

# Evaluation of the Argentinian Parasitoid, *Trichopoda giacomellii* (Diptera: Tachinidae), for Biological Control of *Nezara viridula* (Hemiptera: Pentatomidae) in Australia

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**An Argentinian parasitoid, *Trichopoda giacomellii* (Blanchard) (Diptera: Tachinidae), was evaluated prior to its release in Australia as a biological control agent for the green vegetable bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae). In no-choice host specificity studies, females of *T. giacomellii* with or without prior exposure to *N. viridula* were exposed in separate tests to selected representatives of indigenous Australian Hemiptera. In addition to the target *N. viridula*, only species of the pentatoma group of Pentatomidae, *Plautia affinis* Dallas, *Alciphron glaucas* (Fabricius), and *Glaucias amyoti* (White), attracted oviposition and supported complete development by *T. giacomellii*. Two Pentatomidae, *Cuspicona forticornis* Breddin and *Anaxarchus pardalinus* Stål, attracted oviposition but parasitoids failed to develop. Other Pentatomidae failed to attract oviposition by *T. giacomellii*, including *Biprorulus bibax* Breddin, *Piezodorous hybneri* (Gmelin), *Cuspicona simplex* Walker, *Oechalia schellenbergii* (Guérin-Méneville), and *Cematulus nasalis* (Westwood); likewise for Scutelleridae, including *Lampromicra senator* (Fab.) and *Tectocoris diophthalmus* (Thunberg), as well as for Tessaratomidae, including *Musgraveia sulciventris* Stål, and for Coreidae, including *Amblypelta nitida* Stål and *A. lutescens lutescens* (Distant). Releases of *T. giacomellii* commenced in 1996 at Brookfield, Caboolture, and Indooroopilly in Queensland and near Moree in New South Wales.**

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**Key Words:** biological control; *Trichopoda giacomellii*; *Nezara viridula*; host specificity; Australia.

## INTRODUCTION

The green vegetable bug, *Nezara viridula* (L.), is a pest on a wide range of agricultural and horticultural crops throughout the temperate and tropical regions of the world (Todd, 1989). Nymphs and adults of *N. viridula* withdraw fluids by piercing plant fruiting bodies, stems, and petioles with their rostrum. Feeding

and saliva result in discoloration, malformation, stunting, and shriveling of the plant tissues (Waterhouse and Norris, 1987). The native geographic range of *N. viridula* is thought to be Ethiopia (Jones, 1988), southern Europe, and parts of the Mediterranean region (Hokkanen, 1986). Other species in the genus occur in Africa and Asia (Freeman, 1940). Closely related genera occur in South America and Australia (G. Gross, pers. comm.), indicating that the native range of *N. viridula* may not be known with certainty. In Australia, *N. viridula* is a pest of most legume crops (particularly soybeans), cucurbits, potatoes, tomatoes, passion fruit, sorghum, sunflower, tobacco, maize, crucifers, spinach, grapes, citrus, rice, and macadamia nuts (Hely *et al.*, 1982; Waterhouse and Norris, 1987). *N. viridula* is a serious pest of soybeans and pecans in northern Victoria, central New South Wales, and southern Queensland (Clarke, 1992; Seymour and Sands, 1993).

The extent of damage by *N. viridula* has been reduced in southeastern Australia since the egg parasitoid, *Trissolcus basalis* (Wollaston), was introduced initially from Egypt in 1933 (Wilson, 1960) and later from other countries (Waterhouse and Norris, 1987). *T. basalis* has been distributed wherever *N. viridula* has caused problems, including the USA, South Africa, and parts of South America (Waterhouse and Norris, 1987). In certain regions of eastern Australia, particularly areas that produce grain legume and nut crops, *T. basalis* is not very effective. This prompted Clarke and Walter (1992) to question the extent of biological control of *N. viridula* in Australia. The activity of *T. basalis* as a natural enemy of *N. viridula* in Hawaii is supplemented by two tachinid parasitoids, *Trichopoda pilipes* (F.) originally from the Caribbean and *T. pennipes* (F.) from the United States (Davis, 1964; Jones, 1988; Todd, 1989). *T. pennipes* is also an important natural enemy of *N. viridula* in Italy, though it was not intentionally introduced (Colazza *et al.*, 1996). However, attempts to establish *T. pilipes* and *T. pennipes* in Australia and Papua New Guinea have not succeeded (Waterhouse and Norris, 1987), though eggs of the parasitoids were

recovered from field release sites in Western Australia (Michael, 1981). Small releases of another tachinid parasitoid, *Bogosia antinorii* Rond. from Kenya, were made in Australia in 1958, but this species also failed to become established (Greathead, 1971). Currently, in Australia very few natural enemies attack the nymphs and adults of *N. viridula*. Only one tachinid parasitoid, *Cylindromyia ruffemur* Paramonov, has been recorded from *N. viridula* (Cantrell, 1986) and other species of parasitoids attacking adults or nymphs of *N. viridula* have not been recovered since then (Seymour and Sands, 1993).

Several South American parasitoids were discussed by Bennett (1990) as potential agents for introduction into South Africa where *N. viridula* is a major pest of macadamias. These included several tachinid taxa, though many of these taxa have been synonymized by Liljestrom (1992) as one polymorphic species, *T. giacomellii* (Blanchard). In Argentina, *T. giacomellii* is an important, relatively specific parasitoid of adult and the later instar nymphs of *N. viridula* (La Porta, 1987; Liljestrom, 1991), and with *T. basalis* these contribute to biological control of the pest (Liljestrom and Bernstein, 1990). In South America, indigenous pentatomid hosts of *T. giacomellii* include *Edesia mediatubunda* (Fab.), *Acladra kinbergii* (Stål), *Acrosternum musiva* (Berg.), *A. herbida* (Stål), and *Piezodorus guildinii* (Westwood) (La Porta, 1987; Liljestrom, 1980). In Brazil, *T. giacomellii* (= *Eutrichopodopsis nitens* Blanchard) is also an important parasitoid of *N. viridula* (Ferreira *et al.*, 1991). Based on its performance in Argentina (Liljestrom, 1991), *T. giacomellii* was identified as a promising potential agent for biological control of *N. viridula*, especially in pecan orchards (Seymour and Sands, 1993). Here we report on the host specificity of *T. giacomellii* when tested with selected species of Heteroptera and on the suitability of *T. giacomellii* for introduction into Australia.

## MATERIALS AND METHODS

### *Culture of the Parasitoid*

A consignment of parasitized adult *N. viridula* ( $n = 160$ ) and puparia of *T. giacomellii* ( $n = 140$ ) were imported from La Plata, Argentina (Lat. 34° 58', Long. 57° 53') in February 1994. These individuals were held for culture in a quarantine facility at the CSIRO, Long Pocket Laboratories, Brisbane (AQIS permit No. 99400009; ANCA permit No. PWS P940706). Parasitised *N. viridula* were held in aluminium-framed cages measuring ca 50 × 20 × 20 cm covered with organza, containing a basal layer of moistened potting soil for pupariation by parasitoid larvae. Green beans, a segment of corn cob, and raw peanuts were provided as food for the *N. viridula*, replaced daily until parasitoid larvae pupated. Puparia (10–15 per container) were

maintained in similar cages until eclosion of adult parasitoids.

To establish a culture of *T. giacomellii*, freshly eclosed adults (ca 10 pairs) were transferred to a cage measuring 1.0 × 1.0 × 1.4 m, constructed from an aluminium frame fitted with fine black cotton gauze. Overhead fluorescent (daylight) lighting (12-h photoperiod) was supplemented most days by sunlight for ca 0900–1600 h through a window. Sugar cubes and chopped raisins (i.e., food) and moistened water pads were provided near the ceiling of the cage for the parasitoids. Adults of *N. viridula* (ca 30) in the cage were provided with 12 potted bean plants as a resting substrate and with green beans, segments of corn cobs, and raw peanuts as food. After 12–24 h of exposure, *N. viridula* with ca 3–5 parasitoid eggs attached were transferred to cages measuring 30 × 30 × 30 cm covered with organza. Each contained food and a tray of moist soil for pupation by parasitoid larvae. Puparia were held in moist soil until they eclosed as previously described. After emerging, *T. giacomellii* were held in cages and provided with food (as described above) for mating and exposure to adult *N. viridula*. The number of eggs deposited on each host were recorded.

### *Host-Specificity Tests*

Australian Heteroptera, including representatives of the pentatoma species group, other selected Pentatomidae, two Coreidae, two Scutelleridae, and one Tessaratomidae, were exposed to gravid *T. giacomellii* (Table 1). Oviposition by the parasitoids, development to pupation, and eclosion of adults were recorded. Separate no-choice tests were conducted, the first being

TABLE 1

Hemiptera Selected for Host Specificity Studies with *T. giacomellii*

Family	Species	Predator	Herbivore
Pentatomidae	<i>Plautia affinis</i> Dallas		+
	<i>Alciphron glaucus</i> (Fab.)		+
	<i>Glaucias amyoti</i> (White)		+
	<i>Biprorulus bibax</i> Breddin		+
	<i>Piezodorus hybneri</i> (Gmelin)		+
	<i>Cuspicona simplex</i> Walker		+
	<i>C. forticornis</i> Breddin		+
	<i>Anaxarchus pardalinus</i> Stål		+
	<i>Oechalia schellenbergii</i> (Guérin-Mèneville)	+	
	<i>Cermatulus nasalis</i> (Westwood)	+	
	Scutelleridae	<i>Lampromicra senator</i> (Fab.)	
<i>Tectocornis diopthalmus</i> (Thunberg)			+
Tessaratomidae	<i>Musgraveia sulciventris</i> (Stål)		+
Coreidae	<i>Amblypelta nitida</i> Stål		+
	<i>A. lutescens lutescens</i> (Distant)		+

paired comparison when parasitoids were alternatively exposed to each species to be tested and then to *N. viridula* or in second tests with "naive" parasitoids not alternatively exposed to *N. viridula*. All tests were conducted in a cage constructed as described for culture of parasitoids. For the paired host tests, 8–10 pairs of *T. giacomellii* (after exposure to *N. viridula*) were alternatively exposed for 2 h to both sexes of each bug species tested ( $n = 10$ – $16$ ); this was followed by exposure for 2 h to the same sexes of *N. viridula* ( $n = 16$ ). After each 2-h period, all bugs were removed and numbers of parasitoid eggs deposited per bug were recorded. This procedure was replicated for each species tested and contrasted with *N. viridula* for ovipositional response by *T. giacomellii*. For bug species that attracted oviposition, appropriate food was provided in cages for the bugs until parasitoid development took place or the bugs died. *T. giacomellii* adults that emerged were maintained with food to record longevity and fecundity by exposing them to adults of *N. viridula* in white gauze cages measuring  $30 \times 30 \times 30$  cm. Female parasitoids emerging from hosts other than *N. viridula* were paired with male parasitoids from the same host or, if these were unavailable, paired with males reared from *N. viridula*.

Experiments with parasitoids were conducted to determine if prior exposure to *N. viridula* influenced their selection of other hosts for oviposition. Pairs (8–10) of naive *T. giacomellii* (24–36 h old) were exposed to selected species of Heteroptera ( $n = 10$ – $16$ ) for 2 h followed by exposure to *N. viridula* for a further 2 h. Oviposition and development by parasitoids were assessed as above, but only one paired comparison of each test species was conducted with *N. viridula*. Further tests were conducted to determine if responses to species other than *N. viridula* were affected by compounds from *N. viridula* absorbed onto cage materials (especially pheromones from *N. viridula*) (Harris and Todd, 1980, reported *Trichopoda* spp. utilizing bug aggregation pheromones for locating hosts). To remove such compounds, the cage was dismantled, the frame was washed with 70% alcohol, and the netting was replaced. Naive pairs of *T. giacomellii* ( $n = 10$ ) were then enclosed in cleaned cages for 2 h with *P. affinis* (known host species,  $n = 15$ ). The number of eggs deposited were compared with those on *P. affinis* exposed for the same period to *T. giacomellii* in a cage which previously held *N. viridula*. For each species of bug attracting oviposition by *T. giacomellii*, individuals were held with food to confirm complete development of parasitoids.

## RESULTS

The results of host specificity tests for *T. giacomellii* on selected Heteroptera are shown in Table 2. Of the

**TABLE 2**  
Host Specificity Tests for *T. giacomellii* with  
Indigenous Heteroptera

Host	<i>n</i>	Proportion with eggs	Mean ( $\pm$ s.d.) no. eggs/host
<i>O. schellenbergii</i>	38	0	—
<i>N. viridula</i>	45	0.8	$1.9 \pm 1.9$
<i>C. nasalis</i>	45	0	—
<i>N. viridula</i>	45	0.73	$2.5 \pm 3.1$
<i>P. hybneri</i>	45	0	—
<i>N. viridula</i>	45	0.67	$2.0 \pm 2.7$
<i>B. bibax</i>	27	0	—
<i>N. viridula</i>	45	0.8	$2.4 \pm 1.8$
<i>C. simplex</i>	36	0	—
<i>N. viridula</i>	45	0.78	$2.6 \pm 0.8$
<i>C. forticornis</i> *	12	0.33	$2.2 \pm 1.1^a$
<i>N. viridula</i>	15	0.6	$3.6 \pm 3.2^a$
<i>A. pardalinus</i> *	36	0.5	$0.5 \pm 1.0^a$
<i>N. viridula</i>	45	1.0	$4.4 \pm 3.5^b$
<i>P. affinis</i>	46	0.5	$0.7 \pm 0.8^a$
<i>N. viridula</i>	45	0.87	$1.9 \pm 1.8^a$
<i>G. amyoti</i>	30	0.4	$0.9 \pm 1.6^a$
<i>N. viridula</i>	45	0.67	$1.7 \pm 1.6^a$
<i>A. glaucus</i>	12	0.83	$6.8 \pm 4.9^a$
<i>N. viridula</i>	15	0.8	$3.1 \pm 2.4^a$
<i>L. senator</i>	10	0	—
<i>N. viridula</i>	15	0.73	$1.7 \pm 0.1$
<i>T. diophthalmus</i>	15	0	—
<i>N. viridula</i>	15	0.6	$2.5 \pm 1.8$
<i>M. sulciventris</i>	12	0	—
<i>N. viridula</i>	15	0.93	$3.1 \pm 1.8$
<i>A. lutescens</i>	45	0	—
<i>N. viridula</i>	45	0.64	$1.7 \pm 0.5$
<i>A. nitida</i>	15	0	—
<i>N. viridula</i>	15	0.67	$1.5 \pm 1.6$

Note. Values followed by differing superscript differ significantly at  $P < 0.05$  (paired comparisons only) *t*-test.

\* Failed to support immature development of *T. giacomellii*.

species exposed, *Cuspicona forticornis* and *Anaxarchus pardalinus* attracted oviposition by *T. giacomellii* but failed to support parasitoid development, whereas *P. affinis*, *G. amyoti*, and *A. glaucus* attracted oviposition and supported complete development by the parasitoid. Mean numbers of eggs deposited by *T. giacomellii* on *C. forticornis*, *P. affinis*, *G. amyoti*, and *A. glaucus* did not differ significantly from numbers of eggs deposited on *N. viridula*. However, numbers of parasitoid eggs deposited on *A. pardalinus* in two of the three replicates were significantly ( $P < 0.01$ ) less than on *N. viridula*. In the controls, the mean number of eggs per parasitized *N. viridula* did not differ significantly ( $P < 0.25$  in all tests) between replicates (pooled in Table 2). No differences in host acceptance were detected when naive and experienced *T. giacomellii* were tested with indigenous Australian Heteroptera (Table 3). Species that failed to attract oviposition (*L. senator*; *T. diophthalmus*, *M. sulciventris*, *Amblypelta lutescens*, and *A. nitida*) were not tested with naive *T. giacomellii*.

TABLE 3

Paired Host Tests for Naive *T. giacomellii* with Indigenous Australian Heteroptera

Species tested	<i>n</i>	Proportion with eggs	Mean no eggs ( $\pm$ s.d.) per parasitised bug
<i>O. schellenbergii</i>	9	0	0
<i>N. viridula</i>	15	0.8	2.25 $\pm$ 1.4
<i>C. nasalis</i>	8	0	0
<i>N. viridula</i>	15	0.73	1.82 $\pm$ 0.9
<i>P. hybneri</i>	15	0	0
<i>N. viridula</i>	15	0.87	7.61 $\pm$ 5.6
<i>B. bibax</i>	10	0	0
<i>N. viridula</i>	15	0.8	2.17 $\pm$ 1.2
<i>C. simplex</i> *	15	0.07	1.0
<i>N. viridula</i>	15	0.6	1.78 $\pm$ 0.8
<i>C. forticornis</i> *	12	0.25	1.30 $\pm$ 0.5 <sup>a</sup>
<i>N. viridula</i>	15	0.87	2.54 $\pm$ 1.4 <sup>b</sup>
<i>A. pardalinus</i> *	15	0.4	1.67 $\pm$ 1.1 <sup>a</sup>
<i>N. viridula</i>	15	0.87	4.46 $\pm$ 2.9 <sup>b</sup>
<i>P. affinis</i>	15	0.8	2.42 $\pm$ 1.8 <sup>a</sup>
<i>N. viridula</i>	15	0.87	1.92 $\pm$ 1.0 <sup>a</sup>
<i>G. amyoti</i>	10	0.75	1.67 $\pm$ 0.7 <sup>a</sup>
<i>N. viridula</i>	15	0.87	2.28 $\pm$ 1.4 <sup>a</sup>
<i>A. glaucus</i>	15	0.73	1.82 $\pm$ 1.0 <sup>a</sup>
<i>N. viridula</i>	15	0.67	1.80 $\pm$ 1.0 <sup>a</sup>

Note. For each paired comparison, values followed by differing postscripts differ significantly at  $P < 0.05$  (*t* test).

\* Failed to support immature development of *T. giacomellii*.

Pentatomidae parasitized by *T. giacomellii* and details of oviposition, pupation, size of pupae, and percentage of adults eclosing are presented in Table 4. Both *C. forticornis* and *C. simplex* attracted oviposition but larvae of *T. giacomellii* died as first instars while attempting to penetrate the hosts' exoskeleton. On *A. pardalinus*, first-instar larvae of *T. giacomellii* died within the chorion. Puparia from *P. affinis* were significantly smaller than those from *G. amyoti* and *A.*

TABLE 4

Oviposition, Pupariation, Puparial Lengths and Development of *T. giacomellii* on *N. viridula* and Other Pentatomidae

Species tested	No. attracting oviposition	No. puparia	Size of puparia (mm $\pm$ s.d.)	No. adults	% completed development
<i>N. viridula</i>	231	85	6.7 $\pm$ 0.5 <sup>a</sup>	77	33.3
<i>G. amyoti</i>	24	12	5.8 $\pm$ 0.4 <sup>a</sup>	12	50.0
<i>A. glaucias</i>	38	15	6.3 $\pm$ 0.8 <sup>a</sup>	13	34.2
<i>P. affinis</i>	42	5	4.7 $\pm$ 0.4 <sup>b</sup>	5	11.9
<i>C. forticornis</i>	7	0	—	0	0*
<i>C. simplex</i>	1	0	—	0	0*
<i>A. pardalinus</i>	17	0	—	0	0*

Note. Values followed by differing superscript differ significantly at  $P < 0.05$  (SNK test).

\* Failed to support development of *T. giacomellii*.

TABLE 5

Fecundity and Longevity of Adult Female *T. giacomellii* Reared from *N. viridula* and Other Pentatomidae

Host sp.	<i>n</i>	No. eggs/female (range $\pm$ s.d.)	Longevity in days (range $\pm$ s.d.)
<i>N. viridula</i>	18	163.0 $\pm$ 12.7 <sup>a</sup> (71–275)	9.6 $\pm$ 0.6 <sup>a</sup> (4–15)
<i>G. amyoti</i>	8	21.0 $\pm$ 24.5 <sup>b</sup> (0–59)	2.7 $\pm$ 1.2 <sup>b</sup> (1–5)
<i>P. affinis</i>	5	42.4 $\pm$ 43.8 <sup>b</sup> (0–107)	4.0 $\pm$ 2.2 <sup>b</sup> (1–8)
<i>A. glaucus</i>	6	20.0 $\pm$ 31.6 <sup>b</sup> (0–75)	4.5 $\pm$ 3.0 <sup>b</sup> (1–9)

Note. Values followed by differing superscript differ significantly at  $P < 0.05$ , *t* test.

*glaucus*, indicating probable inefficient use of that host by the parasitoid. Fecundities and mean longevity of *T. giacomellii* reared from *G. amyoti*, *P. affinis*, and *A. glaucus* were significantly less ( $P < 0.05$ ) than those reared from *N. viridula* (Table 5). Removal of residual compounds from the cage surface by cleaning and replacement of netting did not alter oviposition by *T. giacomellii*. Adults of *P. affinis* attracted a mean of 1.2  $\pm$  1.0 eggs per bug during a 2-h exposure period.

## DISCUSSION

Though considerable progress toward the biological control of *N. viridula* in many countries has been achieved by introducing the egg parasitoid, *T. basalis*, establishment of *Trichopoda* spp. has not been successful. Attempts to establish *T. pennipes* or *T. pilipes* in Antigua (Cock, 1985), Australia (Waterhouse and Norris, 1987), Fiji (O'Connor, 1950), New Zealand (Clausen, 1978), Papua New Guinea (Waterhouse and Norris, 1987), Solomon Islands (O'Connor, 1950), and South Africa (Bennett, 1990) have also failed. Failure to establish *Trichopoda* spp. may have been due in part to difficulties with rearing sufficient numbers of parasitoids for release (Michael, 1981). However, *T. pennipes* and *T. pilipes* were both successfully introduced into Hawaii (Davis, 1964) and *T. pennipes* was recently established in California, where large numbers of parasitoids were released (Pickett *et al.*, 1996). A closely related tachinid, *Ectophasiopsis arcuata* (Bigot), was established as an effective agent for *N. viridula* on Easter Island by release of only 254 puparia introduced from mainland Chile (Ripa *et al.*, 1995).

Host specificity of exotic parasitoid natural enemies considered for introduction as biological control of pests has come under increasing scrutiny in recent years, especially when they develop on nontarget, native fauna. For example, Howarth (1991) suggested that a decline in abundance of nontarget Pentatomidae, including predatory *Oechalia* spp., followed establishment of *T. pilipes* and *T. basalis* in Hawaii. Although both were previously approved for release in Australia (Water-

house and Norris, 1987), it is doubtful that *T. pilipes* or *T. pennipes* would be considered today, since their recorded host ranges include other Pentatomidae, Coreidae, Largidae, and Scutelleridae, some being important nontarget predators (Arnaud, 1978). In contrast, the South American *T. giacomellii* has a much more restricted host range (La Porta, 1987; Liljestrom, 1980) and develops in few indigenous hosts, which are all Pentatomidae (Liljestrom, 1980). These other hosts include *Acrosternum*, a genus which is closely related to *Nezara*.

In the current assessment of *T. giacomellii* as a biological control agent for introduction into Australia (Seymour and Sands, 1993), parasitoid development on *N. viridula* was found to be similar to that described by La Porta (1987). However, longevity and fecundity were much greater when the food was varied for adults (Coombs, 1997). *T. giacomellii* has been shown to successfully parasitize three Australian species, all belonging to the pentatoma species group (Coombs and Khan, 1998) and related to the target pest species, *N. viridula* (Gross, 1976). Of these, *P. affinis* is a pest of grain legumes, fruit, and vegetable crops in southeast Queensland and northern New South Wales (McDonald, 1971; Evans, 1985); *G. amyoti* is similar morphologically to *N. viridula*, is a minor pest of vegetables in Queensland (Carver *et al.*, 1991), has been recorded from commercial pecan, *Carya illinoensis* (Wangenh.) C. Koch, in central northern New South Wales (Seymour and Sands, 1993), and usually breeds in forest habitats in eastern Queensland on certain Loganiaceae and Araliaceae (unpublished); and *A. glaucus* occurs in rainforest in eastern Australia where its immature stages are associated with Passifloraceae. Museum records indicate that *A. glaucus* may be an occasional pest of granadilla, *Passiflora quadrangularis* L. (Passifloraceae), in northern Queensland (unpublished).

Three species of Pentatomidae, *C. simplex*, *C. forticornis*, and *A. pardalinus*, attracted oviposition by *T. giacomellii* in this study but none supported development of the immature parasitoid. *C. simplex* and *C. forticornis* belong to the rhynchoris species group, a group closely allied to the pentatoma species group, whereas *A. pardalinus* is more distantly related (Gross, 1976). In each case the first-instar larvae of *T. giacomellii* died either within the chorion or while penetrating the host exoskeleton. These are independent of host selection by the ovipositing parasitoid.

Although the rate of development of *T. giacomellii* on *G. amyoti* and *A. glaucus* was equal to or higher than that on *N. viridula*, the fecundity and longevity of female parasitoids reared from these species and from *P. affinis* were significantly reduced compared with *N. viridula*. Moreover, puparia from *P. affinis* were significantly smaller, suggesting that *P. affinis*, *G. amyoti*, and *A. glaucus* are suboptimal as hosts for development

of *T. giacomellii*. In Argentina, *T. giacomellii* is restricted to open crop and grassland habitats (G. Liljestrom, pers. comm.), whereas in Brazil parasitization of *N. viridula* varied with the bug's plant host. Levels of parasitism were less on *Ricinus communis* L. than the host on other weeds and crops (Panizzi, 1989). It is likely that *T. giacomellii* would encounter both *P. affinis* and *N. viridula* in Australia since they share a number of cropping systems. It is unlikely that *T. giacomellii* will encounter *A. glaucus* in Australia since it is confined to rainforest (G. B. Monteith, pers. comm.).

Current studies have demonstrated that *T. giacomellii* is specific for *N. viridula* and other species belonging to the pentatoma species group. In addition to contributing to control of *N. viridula*, the parasitoid is likely to reduce the abundance of *P. affinis* in crops but unlikely to have a detrimental impact on nontarget Heteroptera in Australia. Releases of *T. giacomellii* commenced at Brookfield, Caboolture, and Indooroopilly, Queensland and near Moree, New South Wales, between February 1996 and January 1997.

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#### REFERENCES

- Arnaud, P. H. 1978. A host-parasite catalogue of North American Tachinidae (Diptera). U.S. Department of Agriculture, Miscellaneous Publication 1319.
- Bennett, F. D. 1990. Potential for biological control of the stink bug, *Nezara viridula*, a pest of macadamias. *Acta Horticult.* **275**, 679-684.
- Cantrell, B. K. 1986. An updated host catalogue for the Australian Tachinidae. *J. Aust. Entomol. Soc.* **25**, 255-265.
- Carver, M., Gross, G. F., and Woodward, T. E. 1991. Hemiptera. In "The Insects of Australia: A Textbook for Students and Research Workers," (CSIRO, Eds.). Melbourne Univ. Press.
- Clarke, A. R. 1992. Current distribution and pest status of *Nezara viridula* (L.) (Hemiptera: Pentatomidae) in Australia. *J. Aust. Entomol. Soc.* **31**, 289-297.
- Clarke, A. R., and Walter, G. H. 1992. Biological control of green vegetable bug (*Nezara viridula* (L.)) in eastern Australia: Current status and perspectives. *Proc. 5th Appl. Entomol. Conference, Canberra, April 1992*. 10 pp.
- Clausen, C. P. (Ed.). 1978. "Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review." USDA Agricultural Handbook, 545 pp.

- Cock, M. J. W. (Ed.). 1985. "A Review of Biological Control of Pests in the Commonwealth Caribbean and Bermuda up to 1982," Technical Communication No. 9. Commonwealth Institute of Biological Control, Commonwealth Agricultural Bureau, U.K. 218 pp.
- Colazza, S., Giangiuliani, G., and Bin, F. 1996. Fortuitous introduction and successful establishment of *Trichopoda pennipes* F.: Adult parasitoid of *Nezara viridula* (L.). *Biol. Control* **6**, 409–411.
- Coombs, M. T. 1997. Influence of adult food deprivation and body size on fecundity and longevity of *Trichopoda giacomellii*: A South American parasitoid of *Nezara viridula*. *Biol. Control* **8**, 119–123.
- Coombs, M., and Khan, S. 1998. Fecundity and longevity of green vegetable bug, *Nezara viridula*, following parasitism by *Trichopoda giacomellii*. *Biol. Control* **12**, 215–222.
- Davis, C. J. 1964. The introduction, propagation, liberation and establishment of parasites to control *Nezara viridula* variety *smaragdina* (Fabricius) in Hawaii (Heteroptera: Pentatomidae). *Proc. Hawaiian Entomol. Soc.* **18**, 369–375.
- Evans, M. L. 1985. Arthropod species in soybeans in southeast Queensland. *J. Aust. Entomol. Soc.* **24**, 169–177.
- Ferreira, B. S. C., Thomazina, M. J., and Zamataro, C. E. 1991. Effect of parasitism by *Eutrichopodopsis nitens* Blanchard on the longevity and reproduction of *Nezara viridula* (In Portuguese, English summary). *Pesquisa Agropecuaria Brasileira* **16**, 837–842. (Biocontrol news and information **16**, 411–423).
- Freeman, P. 1940. A contribution to the study of the genus *Nezara* Amyot and Serville (Hemiptera: Pentatomidae). *Trans. R. Entomol. Soc. London* **90** (pt 12), 351–374.
- Greathead, D. J. 1971. "A Review of Biological Control in the Ethiopian Region," Technical Communication No 5. Commonwealth Institute of Biological Control, Commonwealth Agricultural Bureau, U.K. 162 pp.
- Gross, G. F. 1976. Plant-feeding and other bugs (Hemiptera) of South Australia, Heteroptera, Part II. Handbook of the flora and fauna of South Australia, Government printer: Adelaide, South Australia.
- Harris, V. E., and Todd, J. W. 1980. Male-mediated aggregation of male, female and 5th instar southern green stink bugs and concomitant attraction of a tachinid, *Trichopoda pennipes*. *Entomol. Exp. Appl.* **27**, 117–126.
- Hely, P. C., Pasfield, G., and Gellatley, G. G. 1982. "Insect Pests of Fruit and Vegetables in NSW," Inkata, Melbourne.
- Hokkanen, H. 1986. Polymorphism, parasites and the native area of *Nezara viridula* (L.) (Hemiptera, Pentatomidae). *Ann. Entomol. Fennici* **52**, 28–31.
- Howarth, F. G. 1991. Environmental impacts of classical biological control. *Ann. Rev. Entomol.* **36**, 485–509.
- Jones, W. A. 1988. World review of the parasitoids of the southern stink bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae). *Ann. Entomol. Soc. Am.* **81**, 262–273.
- La Porta, N. C. 1987. Aspectos Biologicos de *Trichopoda giacomellii* (Blanchard) Guimaraes, 1971 (Diptera, Tachinidae), parasitoide de *Nezara viridula* (L.) 1758. Hem. Pentatomidae. *Rev. Soc. Entomol. Argentina* **44**, 433–439.
- Liljestrom, G. 1980. Nota sobre *Trichopoda giacomellii* (Blanchard, 1966) (Diptera: Tachinidae). *Neotropica* **26**, 233–236.
- Liljestrom, G. 1991. Selectividad del parasitoide *Trichopoda giacomellii* (Blanchard) (Diptera: Tachinidae) hacia individuos de *Nezara viridula* (L.) (Hemiptera: Pentatomidae) que difieren en el estado de desarrollo, sexo, edad y patrones de coloracion. *Ecol. Austral* **1**, 41–49.
- Liljestrom, G. 1992. Revision de las especies de los generos *Trichopoda* Berthold, *Trichopodopsis* Townsend y *Eutrichopodopsis* Blanchard, descriptas para la Republica Argentina. *Rev. Soc. Entomol. Argentina* **50**, 51–71.
- Liljestrom, G., and Bernstein, C. 1990. Density dependence and regulation in the system *Nezara viridula* (L.) (Hemiptera: Pentatomidae), host and *Trichopoda giacomellii* (Blanchard) (Diptera: Tachinidae), parasitoid. *Oecologia* **84**, 45–52.
- McDonald, F. J. D. 1971. Life cycle of the green stink bug *Plautia affinis* Dallas (Hemiptera: Pentatomidae). *J. Austr. Entomol. Soc.* **10**, 271–275.
- Michael, P. 1981. *Trichopoda* a tricky parasite. *J. Agric. West. Australia* **22**, 56–57.
- O'Connor, B. A. 1950. *Trichopoda pennipes* F. in Fiji and the British Solomon Islands. *Fiji Agric. J.* **21**, 63–71.
- Panizzi, A. R. 1989. Parasitism by *Eutrichopodopsis nitens* (Diptera: Tachinidae) of *Nezara viridula* (Hemiptera: Pentatomidae) on different host plants. *Pesquisa Agropecuaria Brasileira* **24**, 1555–1558.
- Pickett, C. H., Schoenig, S. E., and Hoffmann, M. P. 1996. Establishment of the squash bug parasitoid, *Trichopoda pennipes* Fabr. (Diptera: Tachinidae), in northern California. *Pan-Pacific Entomol.* **72**, 220–226.
- Ripa, S. R., Rojas, P. S., and Velasco, G. 1995. Releases of biological control agents of insect pests on Easter Island (Pacific Ocean). *Entomophaga* **40**, 427–440.
- Seymour, J. E., and Sands, D. P. A. 1993. Green vegetable bug (*Nezara viridula* (L.)) (Hemiptera: Pentatomidae) in Australian Pecans. In "Pest Control and Sustainable Agriculture" (S. A. Corey, D. J. Dall, and W. M. Milne, Eds.). CSIRO Australia.
- Todd, J. W. 1989. Ecology and behaviour of *Nezara viridula*. *Annu. Rev. Entomol.* **34**, 273–292.
- Wilson, F. 1960. A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea" Technical Communication No. 1. Commonwealth Institute of Biological Control, Commonwealth Agricultural Bureau, U.K. 102 pp.
- Waterhouse, D. F., and Norris, K. R. 1987. "Biological Control, Pacific Prospects," Inkata, Melbourne.