Leafhopper host plant associations for *Anagrus* parasitoids (Hymenoptera: Mymaridae) in the Okanagan Valley, British Columbia

D. THOMAS LOWERY[1], SERGUEI V. TRIAPITSYN[2] and GARY J.R. JUDD[1]

ABSTRACT

Anagrus spp. are important natural regulators of leafhoppers infesting grapes, tree fruits, and other crops in south central British Columbia (BC). Predominantly four species of these egg parasitoids, *A. atomus* (L.), *A. avalae* Soyka, *A. daanei* Triapitsyn, and *A. erythroneurae* Triapitzyn and Chiappini, were reared from dormant host plants and from summer host plants in the Okanagan Valley. The largest numbers of *Anagrus* specimens were collected from roses, *Rosa* spp; blackberry, *Rubus* spp; apple, *Malus domestica*; and other members of the rose (Rosaceae) family. Species of mint, family Lamiaceae, were important host plants for several species, with lavender, *Lavendula angustifolia,* and garden sage, *Salvia officinalis*, being both a summer and winter host plant for some species. The most likely leafhopper host on these plants is the mint leafhopper, *Eupteryx melissae* Curtis. This study contributes to our knowledge of the biology of *Anagrus* species in south central BC and could contribute to future efforts to preserve or enhance populations of these beneficial insects.

Key Words: Mymaridae, *Anagrus*, parasitoids, leafhoppers, plant hosts

INTRODUCTION

Egg parasitoids of the family Mymaridae (Hymenoptera) include the smallest known insects (Chiappini and Huber 2004). Despite being important in natural control of leafhoppers (Cicadellidae) and planthoppers (Delphacidae), they have been underutilized in biological control programs as a result of their minute size, difficulties in their identification and handling (Huber 1986), and their poorly known biology. Species of *Anagrus* Haliday have been used successfully, however, to control leafhoppers on apple, *Malus domestica*; rice, *Oryza sativa*; grapes, *Vitis* sp.; and greenhouse crops (Vidano *et al.* 1987, Chiappini *et al.* 1996, Triapitsyn and Teulon 2002, Agboka *et al.* 2004). For example, *Edwardsiana froggatti* (Baker), native to Europe, was a serious pest of apple in Tasmania, Australia, until it was brought under control with the importation of *Anagrus avalae* Soyka from New Zealand [Vidano and Arzone 1982 - misidentified as *Anagrus armatus nigriventris* Girault (Triapitsyn 2001)]. Their potential as highly effective natural control agents merits further study of their biology, ecology and leafhopper host associations (Agboka *et al.* 2004).

Taxonomic revisions of *Anagrus* (Chiappini 1989, Chiappini *et al.* 1996, Triapitsyn 1998), have greatly improved the reliability of taxonomic and biological information on these important regulators of leafhopper populations. Until recently it was thought that eggs of all the grape-feeding Typhlocibinae in North America (NA) were attacked by the same species, *Anagrus epos* Girault. Differential parasitism rates where two species of leafhoppers co-occurred on grape led to the suspicion

[1] Agriculture and Agri-Food Canada, 4200 Hwy 97, Box 5000, Summerland, BC V0H 1Z0
[2] Department of Entomology, University of California, Riverside, CA, 92521-0314, USA

that *A. epos* consisted of several biotypes, and Pickett *et al.* (1987) assumed that some of these were true species. *Anagrus epos* is now known to consist of several species (Trjapitzin and Chiappini 1994, Triapitsyn 1995, Chiappini *et al.*1996, Triapitsyn 1998), with *A. erythroneurae* Trjapitzin and Chiappini being the most common egg parasitoid of the western grape leafhopper (WGL), *Erythroneura elegantula* Osborn, and the variegated leafhopper, *E. variabilis* Beamer, in California (Trjapitzin and Chiappini 1994). Specimens of *A. erythroneurae* were identified from as far north as Wenatchee, WA, but there are few records of this species from Canada (Trjapitzin & Chiappini 1994, Triapitsyn 1998).

In 1998 we began to research parasitism of Virginia creeper leafhopper (VCL), *Erythroneura ziczac* Walsh, and WGL in vineyards in the Okanagan and Similkameen Valleys, British Columbia (BC), (DTL, unpublished data) with the goal of preserving and possibly increasing populations of *Anagrus* parasitoids. These parasitoids overwinter as immature stages within the eggs of alternate leafhopper hosts (Williams 1983), while the leafhopper pests of grapes spend the winter as adults. Thus, the availability of suitable overwintering and early spring leafhopper hosts plays an important role in the biology of *Anagrus* parasitoids and their ability to control leafhoppers on grape. This paper reports on the rearing of *Anagrus* adults from a wide range of plants that served as hosts for other species of leafhoppers utilized by these parasitoids.

MATERIALS AND METHODS

Between February and June of 1999 to 2003, dormant plant hosts potentially containing overwintering *Anagrus* in their host eggs were gathered throughout the Okanagan Valley and placed in sealed, waxed corrugated cardboard boxes in the laboratory at room temperature. *Anagrus* spp. emerging from these woody prunings were collected in two glass vials (32 ml) screwed into holes cut with cork borers into the upper side of each box. Specimens were preserved in 70% ethanol and shipped to the University of California, Riverside, for identification by one of us (S.V.T). Properly point- and slide-mounted voucher specimens were then deposited in the Entomology Research Museum, University of California, Riverside. Adult *Anagrus* were also collected from leafhopper-infested leaves of grape and other summer hosts. Leaves or stems were placed in distilled water in small flasks (50 ml) with the tops of the flasks sealed as much as possible with parafilm. The cuttings were then placed inside two large waxed paper cups (900 ml, Dixie Cup™, Norwalk, CT) fastened securely together and with a single collection vial (8 ml) fastened into a hole cut into the upper end of one cup. In total, 211 collections were made, including 76 plant species.

RESULTS AND DISCUSSION

More than 2,000 *Anagrus* emerged and were identified from dormant and summer host plants, with nearly half the specimens emerging from dormant roses, *Rosa* spp. (Table 1). Roses were sampled most intensively, 20 of 211 total collections of plant material, but they also harboured large numbers of parasitoids. For cultivated roses heavily infested with leafhoppers, we collected about 31 *Anagrus* per 100 cm of dormant wood, compared with 4.4 per 100 cm for blackberry, *Rubus* spp., and less than 1 per 100 cm for plum, *Prunus domestica.* We successfully reared *Anagrus* from 22 of 76 plant species sampled over the course of this study. The predominant species from all hosts were *A. atomus* (L.), *A. avalae*, *A. daanei* Triapitsyn, and *A. erythroneurae*

Table 1.

Plant species in the Okanagan Valley, British Columbia, that served as winter (W) or summer (S) leafhopper hosts from which *Anagrus* egg parasitoids (numbers in parentheses) emerged. Numbers in parentheses following the sampling season (W or S) refer to the number of sites and number of times each host plant was sampled.

Plant family	Common name	Season	*Anagrus* species
Rose (Rosaceae)	Cultivated rose, *Rosa* sp.	W (3, 10)	*atomus* (~445), *avalae* (3), *erythroneurae* (~76)
	Wild rose, *Rosa* sp.	W (7, 10)	*atomus* (~287), *avalae* (2), *erythroneurae* (~155)
	Blackberry and Tayberry, *Rubus* spp.	W (5, 11)	*atomus* (~190), *erythroneurae* (~15)
	Sweet cherry, *Prunus avium*	W (3, 6)	*erythroneurae* (1)
	Choke cherry, *P. virginiana*	W (7, 11)	*atomus* (~10), *avalae* (~101), *daanei* (2)
	Cultivated plum, *P. domestica*	W (5, 9)	*erythroneurae* (9)
	Apple, *Malus domestica*	W (3, 7)	*atomus* (6), *avalae (1)*, *erythroneurae* (24)
	Strawberry, *Fragaria* x *ananassa*	S (1, 1)	*atomus* or *erythroneurae* (10)
Dogwood	Red osier dogwood, *Cornus stolonifera*	W (3, 3)	*erythroneurae* (1)
	Red osier dogwood, *Cornus stolonifera*	S (4, 7)	*daanei (1?)*, *erythroneurae* (3)
Willow (Salicaceae)	Willow sp., *Salix* sp.	W (3, 10)	near *nigriventrus* (1), *Anagrus* sp. (9)
Birch (Betulaceae)	European white birch, *Betula pendula*	W (2, 2)	*atomus* (1)
	Water birch, *B. occidentalis*	W (3, 5)	*atomus* (4), *avalae* (14), *erythroneurae* (3)
	Alder, *Alnus* sp.	W (3, 3)	*erythroneurae* (1)
Maple (Aceraceae)	Douglas maple, *Acer glabrum*	W (4, 6)	*atomus* (1)
Elm (Ulmaceae)	Siberian elm, *Ulmus pumila*	W (4, 6)	*atomus* (4)
Grape (Vitaceae)	Grape, *Vitis vinifera*	S (5, 6)	*daanei* (348)
	Virginia creeper, *Parthenocissus quinquefolia*	S (2, 3)	*daanei* (15)
Mint (Lamiaceae) (=Labiatae)	Catnip, *Nepeta cataria*	S (6, 11)	*atomus* (217), *erythroneurae* (7)
	Persian catmint, *Nepeta* x *mussinii*	S (1, 2)	*atomus* (~26), *erythroneurae* (~15)
	Garden mint, *Mentha* sp.	S (1, 1)	*atomus* (6), *erythroneurae* (2)
	Mint sp., *Mentha* sp.	S (1, 1)	*atomus* (5), *erythroneurae* (1)
	Lavender, *Lavendula angustifolia*	W (1, 1)	*atomus* (4)
	Garden sage, *Salvia officinalis*	W (1, 1)	*atomus* (~33), *erythroneurae* (~27)

(Table 1). The only other *Anagrus* collected were a single probable specimen of *A. nigriventris* Girault, and an unknown species from willow (*Salix* sp.).

The common and widespread European species, *A. atomus*, which also occurs in South America and Asia (Triapitsyn 2001), was the most commonly collected species (Table 1). It was identified from 16 host plants from six families. Most of our host associations for *A. atomus* confirm earlier reports (Chiappini 1989, Triapitsyn 1998). Although it parasitizes the eggs of leafhoppers on grapes in Europe and Asia, all Nearctic records are from plants other than those in the Vitaceae. We also failed to obtain *A. atomus* from grapes; most of our records were from roses; blackberry, *Rubus* sp.; choke cherry, *Prunus virginiana*; and apple. Material examined by Triapitsyn (1998) included specimens collected from apple and rose in the Okanagan Valley by McKenzie (1973). Reported leafhopper hosts for *A. atomus* associated with these host plants include the white apple leafhopper, *Typhlocyba pomaria* McAtee, and green apple leafhopper, *Empoasca maligna* Walsh, on apple; the rose leafhopper, *Edwardsiana rosae* (L.), on rose and blackberry; and the plum leafhopper, *E. prunicola* (Edwards), on plum (Triapitsyn 1998).

Given their size and abundance, trees in the birch (Betulaceae), maple (Aceraceae) and elm (Ulmaceae) families should be considered important overwintering plant hosts for this species. Yet only a small number of *A. atomus* were collected from dormant twigs from plants in these families (Table 1). Maple, alder and birch support a number of leafhopper species (Hamilton 1985). The likely host for *A. atomus* on Siberian elm, *Ulmus pumila*, is *Empoasca bipunctata* (Oshanin), as it was the only species reported by Hamilton (1985) to feed on Siberian elm in BC. Large numbers of *A. atomus* were collected in summer from several species of plants in the mint (Lamiaceae) family, and it was also collected from sage, *Salvia officinalis*, and lavender, *Lavendula angustifolia*, in March. The mint leafhopper, *Eupteryx melissae* Curtis, occurs on these plants in southern BC (Beirne 1956), and this is the likely host for *A. atomus* during the summer on these plants. It may be the first overwintering record for a species of *Anagrus* on plants in this family.

Anagrus erythroneurae is clearly the most important egg parasitoid of WGL and the variegated leafhopper on grapes in California and Baja California Norte, Mexico (Triapitsyn 1998). In the Napa and Sonoma Valleys of CA, more than 95% of the egg parasitoids emerging from eggs of WGL were *A. erythroneurae*. Triapitsyn (1998) also reported it from apple infested with the white apple leafhopper and from plum infested with the plum leafhopper. *A. erythroneurae* was recognized only recently as a new species (Trjapitzin and Chiappini 1994) and its host associations and biology are not well known. Many previous reports referring to the effective control of WGL by *A. epos* can likely be attributed to *A. erythroneurae* (Chiappini *et al.*1996). *Anagrus erythroneurae* is known to parasitize the eggs of a number of leafhopper species, most of which belong to the genera *Erythroneura* Fitch, *Dikrella* Oman, and *Typhlocyba* Germar. Not all species within these genera are suitable hosts, however. We did not rear *A. erythroneurae* from leaves of grapes or Virginia creeper vines, *Parthenocissus quinquefolia,* infested only with VCL (Table 1). In BC, the rose leafhopper overwinters as eggs in the stems of rose and blackberry, and this is the likely host on these plants. The early spring and summer host on plants of the mint family is likely the mint leafhopper. Other potential summer host plants are strawberry, *Fragaria x ananassa*, and red osier dogwood, *Cornus stolonifera* (Table 1).

Our sampling of potential winter and spring hosts resulted in rearings of *A. erythroneurae* from 14 plant species (Table 1). Overwintering *A. erythroneurae* were collected primarily from roses, blackberry, and plum. Members of the birch family have not been recorded previously as overwintering host plants, and we do not know which leafhopper species are being parasi-

tized by *A. erythroneurae* on these trees. *Anagrus erythronuerae* is likely parasitizing eggs of the mint leafhopper on catmint, *Nepeta x mussinii*; catnip, *Nepeta cataria*; garden sage; and garden mint, *Mentha* spp. Additional research is required to identify the leafhoppers on these trees and other host plants used by *A. erythroneurae* as winter or summer hosts in BC.

Parasitism by *Anagrus erythroneurae* might limit the range of the WGL in the Okanagan Valley. Many of the vineyards on the east side of the Okanagan Valley south of Penticton are located some distance from apple and *Prunus* orchards and few nearby areas support wild roses or blackberry. In California vineyards, some control of WGL usually occurs near riparian areas supporting blackberry or rose (Doutt and Nakata 1965, Williams 1983) or French prune trees (Kido *et al.* 1984) that maintain overwintering *Anagrus*. Reductions in numbers of WGL in Okanagan vineyards might be achieved by preserving natural refugia and planting suitable overwintering (i.e. plum and rose) and early spring (i.e. catmint) hosts, provided that such areas are approximately comparable in size to the nearby vineyards and are able to sustain viable and sizeable populations of alternate host leafhopper species.

Anagrus avalae is another common European species recorded in NA parasitizing eggs of the rose leafhopper on rose and white apple leafhopper on apple (Chiappini and Triapitsyn 1997; Triapitsyn 1998). McKenzie (1973) collected it from roses in the Okanagan Valley. We collected it from dormant twigs of rose, choke cherry, apple and birch (Table 1). Mulla (1956) was able to collect this species, incorrectly referred to as *A. armatus nigriceps* Girault, from the summer eggs of plum leafhopper, but not from overwintering eggs. Interestingly, although it winters in the eggs of leafhoppers on other members of the rose family, we also did not collect *A. avalae* from dormant twigs of plum. This species has not been recorded parasitizing leafhopper eggs on grapes in NA, and we did not rear it from this plant host in BC.

Anagrus daanei was recognized as a new species only recently (Triapitsyn 1998) and there is little unequivocal information available relating to its winter hosts. It has been collected from eggs of leafhoppers infesting grapes in NA (Triapitsyn 1998) and was the only species we recovered from eggs of VCL (Table 1). Triapitsyn (1998) identified *A. daanei* from California associated with dormant blackberry, and from eggs of the rose leafhopper in dormant rose in New York. We were unable to rear any specimens from dormant blackberry and rose in BC, perhaps reflecting differences in leafhopper species on these plants in the two regions. A small number of *A. daanei* were collected from dormant twigs of choke cherry near Armstrong at a location far from commercial vineyards, but not from dormant choke cherry at a number of sites in the south Okanagan Valley close to vineyards. Large numbers of parasitoids moving from vineyards in fall might eliminate nearby alternate leafhopper hosts, or there might be differences in leafhopper species or abundance between the warmer, drier south Okanagan and the cooler, wetter north. Several species of leafhopper occur on choke cherry, including four native species of *Typhlocyba* that occur across the continent (Hamilton 1985).

McKenzie (1973) reared what was at that time believed to be *A. epos* from parasitized eggs of VCL on Okanagan grapes. He described the females as light brown in colour, which is characteristic for *A. daanei* (Triapitsyn 1998). *Anagrus* were also reared from dormant branches of wild rose infested with the rose leafhopper and from apple infested with the white apple leafhopper, but no mention was made as to the colour of females from these collections. McKenzie (1973) noted that *Anagrus* parasitoids emerging from rose shoots in spring did so during two distinct periods and speculated that this bimodal emergence pattern might result from differences in the time when eggs were parasitized in fall. In addition to *A. erythroneurae*, we also reared *A. atomus* and *A. avalae* from dormant rose shoots. The bimodal emergence noted by

McKenzie (1973) most likely represented different emergence times for different species.

VCL is one of the most important pests of grapes in south central BC, and sprays are frequently required to prevent economic damage. The small number of wintering *A. daanei* collected during our study reflect the low rates of parasitism of VCL in most commercial vineyards. Parasitoids are rare or absent from many vineyards until late in the season (DTL unpublished) and *A. daanei* rarely controls VCL populations adequately. In New York vineyards, in contrast, *A. daanei, A. erythroneurae* and *A. tretiakovae* contribute to the biological control of several species of *Erythroneura* leafhoppers infesting grape (Triapitsyn 1998, Williams and Martinson 2000). Known leafhopper hosts for *A. daanei* on grapes in New York include the Eastern grape leafhopper, *Erythroneura comes* (Say), VCL, and *E. bistrata* McAtee (Triapitsyn 1998). Records from dormant plant hosts in eastern NA include apple; sugar maple, *Acer saccharum* Marsh.; prickly ash, *Zanthoxylum americana* Mill.; black locust, *Robinia pseudoacacia* L.; and rambler rose, *Rosa multiflora* Thumb. (Triapitsyn 1998). We did not record *A. daanei* from these or closely related winter hosts in BC. The relative scarcity of VCL in eastern NA vineyards might be due to greater overwintering success of *A. daanei* in that region.

Anagrus tretiakovae, native to eastern NA, was apparently introduced to California in 1987 as a biotype of *Anagrus epos* Girault to control leafhoppers on grape. We did not collect *A. tretiakovae* from dormant host plants or from grape. This species is likely to invade BC eventually, but it could be considered for intentional importation for the biological control of leafhoppers on grape. Detailed rearings of *Anagrus* spp. from leafhopper hosts on their overwintering host plants are needed to confirm host associations and determine which plant species might be used as overwintering refugia around vineyards in BC.

ACKNOWLEDGEMENTS

Technical assistance was provided by Karin Todd, Jocelyn Gartrell, Lisa Wambold and Lauren Bunckle. Funding for this project was provided by the BC Wine Institute and Agriculture and Agri-Food Canada through the Matching Investment Initiative, the National Research Council of Canada Industrial Research Assistance Program, and the BC Investment Agriculture Foundation.

REFERENCES

Agboka, K., A.K. Tounou, R. Al-Moaalem, H.-M. Poehling, K. Raupach and C. Borgmeister. 2004. Life-table study of *Anagrus atomus*, an egg parasitoid of the green leafhopper, *Empoasca decipens*, at four different temperatures. BioControl 49: 261-275.

Beirne, B.P. 1956. Leafhoppers (Homoptera: Cicadellidae) of Canada and Alaska. The Canadian Entomologist 88, Supplement 2.

Chiappini, E. 1989. Review of the European species of the genus *Anagrus* Haliday (Hymenoptera: Chalcidoidea). Bollettino di Zoologia Agraria e di Bachicoltura, Serie II 21: 85-119.

Chiappini, E. and J. Huber. 2004. Fairyflies (Hymenoptera: Mymaridae), pp. 824-825. *In* Capinera, J.L. (Ed.), Encyclopedia of Entomology, vol. 2. Kluwer Academic Press, Dordrecht.

Chiappini, E., S.V. Triapitsyn and A. Donev. 1996. Key to the Holarctic species of *Anagrus* Haliday (Hymenoptera: Mymaridae) with a review of the Nearctic and Palearctic (other than European) species and description of new taxa. Journal of Natural History 30: 551-595.

Chiappini, E. and S.V. Triapitsyn. 1997. Redescription of *Anagrus avalae* Soyka (Hymenoptera: Mymaridae), with new synonymies. Frustula Entomologica 20: 119-126.

Doutt, R.L. and J. Nakata. 1965. Parasites for control of grape leafhopper. California Agriculture 19: 3-5.

Hamilton, K.G.A. 1985. Leafhoppers of ornamental and fruit trees in Canada. Publication 1779/E, Communications Branch, Agriculture and Agri-Food Canada.

Huber, J.T. 1986. Systematics, biology, and hosts of the Mymaridae and Mymarommatidae (Insecta: Hy-

menoptera): 1758-1984. Entomography 4: 185-243.
Kido, H., D.L. Flaherty, D.F. Bosch, and K.A. Valero. French pruce trees as overwintering sites for the grape leafhopper egg parasite. American Journal of Enology and viticulture 35(3): 156-160.
McKenzie, L.M. 1973. The Grape Leafhopper, *Erythroneura ziczac* (Homoptera: Cicadellidae) and its Mymarid (Hymenoptera) Egg-Parasite in the Okanagan Valley, British Columbia. M.Sc. Thesis, Department of Biological Science, Simon Fraser University, Burnaby, British Columbia.
Mulla, M.S. 1956. Two Mymarid egg parasites attacking *Typhlocyba* species in California. Journal of Economic Entomology 49: 438-441.
Pickett, C.H., L.T. Wilson, D. González and D.L. Flaherty. 1987. Biological control of variegated grape leafhopper. California Agriculture 41: 14-16.
Triapitsyn, S.V. 1995. The identities of *Anagrus* (Hymenoptera: Mymaridae) egg parasitoids of the grape and blackberry leafhoppers (Homoptera: Cicadellidae) in California. Pan Pacific Entomologist. 71: 250-251.
Triapitsyn, S.V. 1998. *Anagrus* (Hymenoptera: Mymaridae) egg parasitoids of *Erythroneura* spp. and other leafhoppers (Homoptera: Cicadellidae) in North American vineyards and orchards: a taxonomic review. Transactions of the American Entomological Society 124: 77-112.
Triapitsyn, S.V. 2001. Review of the Australasian species of *Anagrus* (Hymenoptera: Mymaridae). Belgian Journal of Entomology 3(2): 267-289.
Triapitsyn, S.V. and A.J. Teulon. 2002. On the identity of *Anagrus* (Hymenoptera: Mymaridae) egg parasitoids of Froggatt's apple leafhopper, *Edwardsiana crataegi* (Douglas) (Homoptera: Cicadellidae), in Christchurch, New Zealand. New Zealand Entomologist 25: 91-92.
Trjapitzin, S.V., and E. Chiappini. 1994. A new *Anagrus* (Hymenoptera: Mymaridae) egg parasitoid of *Erythroneura* spp. (Homoptera : Cicadellidae). Entomological News 105: 137-140.
Vidano, C., and A. Arzone. 1982. Biotaxonomy and epidemiology of Typhlocybinae on vine, pp. 75-85. *In* Knight, W.J., N.C. Pant, T.S. Robertson and M.R. Wilson (Eds.), Proceedings of the First International Workshop on Biotaxonomy, Classification and Biology of Leafhoppers and Planthoppers (Auchenorrhyncha) of Economic Importance, London, 4-7 October 1982. Commonwealth Institute of Entomology, London.
Vidano, C., A. Arzone and A. Arno. 1987. Researches on natural enemies of viticolous Auchenorrhynca, pp 97-101. *In* R. Cavalloro (Ed.), Integrated pest control in viticulture. Proceedings of a meeting of the EC Experts' Group, Portoferraio, 26-28 Sept, 1985, Amsterdam.
Williams, D.W. 1983. Ecology of a blackberry-leafhopper-parasite system and its relevance to California grape agroecosystems. Hilgardia 52: 1-32.
Williams, L., and T.E. Martinson. 2000. Colonization of New York vineyards by *Anagrus* spp. (Hymenoptera: Mymaridae): overwintering biology, within-vineyard distribution of wasps, and parasitism of grape leafhopper, *Erythroneura* spp. (Homoptera: Cicadellidae), eggs. Biological Control 18: 136-146.