Prospective agents for the biological control of *Tithonia rotundifolia* (Mill.) S.F.Blake and *Tithonia diversifolia* (Hemsl.) A.Gray (Asteraceae) in South Africa

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Starting in 2007, two weedy sunflower species, *Tithonia rotundifolia* (Mill.) S.F.Blake and *Tithonia diversifolia* (Hemsl.) A.Gray (Asteraceae: Heliantheae), were targeted for biological control in South Africa. Surveys conducted in their native range (Mexico) revealed that there were five potential biological control agents for *T. rotundifolia*, and three of these are currently undergoing host-specificity and performance evaluations in South Africa. Two leaf-feeding beetles, *Zygogramma signatipennis* (Stål) and *Zygogramma piceicollis* (Stål) (Coleoptera: Chrysomelidae), are the most promising biological control agents for *T. rotundifolia*: preliminary host-specificity trials suggest that they are adequately host-specific. The stem-boring beetle, *Lixus fimbriolatus* Boheman (Coleoptera: Curculionidae), is also highly damaging to *T. rotundifolia*, but its host range is yet to be determined. Two other stem-boring beetles, *Canidia mexicana* Thomson (Coleoptera: Cerambycidae) and *Rhodobaenus auctus* Chevrolat (Coleoptera: Curculionidae), have also been recorded on *T. rotundifolia*, and these will be considered for further testing if *L. fimbriolatus* is found to be unsuitable for release in South Africa. Only two insect species were imported as candidate agents on *T. diversifolia*, the leaf-feeding butterfly *Chlosyne* sp. (Lepidoptera: Nymphalidae), and an unidentified stem-boring moth (Lepidoptera: Tortricidae): the latter was tested in quarantine but rejected because it attacked several sunflower cultivars. Only one pathogen, *Puccinia enceliae* Dietel & Holw. (Uredinales: Pucciniaceae), was found that could potentially have been used as a biological control agent against the *Tithonia* species, but attempts to culture this rust were unsuccessful.

**Key words:** red sunflower, Mexican sunflower, *Zygogramma signatipennis*, *Zygogramma piceicollis*, *Lixus fimbriolatus*.

**INTRODUCTION**

Red sunflower, *Tithonia rotundifolia* (Mill.) S.F.Blake, and Mexican sunflower, *Tithonia diversifolia* (Hemsl.) A.Gray (Asteraceae: Heliantheae), from Mexico have become invasive in the humid and sub-humid tropics of Central and South America, South East Asia and tropical and subtropical Africa (Lazarides *et al.* 1997; Meyer 2000; Varnham 2006; Henderson 2001). The increasing abundance of *T. rotundifolia* and *T. diversifolia* in conservation and agricultural areas over the past ten years in South Africa has been of concern, resulting in the initiation of a biological control programme against these two species in 2007.

The genus *Tithonia* comprises 11 species, with the centre of distribution in Mexico, but with one species extending into the southwestern U.S.A., and several species extending into some Central American countries (Muoghalu & Chuba 2005).

*Tithonia rotundifolia* (Fig. 1) is a large, robust annual plant and grows up to 3 m in height. The leaves of *T. rotundifolia* are often paired, each triangular-ovate, or sometimes deeply three-lobed, and the reddish-orange flowers are held singly on long stems. *Tithonia diversifolia* (Fig. 2) is a large evergreen perennial shrub and grows up to 5 m tall, and has deeply divided, paired leaves and orange-yellow flowers on erect, hollow woody stems. In South Africa, flowering in *T. rotundifolia* occurs from late summer and throughout autumn, while *T. diversifolia* flowers in autumn and winter. *Tithonia rotundifolia* produces fewer, larger and heavier seeds, which may explain its early and vigorous seedling growth and longer survival in relatively unfavourable conditions (Muoghalu & Chuba 2005). By contrast, *T. diversifolia* produces numerous, smaller, lighter seeds which allow for dispersal over large areas (Muoghalu & Chuba 2005), and *T. diversifolia* cuttings, buried horizon-
tally into the soil, often sprout, contributing to the densification of stands of this species.

Deliberately introduced and widely cultivated as ornamental plants, both *T. rotundifolia* and *T. diversifolia* have become invasive in the tropics and subtropics (Lazarides *et al.* 1997; Meyer 2000), including several countries in sub-Saharan Africa (Chukwuka *et al.* 2007). In Nigeria, *T. diversifolia* is becoming an important weed of arable crops in Oyo, Gbongan and Ogun States, forcing some farmers to abandon their lands (Chukwuka *et al.* 2007). Following their introduction into South Africa in the 1900s (Henderson 2006), both *Tithonia* species are now invasive in KwaZulu-Natal (KZN), Limpopo and Mpumalanga provinces, with *T. rotundifolia* extending its range into the North West and Gauteng provinces (Fig. 3) and *T. diversifolia* being more abundant and widespread along the humid and low-altitude areas of Mpumalanga and KZN provinces (Fig. 4) (Henderson 2001). Both *T. rotundifolia* and *T. diversifolia* are aggressive colonizers, particularly in disturbed, sun-exposed ecosystems, abandoned sites, and along railways and roads, and they are declared Category 1 weeds in South Africa (Henderson 2001).

Although the uses of *Tithonia* species as medicinal plants (Lin *et al.* 1993; Takahashi 1998; Tona *et al.* 1998), livestock fodder (Roothaert & Paterson 1997), poultry feed (Odunsi *et al.* 1996) and green manure (Nagarajah & Nizer 1982; Drechsel & Reck 1998; Jama *et al.* 2000) are widely acknowledged in various parts of the world, the problems they cause in Africa as invasive weeds far outweigh their benefits.

There are no herbicides registered for the control of either of the *Tithonia* species in South Africa, and mechanical control is largely ineffective due to the ability of *T. diversifolia* to coppice from stems and because of the rapid recruitment of seedlings of

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**Fig. 1.** *Tithonia rotundifolia.* (Drawn by W. Roux; first published in Henderson (1995), ARC-Plant Protection Research Institute, Pretoria.)
both species in cleared areas. Consequently, a bio-
logical control programme was initiated, and field
surveys for potential biological control agents
were conducted in Mexico during 2007 and 2008
(Fig. 5). Nine candidate agents were recorded on
*Tithonia* species at over 100 sites, and eight of these
were subsequently introduced into quarantine in
South Africa for further evaluation. The biology,
host specificity and impact of those that were
introduced and evaluated for possible release are
reviewed below in descending order of their per-
ceived suitability as biological control agents.

**INSECT NATURAL ENEMIES OF**

**TITHONIA ROTUNDIFOLIA**

**Zygogramma signatipennis** (Stål) and
**Zygogramma piceicollis** (Stål)
(Coleoptera: Chrysomelidae)

The two leaf-feeding beetles, *Z. signatipennis* and
*Z. piceicollis*, are the most promising biological
control agents for *T. rotundifolia*. Although
*Z. signatipennis* was initially collected from a
closely-related plant species, *Tithonia tubaeformis* (Jasq.) Cass, in and around Mexico City in 2007, it
was later recorded on *T. rotundifolia* at several sites
in the Oaxaca and Chiapas states of Mexico. In
2008, *Z. piceicollis* was collected on *T. rotundifolia*
near Puerto Angel, along the humid south coast
region of Mexico. *Zygogramma signatipennis* is the
larger of the two, and is shiny black in colour with
silver green markings on the elytra. *Zygogramma*
*piceicollis* has a dark red head and thorax with light
grey markings on the elytra. The two beetle species
have very similar life histories and feeding habits.
Females of both species usually deposit their eggs
 singly on the lower leaf surface, mostly along the
leaf veins, but occasionally on the flower heads.
Adult and larval feeding by both beetle species on
the leaves is highly damaging, often skeletonizing
them completely. Late-instar larvae drop from the
host plant and burrow into the ground to pupate.
Development from egg to adult takes about four to
five weeks.

To determine the host range of the two *Zyg-}
gramma* species, trials were initiated in 2008 under
quarantine conditions in South African, and in the
field in Mexico. Preliminary results of paired- and
no-choice tests indicated that both species of *Zygogramma* strongly prefer *T. rotundifolia* to other closely-related plant species for feeding, oviposition and larval development. If, after further testing, they are found to be adequately host-specific to *T. rotundifolia*, permission to release both beetle species in South Africa will be sought. Surveys in Mexico indicate that *Z. signatipennis* is predominant in drier inland regions while *Z. piceicollis* is mainly found in warm, humid coastal regions, which might indicate that the release of both species could result in effective control throughout the distribution range of *T. rotundifolia* in South Africa.

*Lixus fimbriolatus* Boheman  
(Coleoptera: Curculionidae)

The stem-boring weevil *L. fimbriolatus* was collected from *T. rotundifolia* in Mexico and introduced into quarantine in South Africa in October 2008. *Lixus fimbriolatus* adults, which are dark grey to black in colour, are long-lived, with combined pre-oviposition and oviposition periods of over 12 months. The adults nibble along the margin of the leaf and lay their eggs into the stems, approximately 4 cm above the soil surface. The larvae tunnel in and hollow out the stem, which could increase the vulnerability of plants to wind damage. The larvae are very destructive, especially when plants are attacked at an early stage of development. Larvae often pupate near the shoot tip, from where the adults emerge. Development from the egg to adult stage is completed in five to six months. A reliable rearing technique has been developed (Mawela & Simelane 2009), and host-specificity studies on this weevil have been initiated.

*Canidia mexicana* Thomson  
(Coleoptera: Cerambycidae)

Larvae of the stem-boring longhorn beetle,
C. mexicana, were found almost everywhere within the natural distribution of T. rotundifolia in Mexico (Fig. 5). As in the case of L. fimbriolatus, C. mexicana adults deposit their eggs into the stem. Upon eclosion, the larvae tunnel in the stem, causing extensive damage. However, several attempts to rear the beetle under quarantine laboratory conditions were unsuccessful.

*Rhodobaenus auctus* Chevrolat (Coleoptera: Curculionidae)

The stem-boring snout beetle *R. auctus* was collected on both *T. rotundifolia* and *T. tubaeformis* around the city of Cuarnavaca, Mexico, in 2007 and 2008. The adult beetles are mainly black ventrally with a red dorsal thorax and elytra. As in the case of *C. mexicana*, *R. auctus* has not been successfully reared under quarantine conditions, but both species could be considered for further testing if the more damaging *L. fimbriolatus* proves to be unsuitable for release against *T. rotundifolia*.

**INSECT NATURAL ENEMIES OF TITHONIA DIVERSIFOLIA** (Table 1)

*Chlosyne* sp. (Lepidoptera: Nymphalidae)

A defoliating butterfly *Chlosyne* sp. was collected from various localities within the distributional range of *T. diversifolia* in Mexico, and was introduced into quarantine in South Africa in 2007 and 2008. Larvae of the butterfly are extremely damaging to the leaves. Preliminary trials have shown that oviposition and development occur on both invasive *Tithonia* species. Many of the larvae collected in the field in 2007 and 2008 were heavily parasitized by various wasp species, and this limited the number of adults available to start cultures and to conduct host-specificity tests. This candidate agent has thus been shelved.
An unidentified stem-boring moth (Lepidoptera: Tortricidae)

A very damaging, unidentified moth, was collected from *T. diversifolia* near Puerto Angel on the southeast coast of Mexico, and was introduced into South Africa in 2008 for host-specificity testing. Adults oviposit onto the shoot tips. The larvae burrow into the stems, feed internally, gradually causing permanent wilting of the entire branch, and sometimes kill the whole plant. After preparing exit holes for adult emergence, larvae pupate within the stem. During multi-choice host-specificity tests, the moth attacked several cultivars of sunflower *Helianthus annuus* L. (Asteraceae) and was therefore rejected.

*Platyphora ligata* (Stål)
(Coleoptera: Chrysomelidae)

This leaf-feeding beetle was recorded on *T. diversifolia* in Mexico during the present investigations, and had been previously noted on this host plant in Costa Rica. Although it has never been imported into South Africa, nor studied further, it may have potential as a biological control agent.

PATHOGENS OF THE TWO *TITHONIA* SPECIES (Table 1)

*Puccinia enceliae* Dietel & Holw.
(Puccinales: Pucciniaceae)

A number of destructive pathogens are known to occur on *T. diversifolia* and *T. rotundifolia* in their native range (Farr & Rossman 2007), and these were selected for further attention as potential biological control agents. Isolates of one of the rust species, *Puccinia enceliae*, were collected from *T. diversifolia*, *T. rotundifolia* and *T. tubaeformis* during 2007 and 2008 (Table 1), and were subsequently introduced into the Agricultural Research Council-Plant Protection Research Institute (ARC-PPRI) quarantine facility in Stellenbosch for screening against the South African *Tithonia* species. The spores from all the different isolates proved to be viable and were able to germinate and penetrate the cells on the leaf surface of the targeted South African *Tithonia* species. However, further investigation by light microscopy showed that there was no development beyond the point of penetration. The reasons for this incompatibility between the rust isolates and the South African
T. diversifolia and T. rotundifolia biotypes remain unknown.

Future studies on pathogens should include the planting of trap-plants of South African biotypes of Tithonia species in Mexico to obtain compatible rust isolates, determination of possible influence of host-physiology on rust infection, and the expansion of surveys to previously unexplored native regions (e.g. south east of Mexico, Guatemala and Costa Rica). A study on DNA matching of South African and Mexican populations of Tithonia species should also be considered during searches for compatible rust isolates.

CONCLUSION

Although Tithonia species are primarily invaders of disturbed habitats, biological control could be a viable option for their management. The prospects for releasing biological control agents against T. rotundifolia appear promising. Efforts to find candidate agents for T. diversifolia, particularly the leaf-feeding beetle P. ligata which was previously recorded on this weed in Costa Rica, need to be intensified.

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