *P. xylophaea,* have leaf-tying larvae that have only been recorded on balloon vine, and were abundant at several sites in Argentina during surveys in 2007. However, neither species was encountered during subsequent surveys conducted from 2008 to 2010. Both species were imported into quarantine in 2007, but were not successfully cultured. Consequently, their life histories and host ranges remain unknown.

Phyllachora rimulosa Speg.
(Phyllachorales: Phyllachoraceae)

The tarspot fungus *P. rimulosa* was found to be damaging on the stems, leaves, and petioles of *C. grandiflorum* at several sites in northeastern Argentina. An isolate of the fungus was opportunistically collected and imported for further investigation under quarantine conditions in South Africa (Fourie 2008). The fungal spores proved to be viable, but could not be established on South African *C. grandiflorum* plants. As the results of host-specificity tests on the rust fungus *P. arechavaletae* appear to be promising, further research on this tarspot fungus has been shelved, but not abandoned.

PHYLOGENETICS IN TRACING THE NATIVE RANGES OF *CARDIOSPERMUM* SPECIES

The uncertainty surrounding the native ranges of *C. halicacabum* and *C. corindum* has complicated and prolonged the biological control programme by causing the rejection of candidate agents and thereby limiting the pool of potential agents for use against this weed. Whilst the native range of *C. grandiflorum* is certainly neotropical America (Carroll *et al.* 2005; Ferrucci 2000), that of *C. halicacabum* and *C. corindum* remains contentious. Although *C. corindum* is listed by some (Davies & Verdcourt 1998; Germishuizen *et al.* 2006) as being of tropical East African origin, others (*e.g.* Castellanos *et al.* 1999; Molina-Freaner & Tinoco-Ojanguren 1997; Aldrich *et al.* 1990) consider it to be an American native. Similarly, some authors have reported

C. halicacabum to be indigenous to both the Americas and to Africa (Rock 1972) while others argue in favour of an African native range (Davies & Verdcourt 1998; Exell 1966; Hyde & Wursten 2009). The uncertainty surrounding the native ranges of these two *Cardiospermum* species has serious implications for the release of potential biological control agents of *C. grandiflorum* in South Africa. If *C. corindum* and *C. halicacabum* are indeed native to Africa, only strictly monophagous candidate agents would qualify for release in South Africa. However, any non-target attacks on *C. corindum* and *C. halicacabum* would be of no concern in South Africa if these species were exotic, and this would substantially increase the pool of potential agents that could qualify for release against *C. grandiflorum.*

A phylogenetic study is currently under way at the Centre for Invasion Biology at Stellenbosch University to clarify the origin of *C. halicacabum* and *C. corindum.* This study was specifically aimed at determining the phylogeographic relationships within and among selected *Cardiospermum* species, notably the South American *C. grandiflorum,* the African *Cardiospermum pechuelii* Kuntze and the two species (*C. corindum* and *C. halicacabum*) that are of uncertain origin and present in South Africa. Should the phylogenetic study show that *C. corindum* and *C. halicacabum* are of American origin, two additional seed-feeding species (*Moodnopsis* n. sp. and *L. flava*), that have been recorded on these species in Argentina could also be considered for release against balloon vine in South Africa.

CONCLUSIONS

Whilst the uncertainty surrounding the origin *C. halicacabum* and *C. corindum* persists, open-field experiments conducted in the native range suggest that only two insect agents would qualify for release against *C. grandiflorum* in South Africa, namely the seed-feeding weevil *C. tuberculipennis* and the gall-forming midge *Contarinia* sp. Preliminary results of host-specificity tests and other pre-release studies indicate that *C. tuberculipennis* is strictly monophagous, ovipositing and developing only on *C. grandiflorum.* Considering that *C. grandiflorum* is an emerging weed that reproduces mainly through seeds, it seems that fruit- and seed-feeding agents like *C. tuberculipennis* and *Contarinia* sp. would be most effective as biological control agents. However, two additional seed feeders (*Moodnopsis* n. sp. and *L. flava*) could be prioritized for introduction and further host-specificity testing if the phylogenetic study shows that *C. corindum* and *C. halicacabum* are indeed of American origin. Although the rust fungus *P. arechavaletae* has a narrow host range and is highly destructive on the target weed, it also manifests disease symptoms on *C. halicacabum* and *C. corindum.* Besides the possibility that these two species are exotic, climatic modelling and field surveys have demonstrated that *P. arechavaletae* poses a negligible risk to these two non-target congeners because it would only persist in the wetter areas of South Africa where *C. grandiflorum* is a problem, but not in the drier parts of the country where *C. halicacabum* and *C. corindum* occur.

Despite the phylogenetic and other difficulties associated with this programme, the suite of candidate agents available, particularly those that attack the plant's reproductive tissues, may hold promise for successful biological control of *C. grandiflorum* in South Africa. Close collaboration with a professional Argentinean institution has been a major factor in the progress achieved so far and should be fostered in the future. Although this programme is currently unique to South Africa, its outcomes may well be extended to other countries where *C. grandiflorum* is problematic.

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REFERENCES

ALDRICH, J.R., CARROLL, S.P., LUSBY, W.R., THOMPSON, M.J., KOCHANSKY, J.P. & WATERS, R.M. 1990. Sapindaceae, cyanolipids, and bugs. *Journal of Chemical Ecology* **16**: 199–210.

CARROLL, S.P., MATHIESON, M. & LOYE, J.E. 2005. Invasion history and ecology of the environmental

weed balloon vine, *Cardiospermum grandiflorum* Swartz, in Australia. *Plant Protection Quarterly* **20**: 140–144.

CASTELLANOS, A.E., TINOCO-OJANGUREN, C. & MOLINA-FREANER, F. 1999. Microenvironmental heterogeneity and space utilization by desert vines within their host trees. *Annals of Botany* **84**: 145–153.

CLARK, W.E. 2006. Removal of *Cissoanthonomus* Hustache from synonymy with *Atractomerus* Duponchel and Chevrolat (Coleoptera: Curculionidae). *The Coleopterists Bulletin* **60**: 345–346.

CLARK, W.E., BURKE, H.R. & MC KAY, F. 2007. The weevil genus *Achia* Champion (Coleoptera: Curculionidae): new species associated with *Urvillea* (Sapindaceae) and new *Serjania* host plant records for *A. ancile* Burke and *A. affinis* Hustache. *The Coleopterists Bulletin* **61**: 542–550.

COWAN, C.P. 1983. Flora de Tabasco. *Listados florísticos de México* **1**: 1–123.

DAVIES, F.G. & VERDCOURT, B. 1998. *Cardiospermum.* In: Beentjie, H.J. & Whitehouse, C.M. (Eds) *Flora of Tropical East Africa: Sapindaceae.* 97–102. Royal Botanical Gardens, Kew, U.K.

EXELL, A.W. 1966. Sapindaceae. In: Exell, A.W., Fernandes, A. & Wild, H. (Eds) *Flora Zambesiaca.* 494–544. Crown Agents for Governments and Administrations, London.

FARR, D.F. & ROSSMAN, A.Y. 2009. Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA. Online at: http://nt.ars-grin.gov/fungaldatabases/ (accessed January 2009)

FERRUCCI, M.S. 1991. Sapindaceae. In: Spichiger, R.S. & Ramella, L. (Eds) *Flora del Paraguay.* Editions des Conservatoire et Jardin botaniques dela Ville de Genève, Chambésy.

FERRUCCI, M.S. 2000. Revisión de los géneros *Cardiospermum* y *Urvillea* para el neotrópico (*Sapindaceae*). Tesis doctoral, FCEFyN-Universidad Nacional Córdoba.

FOURIE, A. 2008. Survey for natural enemies of *Cestrum* and *Cardiospermum* species in Argentina. *Plant Protection News* **76**: 10.

GAGNÉ, R.J. 1989. *The Plant-feeding Gall Midges of North America.* Cornell University Press, Ithaca, New York.

GERMISHUIZEN, G., MEYER, N.L., STEENKAMP, Y. & KEITH, M. (Eds) 2006. *A Checklist of South African Plants.* Southern African Botanical Diversity Network Report No. 41, SABONET, Pretoria.

HENDERSON, L. 1995. *Plant Invaders of Southern Africa.* Plant Protection Research Institute Handbook No. 5. Agricultural Research Council, Pretoria, South Africa.

HENDERSON, L. 2001. *Alien Weeds and Invasive Plants: A Complete Guide to Declared Weeds and Invaders in South Africa.* Plant Protection Research Institute Handbook No. 12, Agricultural Research Council, Pretoria, South Africa.

HENDERSON, L. 2006. Comparison of invasive plants in southern Africa originating from Southern temperate, Northern temperate and tropical regions. *Bothalia* **36**: 201–222.

HENNEN, J.F., FIGUEIREDO, M.B., DE CARVALDO, A.A. & HENNEN, P.G. 2005. Catalogue of the species of plant rust fungi (Uredinales) of Brazil. Instituto de Pesquisas Jardim Botânico do Rio de Janeiro Online at: http://www.jbrj.gov.br (accessed July 2009).

HYDE, M.A. & WURSTEN, B. 2009. Flora of Zimbabwe: Genus Page: *Cardiospermum. Online at:* http://www.zimbabweflora.co.zw/speciesdata/genus.php?genus_id=900 (accessed May 2009).

MC KAY, F., OLERIO, M., FOURIE, A. & SIMELANE, D. 2010. Natural enemies of balloon vine, *Cardiospermum grandiflorum* Swartz (Sapindaceae), in Argentina and their potential use as biological control agents in South Africa. *International Journal of Insect Science.* **30**: 67–76.

MEYER, J-Y. 2000. Invasive plants in the Pacific Islands. In: Sherley, G. (Ed.) *The Invasive Species in the Pacific: A Technical Review and Draft Regional Strategy.* 85–114. South Pacific Regional Environment Programme (SPREP), Apia, Samoa.

MOLINA-FREANER, F. & TINOCO-OJANGUREN, C. 1997. Vines of a desert plant community in central Sonora, México. *Biotropica* **29**: 46–56.

MORANES, M. 1990. Lista prelimar de esspecies Botanicas coleccionadas durante la Expedicion Rio Madre de Dios (Norte de Bolivia). *Museo Nacional de Historia Natural (Bolivia) Communicacion* **10**: 32–52.

NICOLAY, S. 1980. The genus *Chlorostrymon* and a new subspecies of *C. simaethis. Journal of the Lepidopterists' Society.* **34**: 253–256.

OLCKERS, T. 2004. Targeting emerging weeds for biological control in South Africa: the benefits of halting the spread of alien plants at an early stage of their invasion. *South African Journal of Science* **100**: 64–68.

PRATT, G.F. & BALLMER, G.R. 1991. Acceptance of *Lotus scopurius* (Fabaceae) by larvae of Lycaenidae. *Journal of the Lepidopterists' Society* **45**: 188–196.

ROBINSON, G.S., ACKERY, P.R., KITCHING, I.J., BECCALONI, G.W. & HERN NDEZ, L.M. 2009. *Host a Database of the World's Lepidopteran Hostplants.* The Natural History Museum, London.

ROCK, B.N. 1972. The woods and flora of the Florida Keys: "Pinnatae". *Smithsonian Contributions to Botany* **5**: 1–35.

UNITED STATES DEPARTMENT OF AGRICULTURE – NATIONAL RESOURCE CONSERVATION SERVICE. 2009. The Plants Database: Weeds of Hawaii. National Plant Data Center, Baton Rouge, LA, U.S.A.