POST-RELEASE EVALUATION OF *TRICHOPODA GIACOMELLII* (DIPTERA: TACHINIDAE) FOR EFFICACY AND NON-TARGET EFFECTS

M. Coombs

Commonwealth Scientific and Industrial Research Organization, Entomology,
Long Pocket Laboratories, Indooroopilly, Queensland, Australia

INTRODUCTION

The tachinid parasitoid *Trichopoda giacomellii* (Blanchard) was approved for release in Australia in 1996 following quarantine evaluation as a biological control agent for *Nezara viridula* (L.) (Hemiptera: Pentatomidae) (Sands and Coombs, 1999). Release and establishment studies were completed in 1999 with establishment centered on a 1,400 acre pecan orchard located at Moree in western New South Wales, Australia (Coombs and Sands, 2000). The target pest *N. viridula*, as in other parts of the world, attacks a wide range of horticultural and agricultural crops in Australia (Waterhouse, 1998). The primary means of control of *N. viridula* has remained primarily the use of pesticides either indirectly from sprays targeting other pests (most often *Helicoverpa* spp.) or less often applied as a direct control, as was the situation in pecans (Seymour and Sands, 1993).

Previous attempts at classical biological control of *N. viridula* in Australia have included the introduction of several egg parasitoids (primarily scelionid parasitoids of the genus *Trissolcus*) and tachinid parasitoids attacking adult bugs (*Bogosia antinorii* Rondani, *Trichopoda pilipes* [Fabricius], and *Trichopoda pennipes* [Fabricius]) (Waterhouse, 1998; Waterhouse and Sands, 2001). Whereas *Trissolcus basalis* (Wollaston) has proved effective in reducing *N. viridula* populations over parts of the pest's range in Australia, none of the tachinid species established. Because *N. viridula* has remained a significant pest in Australia, I studied the tachinid *T. giacomellii*, which appeared to have potential to improve biological control of *N. viridula* in those regions poorly suited to *T. basalis*.

Quarantine testing of arthropods in Australia follows a process that parallels weed biological control testing (Harley and Forno, 1992), whereby the agent is evaluated against the target pest and a range of potential non-target species. Prerelease quarantine studies for *T. giacomellii* identified three native pentatomid bugs as supporting complete development of the agent (Sands and Coombs, 1999). These were *Plautia affinis* Dallas, a pest of agricultural and horticultural crops often occurring in close association with *N. viridula; Glaucias amyoti* (White), a forest-adapted species with occasional records as a minor pest of horticultural crops; and *Alciphron glaucus* (Fabricius), a species confined to rainforest habitats in coastal eastern Australia (Table 1). All three species are closely allied to *N. viridula* (Gross, 1976) and were found in the laboratory to be comparable to *N. viridula* in level of attractiveness for attack by *T. giacomellii*. Other species, including predatory Asopines, either failed to attract oviposition by the parasitoid or when oviposition occurred, parasitoid larvae failed to develop. Approval for release of *T. giacomellii* was granted, acknowledging that some attack and development on native pentatomids might occur in the field. It was deemed that if these nontarget hosts were encountered by *T. giacomellii* in the field that any impacts would be minor. Further, any potential non-target impacts would be significantly less than those caused by failure to control the target organism throughout Australia.

This study provides quantitative data on pre- and post-release abundances of the target pest *N. viridula*. It provides information on realized (field) versus predicted (quarantine) host ranges for *T. giacomellii*. Further, it provides quantitative data on the abundance of non-target species following release of the agent. Interpretation of the success or otherwise of previous biological control programs for *N. viridula* in Australia (particularly by the egg parasitoid *T. basalis*) have been hampered by a lack of quantitative data. Similarly, non-target effects from previous introductions (*T. basalis* has 25 non-target hosts recorded in Australia; Loch, 2000), though widely suspected to have occurred have not been documented.

Table 1. Non-target species selected for host range tests with the tachinid *Trichopoda giacomellii* Blanchard.

Pentatomidae
Plautia affinis Dallas*
Glaucias amyoti (White)*
Alciphron glaucus (Fabricius)*
Biprorulus bibax Breddin
Anaxarchus pardalinus Stal
Piezodorous hybneri (Gmelin)
Cuspicona simplex Walker
Oechalia schellembergii (Guerin-Meneville)
Cermatulus nasalis (Westwood)
Tessaratomidae
Musgraveia sulciventris Stal
Scutelleridae
Lampromicra senator (Fabricius)
Tectocornis diopthalmus (Thunberg)
Coreidae
Amblypelta nitida Stal
Amblypelta lutescens (Distant)

*Species supporting complete development of *T. giacomellii*

MATERIALS AND METHODS

Study Site

The study was conducted on the 1400-acre "Trawalla" pecan orchard located 35 km east of Moree, New South Wales, Australia. The orchard consists of 68,500 trees planted with primarily two varieties, Wichita and Western Schley, grown in alternate rows and averaging 30 years of age. During spring and summer, the orchard understory supports growth of various weeds that are hosts for the development of *N. viridula*, including dock (*Rumex* spp.), marsh mallow (*Malva parviflora* L.), yellow vine (*Tribulus terrestris* L.), variegated thistle (*Silybum marianum* [L.]), and Lucerne (*Medicago sativa* L.). Adjacent vegetation is dominated by castor oil (*Ricinus communis* L.) and native plants of the genera *Callistemon*, *Casuarina,* and *Eucalyptus* (Coombs, 2000). Eleven residential properties are located in the orchard and contain a range of ornamentals and garden vegetables as further hosts for *N. viridula*. Nine other pentatomid and two scutellerid species co-occur with *N. viridula* in this horticultural landscape (Table 2) (Seymour and Sands, 1993).

Pre- and Post-release Evaluation of *N. viridula* Abundance

To assess the impact of *T. giacomellii* on *N. viridula* abundance, adult bug populations were monitored on castor oil (*R. communis*) from April 1996 to April 2002. Establishment occurred in December 1998 (Coombs and Sands, 2000). Numbers of adults per plant were recorded at least monthly (20 plants per sample) to generate seasonal profiles of abundance. A subsample of bugs (100-200) was collected monthly and percentage parasitism was calculated from the proportion of *N. viridula* adults found with *T. giacomellii* eggs attached.

Determining the Field Host Range of *T. giacomellii*

Weekly sampling of host plants (weeds and garden ornamentals) commenced in January 1999 to determine the field host range and percent parasitism of hosts by *T. giacomellii*. Adult bugs were recovered either from sweep net samples or via visual inspection and hand capture. All pentatomid and scutellerid species encountered were returned to the laboratory and examined for the presence of tachinid eggs. (*Trichopoda giacomellii* lays macrotype eggs, attaching them externally to the host's thorax and abdomen.) A record was made of the identity and numbers of individuals collected. Those individuals bearing tachinid eggs were held on an appropriate host plant to allow development of any parasitoids.

Determining Impact of *T. giacomellii* on the Native, Non-target Hosts *Plautia affinis* and *Glaucias amyoti*

Populations of *P. affinis*, *G. amyoti,* and *N. viridula* were monitored on *Ligustrum lucidum* Aiton (broad-leaved privet) following establishment of *T. giacomellii*. *Ligustrum lucidum* is the only known host for *G. amyoti* at the establishment site (M. Coombs, unpublished data). To measure the relative abundances of *P. affinis, G. amyoti,* and *N. viridula,* nymphs and adults of each species were dislodged by lightly beating privet foliage sufficient to cover a 1 m^2 canvas tray held horizontally beneath the plant. Twenty samples were obtained on each collection date and repeated at two week intervals from January 1998 to July 2000. Individual samples were sorted and means (± SE) calculated to generate profiles of seasonal abundance for each species.

Table 2. Numbers of pentatomid and scutellerid bugs collected and percent parasitism by *Trichopoda giacomellii* (Blanchard) at the Trawalla pecan orchard during 1999-2000. Values represent percent parasitism followed by sample size (n).

	Pentatomid and Scutellerid Bugs*											
Host plant	*Nv*	*Pa*	*Ga*	*Ph*	*Cs*	*Dc*	*Bb*	*Os*	*Cn*	*Vw*	*Sp*	*Cc*
Solanum nigrum Linnaeus	70 (244)	45 (114)	-	-	0 (81)	-	-	0 (27)	-	-	-	-
Malva parviflora Linnaeus	35 (455)	-	-	-	-	-	-	-	-	-	-	-
Medicago sativa Linnaeus	33 (158)	-	-	0 (388)	-	0 (15)	-	0 (40)	0 (32)	-	-	-
Silybum marianum (Linnaeus)	32 (271)	-	-	-	-	-	-	0 (17)	-	-	-	-
Tribulus terrestris Linnaeus	32 (175)	10 (20)	-	-	-	-	-	-	-	-	-	-
Brassica spp.	32 (163)	-	-	-	-	-	-	-	-	-	-	-
Amaranthus viridis Linnaeus	31 (309)	10 (75)	-	-	-	-	-	-	-	-	-	-
Ricinus communis Linnaeus	29 (4177)	18 (28)	-	-	-	-	-	-	-	-	0 (45)	-
Citrus spp. (lemon)	21 (86)	-	-	-	-	-	0 (55)	-	-	0 (200)	-	-
Beta vulgaris Linnaeus	17 (603)	-	-	-	-	-	-	-	-	-	-	-
Ligustrum lucidum Aiton	9 (820)	1 (222)	1 (369)	-	-	-	-	-	-	-	-	0 (26)
Total	28 (7461)	21 (441)	1 (369)	0 (338)	0 (81)	0 (15)	0 (55)	0 (84)	0 (32)	0 (200)	0 (45)	0 (26)

*Nv-*Nezara viridula* L., Pa-*Plautia affinis* Dallas, Ga-*Glaucias amyoti* (White), Ph-*Piezodorus hybneri* (Gmelin), Cs-*Cuspicona simplex* Walker, Dc-*Dictyotis caenosus* (Westwood), Bp-*Biprorulus bibax* Breddin, Os-*Oechalia schellembergii* (Guerin-Meneville), Cn-*Cermatulus nasalis* (Westwood), Vw-*Vitellus warreni* Gross and McDonald (Pentatomidae) and Sp-*Scutiphora pedicellata* (Kirby), Cc-*Coleotichus costatus* (Fabricius) (Scutelleridae).

RESULTS

Abundance of *N. viridula* on Castor Bean

Before the establishment of *T. giacomellii*, peak abundance of *N. viridula* on castor bean plants averaged five to 13 adults per plant from 1995 to late 1998 (Fig. 1). In the three years following establishment, abundances have declined to an average of two or fewer adults per plant. Parasitized *N. viridula* were recovered each season from approximately mid November until May, with parasitism peaking at 65-75% from February to April. Parasitism rates during autumn (May/June) and just prior to the onset of diapause for *N. viridula* ranged from 35 to 40%.

Field Host Range of *T. giacomellii*

Surveys on weeds and garden vegetables indicated that parasitism of *N. viridula* by *T. giacomellii* occurred on an additional 10 plant species during 1999 and 2000. Nine other pentatomid and two scuttellerid species were recorded as co-occurring with *N. viridula* on these host plants (Table 2). For *N. viridula*, percent parasitism was greatest (70%) on nightshade (*Solanum nigrum* L.) and least (9%) on broadleaved privet (*L. lucidum*). The majority of *N. viridula* (n = 4,177) were recovered from castor bean, with a yearly average of 29% parasitism. Two other pentatomids, *P. affinis* and *G. amyoti*, were recorded as field hosts for *T. giacomellii*. Percent parasitism of *P. affinis* ranged from 45% on *S. nigrum* to 1% on *L. lucidum*. *Glaucias amyoti* was recovered only from *L. lucidum*, for which parasitism averaged less than 1%. There was no evidence of parasitism of the remaining species of pentatomid or scutellerid bugs by *T. giacomellii*.

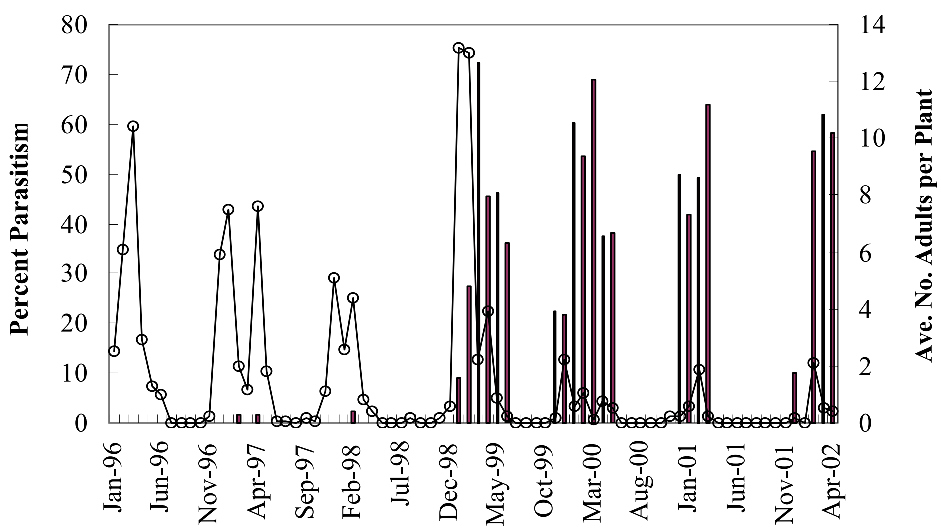

Figure 1. Abundance of *Nezara viridula* (open circles) and percent parasitism by *Trichopoda giacomellii* (vertical bars) on castor bean, *Ricinus communis*, from January 1996 to April 2002 at the Trawalla pecan orchard, Moree, New South Wales, Australia.

Abundances of *Plautia affinis, Glaucias amyoti* and *Nezara viridula* on Broadleaved Privet

Plautia affinis, *G. amyoti*, and *N. viridula* were present on broadleaved privet from approximately mid summer (January) until late autumn-early winter (May-June) of the years 1998, 1999, and 2000 (Fig. 2). *Nezara viridula* was found from February to April of each year and declined from an average of 3-5 adults per m² in 1998 and 1999 to an average of 1 adult per m² in 2000. The abundance of *P. affinis* increased from a peak of 1-2 adults per m² in 1998 and 1999 to 5 adults per m² in 2000. The peak abundance of *G. amyoti* remained at 1-2 adults per m² for each of the three years. Both *P. affinis* (11-13 weeks) and *G. amyoti* (9-15 weeks) persisted on broadleaved privet for a longer period each season than did *N. viridula* (5-6 weeks).

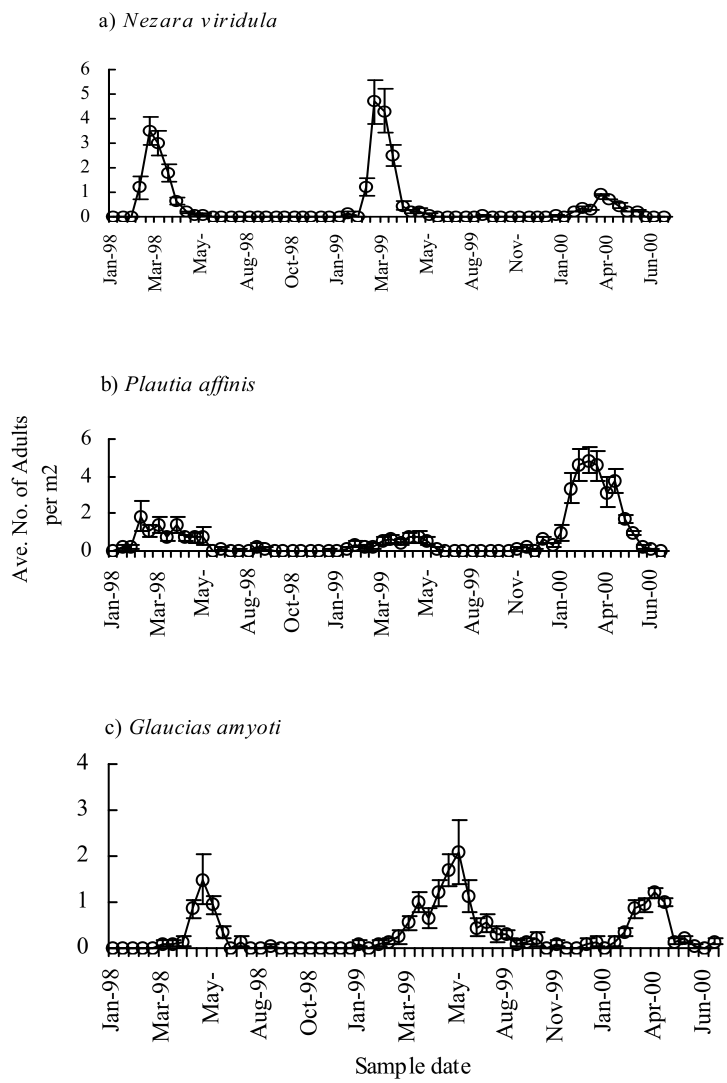

Figure 2. Abundances of (a) *Nezara viridula*, (b) *Plautia affinis* and (c) *Glaucias amyoti* on broadleaved privet *Ligustrum lucidum* from January 1998 to July 2000 at the Trawalla pecan orchard, Moree, New South Wales, Australia.

DISCUSSION

Trichopoda giacomellii has been shown to have had a sustained impact on the target pest *N. viridula* in the three years after establishment, reducing peak abundances to 15 to 35% of preestablishment densities. The timing, degree of parasitism, and observed impact by *T. giacomellii* on *N. viridula* are consistent with the behavior of *T. giacomellii* in its native range. Liljesthrom and Bernstein (1990) showed adult mortality and reduction in potential natality due to parasitization by *T. giacomellii* to be a significant mortality factor for *N. viridula* in Argentina. In addition, La Porta (1990) reported parasitization of *N. viridula* ranging from 26 to 90% of adults during February to April over a range of crop types.

Quarantine evaluation indicated that three Australian native pentatomids closely allied to *N. viridula* were likely to be potential hosts for *T. giacomellii* in the field (Sands and Coombs, 1999). These species were *P. affinis*, *G. amyoti,* and *A. glaucus*. All were assessed as being of equal attractiveness to *T. giacomellii* in the laboratory. *Alciphron glaucus* does not occur at the establishment site, being restricted to rainforest habitats in coastal eastern Australia. Habitat separation thus may exclude this species as a host for *T. giacomellii* in the field. The results of this study confirmed *P. affinis* and *G. amyoti* as realised field hosts; however, parasitism rates for *P. affinis* were consistently lower than anticipated and were significantly lower than expected for *G. amyoti*. The only known host for *G. amyoti* at the establishment site is the introduced broadleaved privet, *L. lucidum*. Parasitism rates for *P. affinis* and *N. viridula* were also low on this host plant, suggesting poor searching ability by *T. giacomellii*. The long term monitoring on *L. lucidum* undertaken in this study confirmed that there was no impact by *T. giacomellii* on *G. amyoti* and *P. affinis* populations. Whereas, numbers of *N. viridula* were observed to decline in parallel with the general population reduction observed on castor bean. *Ligustrum lucidum* may be of less significance in the local population dynamics of *N. viridula* because of its relatively short period of suitability (5-6 weeks). *Plautia affinis* and *G. amyoti,* in comparison, are present on *L. lucidum* for a significantly longer period of time (up to 15 weeks), presumably allowing a greater number of generations to complete development in isolation from attack by *T. giacomellii*.

An important outcome of the study has been the absence of unpredicted host use. Of the seven other pentatomid and two scutellerid species recovered in the survey, none were found to be attacked by *T. giacomellii*. Also, the predatory Asopines *Oechalia schellembergii* (Guerin-Meneville) and *Cermatulus nasalis* (Westwood) both species of economic importance, were not attacked. Indigenous hosts of *T. giacomellii* in Argentina include species of the genera *Acrosternum, Acledra,* and *Edesia* (Liljesthrom, 1980), whereas parasitism of *N. viridula* represented a new association. Clearly, *T. giacomellii* has a demonstrated ability to expand its host range. The results of this study further demonstrate that ability with the inclusion in its host list of the Australian native species *P. affinis* and *G. amyoti*. A parallel biological control program operating in South Africa using *T. giacomellii* originating from this project reported inclusion of the South African native species *Bathycoelia natalicola* Schouteden and *Nezara pallidoconspersa* Stål as field hosts (M. van den Berg, pers. comm.). Both species are pests of macadamia (Bruwer, 1992), and any potential population suppression by *T. giacomellii* was viewed as desirable. Taxonomically, *P. affinis, G. amyoti,* and *A. glaucus* are the most closely allied species to *Nezara* in Australia (Gross, 1976). It is quite likely that these species share commonalities in the chemistry of kairomones that *T. giacomellii* uses as host-finding cues. Presumably a similar situation exists for those species attacked in Argentina and South Africa. For *P. affinis*, as a non-target pest, any attack on this species was unplanned at the inception of the project and as such should be considered fortuitous. Potential impacts on *G. amyoti* require further study and these impacts will be better understood as this species' ecological requirements become known.

ACKNOWLEDGMENTS

This study was supported by funds from the Horticultural Research and Development Corporation (HRDC), the Australian Centre for International Agricultural Research (ACIAR), and Stahmann Farms Inc. The generous support provided by Mr. D. Stahmann and Mr. M. Crouch, and the technical assistance of C. Crouch and K. McNamara are gratefully acknowledged.

REFERENCES

Bruwer, I. J. 1992. The influence of various Hemipteran species on macadamia and some factors which limit nut damage. Ph.D. dissertation. Department of Entomology and Nematology, University of Stellenbosch, Stellenbosch, South Africa.

Clarke, A. R. 1990. The control of *Nezara viridula* L. with introduced parasitoids in Australia. A review of a 'landmark' example of classical biological control. *Australian Journal of Agricultural Research* 41: 1127-1146.

Coombs, M. 2000. Seasonal phenology, natural enemies and evaluation of mowing as a control measure for *Nezara viridula* (L.) (Hemiptera: Pentatomidae) in Australian pecans. *Environmental Entomology* 29: 1027-1033.

Coombs, M. and D. P. A. Sands. 2000. Establishment in Australia of *Trichopoda giacomellii* (Blanchard) (Diptera: Tachinidae) a biological control agent for *Nezara viridula* (L.) (Hemiptera: Pentatomidae). *Australian Journal of Entomology* 39: 219-222.

Gross, G. F. 1976. *Plant Feeding and Other Bugs (Hemiptera) of South Australia; Heteroptera, Part II.* Government Printer, Adelaide, Australia.

Harley, K. L. S. and I. W. Forno. 1992. *Biological Control of Weeds, a Handbook for Practitioners and Students*. Inkata Press, Melbourne, Australia.

La Porta, N. C. 1990. Evaluation of field parasitism by *Trichopoda giacomellii* (Blanch.) Guimaraes, 1971 (Diptera, Tachinidae), on *Nezara viridula* (L.) 1758. (Hemiptera: Pentatomidae). *Revista Chilena de Entomologia* 18: 83-87.

Liljesthrom, G. 1980. Nota sobre *Trichopoda giacomellii* (Blanchard, 1966) (Diptera, Tachinidae). *Neotropica* 26: 233-236.

Liljesthrom, G. and C. Bernstein, 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.

Loch, A. D. 2000. Abundance, distribution, and availability of *Trissolcus basalis* (Wollaston) (Hymenoptera: Scelionidae) hosts in a soybean agricultural system in southeastern Queensland. *Biological Control* 18: 120-135.

Sands, D. P. A. and M. Coombs. 1999. Evaluation of the Argentinian parasitoid, *Trichopoda giacomellii* (Diptera: Tachinidae), for biological control of *Nezara viridula* (Hemiptera: Pentatomidae) in Australia. *Biological Control* 15: 19-24.

Seymour, J. E. and D. P. A. Sands. 1993. Green vegetable bug (*Nezara viridula* [L.]) (Hemiptera: Pentatomidae) in Australian pecans, pp. 226–228. *In* Corey, S. A., D. J. Dall, and W. M. Milne (eds.). *Pest Control and Sustainable Agriculture*. Commonwealth Scientific and Industrial Research Organization (CSIRO), Melbourne, Australia.

Waterhouse D. F. 1998. *Biological Control of Insect Pests: Southeast Asian prospects*. Australian Centre for International Agricultural Research (ACIAR) Monograph No. 51, Melbourne, Australia.

Waterhouse, D. F. and D. P. A. Sands. 2001. *Classical Biological Control of Arthropods in Australia.* Australian Centre for International Agricultural Research (ACIAR) Monograph No. 77, Melbourne, Australia.