Dasineura rubiformis (Diptera: Cecidomyiidae), a new biological control agent for *Acacia mearnsii* in South Africa

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A cecidomyiid midge, *Dasineura rubiformis,* is the most recent addition to the suite of biological control agents that have been deployed in South Africa against invasive Australian *Acacia* species. This insect is associated with *Acacia mearnsii* (black wattle), which is extremely invasive, but also an important agro-forestry species, in South Africa. It induces development of galls in the flowers of *A. mearnsii,* thereby preventing pod development and reducing the reproductive capacity of the plants. The useful attributes of this economically important plant species should not be affected by the introduction of *D. rubiformis.* The midge is established in the vicinity of Stellenbosch, where it is increasing in abundance. Studies have been initiated to (i) evaluate the performance of the midge; (ii) confirm that galling does not cause a reduction in vegetative growth of *A. mearnsii;* and (iii) determine the potential effectiveness of *D. rubiformis* as a biological control agent of *A. mearnsii.* All indications are that the insect has the potential to become an excellent seed-reducing biological control agent of *A. mearnsii.*

Background

A diverse array of gall midges (Cecidomyiidae) is associated with the Australian acacias in their native habitat.[1] In the late 1990s, attention was focused on them in a drive to find additional biological control agents for use against invasive Australian *Acacia* species in South Africa with emphasis on black wattle (*Acacia mearnsii*).[2,3]

Acacia mearnsii is one of South Africa's most widespread and problematic invasive plants.[4–7] Its presence in natural forests, grasslands and water courses continues to threaten ecosystems in terms of loss of biodiversity, reduced water supplies, increased soil erosion and by exacerbating the intensity of fires.[8–12] The success of the plant as an invasive weed and its persistence in the landscape is largely attributable to the annual production of enormous seed crops which accumulate and persist in the soil for many years.[6,13]

Historically, the biological control programme against invasive Australian *Acacia* species in South Africa has been fraught with conflict, particularly due to the economic importance (for tannin and paper pulp) of black wattle.[14–18] As a compromise, the choice of biological control agents has been restricted to those that reduce the reproductive capacity but not the useful attributes of the plants.[6,18,19] The concerns about biological control potentially disrupting commercial supplies of seed were resolved by demonstrating that the prospective agents can be effectively controlled with conventional insecticides,[3,20] some of which are routinely applied in wattle plantations.[21–23]

The first agent to be released against *A. mearnsii* was a seed-feeding weevil, *Melanterius maculatus,* which is now established at a number of sites across the country.[6] Although *M. maculatus* can cause substantial levels of seed reduction of *A. mearnsii,* considerable quantities of seed are still produced annually (F. Impson, unpublished data). The addition of complementary biological control agents to further reduce reproductive output of *A. mearnsii* was therefore desirable.

Eight gall midge species are associated with the reproductive structures of black wattle in Australia. Of these, *D. rubiformis* was considered to be the most suitable candidate for use in the biological control programme against black wattle in South Africa. This decision was based partly on observations that *D. rubiformis* substantially reduces pod production of *A. mearnsii* in Western Australia, where both the midge and host plant have become naturalized after being introduced from eastern Australia.[3] In this article we summarize progress with *D. rubiformis* in South Africa and discuss the issues that need to be addressed before the insect is exploited fully as a biological control agent of *A. mearnsii.*

Life cycle of *D. rubiformis*

The life cycle of *D. rubiformis* has been described by Adair.[3] It is a univoltine species in which adult emergence is closely synchronized with the distinct flowering pulse exhibited by *Acacia mearnsii* during spring (September/October). Adult *D. rubiformis* live only a few days and females require open flowers for oviposition, so this synchrony is essential. The eggs are laid within the perianth tube of the flower and, on hatching, the larvae start feeding on the surface of the ovary, at the same time inducing gall-formation and preventing pod set by affected flowers. The flowers of *A. mearnsii* occur in globular flower-heads, each with about 45 flowers. Afflicted flower-heads generally produce a small, tightly packed cluster of up to 36 galls [10.5 ± 1.0 s.e., n = 83 at Stellenbosch in July 2007 (unpublished data)] instead of pods. Each gall within the cluster contains 1–5 chambers, and generally a single larva develops within each chamber. Third-instar larvae emerge from the galls during winter (June/July) and drop to the soil where they pupate in silken cocoons.

Host range

Surveys in Australia of 147 native *Acacia* species, including 27 within the section Botrycephalae, along with three introduced African species and one introduced American species,[3] showed that, besides *A. mearnsii, D. rubiformis* may be associated with the following Botrycephalae species in eastern Australia: *Acacia parramattensis, A. irrorata, A. deanei, A. leucoclada* and *A. constablei.* The structure of galls on these five species resembles that of *D. rubiformis* on *A. mearnsii* and DNA sequences of larvae from the first four species matched those of *D. rubiformis.* Larvae from the fifth species were not sequenced. To confirm these putative identifications, adults need to be reared from the galls and examined.[1] In Western Australia, where both insect and host plant are naturalized, *D. rubiformis* was found only on *A. mearnsii.*[1] Of the species listed above, only *A. mearnsii* currently occurs in South Africa.

Host-specificity tests, conducted at the Plant Protection Research Institute in Stellenbosch between 1999 and 2001, confirmed the restricted host range of *D. rubiformis.* During these studies flowering branches of 10 Australian *Acacia* species [including four species from the section Botrycephalae, namely, *A. mearnsii, A. dealbata, A. baileyana* and *A. decurrens,* 13 African *Acacia* species, an American acacia, and an additional four species of test plant (*Paraserianthes lophantha,* Mimosaceae; *Cydonia oblonga* and *Prunus armeniaca,* both Rosaceae; and *Vitis vinifera,* Vitaceae)] were exposed to cohorts

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of *D. rubiformis* adults and monitored for subsequent development of galls. Under the test conditions, gall induction occurred only on *A. mearnsii*.[3]

Host plant growth

One of the concerns when using biological control agents that reduce seed production of invasive acacias by forming galls is that the galling may also suppress the growth rate of the host plants. A case in point is that of the gall wasp, *Trichilogaster acaciaelongifoliae*, which is an extremely effective biological control agent of *A. longifolia* in South Africa.[18,24] Although most *T. acaciaelongifoliae* galls are induced in flower buds, the wasps also stunt vegetative growth of *A. longifolia* because: (i) galls induced in vegetative meristematic tissues destroy the growth points which would give rise to new stems; and (ii) galls suppress growth indirectly because their biomass is routinely much higher than that of normal seed pod loads (that is, that would occur on ungalled trees).[24,25]

Conversely, two other introduced gall-forming insects on Australian acacias in South Africa have had little or no indirect effect on the vegetative growth of their host plants.[26] Physiological studies have shown that compensatory photosynthesis in adjacent phyllodes offsets the carbon demands placed on the host plant by galls of *Trichilogaster signiventris* on *Acacia pycnantha*[27] and by galls of *Dasineura dielsi* on *Acacia cyclops* (C. Moseley, University of Cape Town, unpublished data). The compensation is possible because the galls induced by these two species do not disrupt plant tissue functioning.[27] The studies also demonstrated that photosynthetic activity of the galls themselves may contribute substantially to the carbon budgets of the galls,[27] thus further offsetting the carbon demands of the galls.

Dasineura rubiformis is expected to resemble *D. dielsi* most closely and not cause any reduction in the growth rates of the host plant because: (i) *D. rubiformis* lays its eggs exclusively in flowers of *A. mearnsii*, and consequently galls never develop in vegetative meristematic tissue; and (ii) the biomass of each *D. rubiformis* gall is much less than a seed pod [gall mean dry biomass = 5.8 ± 0.3 mg (n = 50), seed pod mean dry biomass = 292 ± 27 mg (n = 40)]. The number of galls that are produced may exceed the number of pods that would normally be generated, but this would need to be about 50-fold to require equivalent resources.

Evaluation studies

Dasineura rubiformis is currently established in the Stellenbosch region of South Africa. Qualitative assessments have shown that levels of galling are increasing (unpublished data). In 2006, galls were detectable over a range that extended for about 800 m. In 2007 this range had increased sixfold, up to 5000 m. In Western Australia *D. rubiformis* has demonstrated an ability to locate disparate populations of *A. mearnsii*, including trees that occur in isolation.[3] The midge will probably show the same dispersal ability and eventually become established widely in South Africa. At present no efforts are being made to distribute the insects manually until the completion of studies, to confirm that *D. rubiformis* is no threat to the integrity of the wattle industry.

These studies have begun and include monitoring of the extent and intensity of galling on *A. mearnsii* along with rates of spread and impact on pod production. Physiological studies are being undertaken to confirm that compensatory photosynthesis occurs and to determine the extent of photosynthesis by the galls themselves. A comparison of the vegetative growth of *A. mearnsii*, relative to intensity of galling, is being undertaken to confirm that growth is not suppressed.

Additional studies will determine how *D. rubiformis* (i) interacts with the introduced seed weevil, *M. maculatus*; and (ii) might be influenced by acquired parasitoids and predators in South Africa. Cecidomyiid midges have a poor reputation as biological control agents because they are prone to parasitoid attack when introduced into new areas.[28–30] In Western Australia, however, *D. rubiformis* has become abundant and effective in suppressing pod production despite the acquisition of parasitoids.[3]

Conclusion

Based on available evidence, *D. rubiformis* will be restricted to *A. mearnsii* in South Africa with the capacity to reduce pod production substantially while not reducing the vigour of the plants. All indications are that the midges will be compatible with the commercial exploitation of wattle. In combination, it is anticipated that *M. maculatus* and *D. rubiformis* will make a beneficial contribution to curbing the invasiveness of one of South Africa's most troublesome alien plant species.

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