Susceptibilities of Apple Aphid and Spirea Aphid Collected from Apple in the Pacific Northwest to Selected Insecticides

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J. Econ. Entomol. 99(4): 1369–1374 (2006)

ABSTRACT Laboratory bioassays using leaf disks of apple dipped in test solutions of insecticides demonstrated that the apple aphid, *Aphis pomi* De Geer, and the spirea aphid, *Aphis spiraecola* Patch, differed significantly in susceptibility to a number of insecticides registered for control of aphids on apple (*Malus* spp.). Compared with *A. pomi*, *A. spiraecola* was approximately four- and three-fold less susceptible to pirimicarb and lambda-cyhalothrin, respectively, whereas there was little difference in response to dimethoate. Pymetrozine is thought to act on aphids primarily as a feeding inhibitor. Exposure of aphids to this material generated data that fit the probit model for only half the tested clones. However, the LC_{50} value for one clone of *A. spiraecola* was nearly 1,000 times higher than the value for one clone of *A. pomi*. Although the results from these trials did not indicate that either species had developed significant levels of resistance to the test materials, differences in LC_{50} levels of >10-fold suggest insecticide tolerances and the possibility of control failures in the future. The demonstrated differences in susceptibility to insecticides between these two morphologically similar species also should be considered during the evaluation of new products for use on apple.

KEY WORDS *Aphis pomi*, *Aphis spiraecola*, susceptibility, toxicity, insecticides

The apple aphid, *Aphis pomi* De Geer, often called the green apple aphid, is a significant pest of apples (*Malus* spp.) produced in the Pacific Northwest and elsewhere. The British Columbia Tree Fruit Production Guide for Commercial Growers (BCMAF 2000) states that damage is likely if 50% of the shoots on a mature tree are infested. Damage consists of curled leaves, contamination of foliage and fruit with honeydew, and possible stunting and malformation of shoots and fruits. Recommended control products include the systemic organophosphate dimethoate, imidacloprid, and pirimicarb. Use of the latter material is generally limited to nonbearing trees, as pirimicarb is not registered in the United States. *A. pomi* remain on apples throughout the season, exposing them to a number of other insecticides from various classes that also might contribute to insecticide resistance development. Some other commonly used insecticides include endosulfan, the carbamate carbaryl, and pyrethroids such as lambda-cyhalothrin (BCMAF 2000, Smith et al. 2005).

In a previous article (Lowery et al. 2005), we showed that, depending on the bioassay method, the spirea aphid, *Aphis spiraecola* Patch, was less susceptible to the neonicotinyl insecticide imidacloprid compared with the apple aphid. These findings supported previous research of Hogmire et al. (1990, 1992) that also demonstrated significant differences in susceptibility to a number of insecticides between these two species. In light of findings that *A. spiraecola* is more common than *A. pomi* on apple in Virginia, West Virginia, Maryland, and south central Washington (Pfeiffer et al. 1989, Mayer and Lunden 1996), differences in response to aphicides for these morphologically similar species should be considered in the development of aphid management programs and testing of new products for use on apple.

The purpose of this study was to evaluate susceptibilities of *A. pomi* and *A. spiraecola* to insecticides registered for control of aphids on apple in Canada. Bioassays using treated leaf disks were used to establish dose–response curves for a number of clones of both species from south central British Columbia and central Washington. Clones used in these studies were included in a previous study of imidacloprid toxicity (Lowery et al. 2005).

Materials and Methods

Aphids. During the 1999, 2000, and 2001 growing seasons, aphids were collected from conventional and organic apple orchards, wild apple, and ornamental crab apple, *malus* spp., in south central British Columbia and central Washington. Information and a map of the collection sites, as well as the collecting and

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Table 1. Determination of lethal concentrations (ppm AI) of pirimicarb applied to leaf disks of apple to third instars of *A. pomi* and *A. spiraecola* from south central British Columbia and central Washington based on probit analyses of mortality after 48 h

Province/state	Yr	Code	*n*	Slope (SE)	LC_{50} (95% CI)	LC_{90} (95% CI)	χ^2 (*P*)
A. pomi							
BC	1999	BC4-99a	570	2.19 (0.28)	0.36 (0.32–0.41)	0.65 (0.57–0.81)	3.61 (0.17)
		BC6-99	320	0.79 (0.10)	0.45 (0.32–0.59)	2.26 (1.61–3.74)	0.24 (0.62)
		BC11-99	420	1.67 (0.19)	0.59 (0.49–0.69)	1.26 (1.04–1.62)	0.06 (1.00)
		BC2-99	550	1.54 (0.20)	0.61 (0.49–0.72)	1.40 (1.17–1.76)	0.74 (0.69)
		BC5-99	370	1.18 (0.18)	0.68 (0.55–0.88)	2.02 (1.41–3.78)	1.09 (0.30)
		BC4-99b	690	1.24 (0.11)	0.69 (0.58–0.82)	1.95 (1.60–2.51)	2.42 (0.30)
		BC10-99	470	1.14 (0.11)	0.76 (0.62–0.90)	2.31 (1.87–3.07)	0.92 (0.63)
	2001	BC12-01	730	2.20 (0.29)	1.13 (0.49–2.20)	4.32 (2.22–25.19)	6.03 (0.05)
WA	2000	WA18-00	520	3.13 (0.31)	0.57 (0.48–0.66)	1.47 (1.26–1.80)	2.96 (0.23)
		WA17-00	520	2.46 (0.33)	1.18 (0.99–1.43)	3.92 (2.86–6.53)	4.33 (0.12)
		WA19-00	480	2.90 (0.30)	1.65 (1.40–1.95)	4.57 (3.68–6.16)	2.11 (0.35)
A. spiraecola							
BC	1999	BC7-99b	530	0.89 (0.08)	0.58 (0.47–0.71)	2.48 (1.90–3.52)	1.02 (0.60)
		BC7-99a	500	1.60 (0.19)	1.65 (1.42–1.91)	3.68 (3.01–4.96)	0.00 (0.98)
		BC4-99b	340	1.26 (0.13)	1.99 (1.65–2.39)	5.48 (4.32–7.62)	2.55 (0.11)
		BC6-99	420	1.48 (0.16)	2.27 (1.91–2.68)	5.39 (4.36–7.21)	0.02 (0.99)
		BC4-99a	410	1.18 (0.13)	2.64 (2.16–3.19)	7.84 (6.10–11.18)	0.88 (0.64)
		BC7-99c	480	1.76 (0.18)	3.19 (2.82–3.58)	6.61 (5.68–8.11)	0.15 (0.93)
WA	2000	WA16-00b	570	3.46 (0.51)	1.40 (0.85–2.29)	3.28 (2.08–16.46)	5.23 (0.07)
		WA16-00a	590	3.35 (0.35)	2.17 (1.82–2.51)	5.24 (4.48–6.40)	0.40 (0.94)
		WA-19-00	510	2.60 (0.24)	2.48 (2.08–2.93)	7.71 (6.23–10.19)	3.06 (0.22)
		WA14-00	590	3.30 (0.39)	3.58 (2.95–4.21)	8.75 (7.26–11.30)	0.44 (0.80)
		WA22-00	430	2.57 (0.30)	4.07 (3.37–4.87)	12.79 (9.89–18.56)	1.21 (0.55)
		WA20-00	460	2.22 (0.35)	4.95 (1.30–13.02)	18.70 (8.08–310.24)	7.09 (0.03)
		WA21-00	500	2.65 (0.28)	5.26 (4.33–6.22)	16.00 (12.97–21.28)	4.55 (0.10)
		WA17-00b	480	3.73 (0.39)	6.20 (5.26–7.14)	13.66 (11.62–16.85)	2.06 (0.36)
		WA15-00	410	3.46 (0.32)	6.30 (5.42–7.21)	14.79 (12.58–18.18)	0.01 (0.91)

BC, British Columbia; WA, Washington.

laboratory rearing protocol for the clones used in this study was published previously (Lowery et al. 2005). Samples from each aphid clone were preserved in 70% ethanol and sent to the Eastern Cereals and Oilseeds Research Centre, Agriculture and Agri-Food Canada, for identification and deposition of vouchers in the Canadian National Insect Collection.

Apple seedlings used for culturing aphids and to provide leaf disks for insecticide bioassays were grown in a growth chamber at 22°C in 4.5-liter plastic pots as outlined previously (Lowery et al. 2005).

Insecticide Bioassays. Apple leaf disks dipped in solutions of the test insecticides were used to rear third instars, 10 per dish, on treated leaf disks in small petri dishes as outlined by Lowery and Smirle (2003). The insecticides used in these tests included the pyrethroid lambda-cyhalothrin (Matador 120 EC, Syngenta Crop Protection Canada, Guelph, Ontario, Canada), the selective carbamate aphicide pirimicarb (Pirimor 50 DF, Syngenta Crop Protection Canada, Guelph, Ontario, Canada), the systemic organophosphate dimethoate (Cygon 480 EC, Nu-Gro Corporation Inc., Brantford, Ontario, Canada), and the pyridine azomethine insecticide pymetrozine (Fulfill 50 WG, Novartis Crop Protection Canada Inc., Guelph, Ontario, Canada). Based on preliminary results involving 10-fold dilutions of the recommended spray concentration, aphids were exposed to five to seven test concentrations of each material, including appropriate controls. Except for pymetrozine where mortality was assessed after 5 d, bioassays ran for 48 h. The surfactant Agral 90 (Zeneca Agro, Calgary, Alberta, Canada) was added at a uniform concentration (0.25 ml/liter) to all treatments; controls consisted of the surfactant solution only. For both species, trials with each test material were replicated at least twice. Lethal concentrations required to kill 50% (LC_{50}) and 90% (LC_{90}) of the test populations were determined by probit analysis (SAS Institute 2000).

Results

Susceptibilities to Pirimicarb. For third instars of *A. pomi* exposed to pirimicarb, LC_{50} values ranged from 0.36 ppm (AI) to 1.65 ppm (AI), for a 4.6-fold range in response values (Table 1). Clones collected from Washington were moderately more tolerant to pirimicarb, average LC_{50} value 1.13 ppm (AI), compared with those from British Columbia, average 0.66 ppm (AI), but there was considerable overlap in individual values. There was more variation in susceptibility to pirimicarb in *A. spiraecola*, with LC_{50} values ranging from 0.58 ppm (AI) to 6.30 ppm (AI). As for *A. pomi*, the average LC_{50} value for clones of *A. spiraecola* from Washington (4.05 ppm [AI]) was about twice that for British Columbia (2.05 ppm [AI]), but the range in values overlapped.

Comparing the responses of the two species showed that *A. spiraecola* was moderately more tolerant to pirimicarb compared with *A. pomi*. Average values were 3.25 ppm (AI) and 0.79 ppm (AI), respectively, for a four-fold difference (Table 1). Based on overlapping 95% confidence intervals (CI), however, several of the values for the two species did not differ

Table 2. Determination of lethal concentrations (ppm AI) of dimethoate applied to leaf disks of apple to third instar *A. pomi* and *A. spiraecola* from south central British Columbia and central Washington based on probit analyses of mortality after 48 h

Province/state	Yr	Code	*n*	Slope (SE)	LC_{50} (95% CI)	LC_{90} (95% CI)	χ^2 (*P*)
A. pomi							
BC	1999	BC2-99	560	0.77 (0.08)	4.81 (3.84–5.91)	25.19 (18.72–37.91)	3.47 (0.18)
		BC4-99a	330	0.92 (0.12)	6.80 (5.42–8.31)	27.21 (20.10–43.48)	0.58 (0.45)
		BC6-99	320	1.22 (0.15)	9.20 (7.60–11.07)	26.41 (20.43–38.60)	0.56 (0.46)
		BC5-99	450	0.98 (0.11)	10.89 (8.87–13.35)	40.17 (29.75–62.50)	1.08 (0.58)
		BC11-99	420	0.92 (0.10)	11.42 (9.49–13.65)	46.04 (34.55–69.95)	1.13 (0.77)
		BC10-99	530	1.45 (0.14)	13.42 (11.65–15.44)	32.53 (26.97–41.78)	1.23 (0.54)
		BC4-99b	340	1.16 (0.14)	14.73 (12.08–17.88)	44.67 (34.16–66.31)	0.81 (0.37)
	2001	BC12-01	700	1.02 (0.09)	22.44 (18.70–26.62)	78.54 (63.10–103.73)	3.33 (0.34)
WA	2000	WA18-00	620	1.70 (0.17)	16.22 (12.94–20.47)	92.18 (64.38–151.54)	1.11 (0.78)
		WA17-00a	500	2.21 (0.19)	27.90 (23.21–33.670)	106.02 (81.37–149.81)	4.15 (0.13)
		WA19-00	600	3.77 (0.39)	55.44 (48.32–62.48)	121.35 (104.7–147.93)	0.18 (0.98)
A. spiraecola							
BC	1999	BC7-99b	330	1.33 (0.17)	6.27 (5.33–7.32)	16.46 (13.09–23.48)	1.64 (0.20)
		BC7-99a	420	0.87 (0.10)	6.66 (5.27–8.25)	28.97 (21.28–45.42)	3.68 (0.16)
		BC4-99a	500	0.94 (0.10)	7.45 (6.24–8.79)	29.24 (22.55–42.29)	2.42 (0.12)
		BC6-99	420	1.17 (0.13)	7.89 (6.67–9.35)	23.66 (18.44–33.84)	2.28 (0.32)
		BC7-99c	340	1.16 (0.14)	10.81 (8.87–13.08)	32.59 (25.14–47.41)	0.61 (0.44)
		BC4-99b	450	1.17 (0.12)	12.17 (10.31–14.50)	36.45 (28.36–51.65)	1.81 (0.40)
WA	2000	WA16-00b	480	2.63 (0.27)	8.71 (7.36–10.28)	26.76 (21.14–37.01)	1.42 (0.49)
		WA19-00	500	1.97 (0.19)	12.26 (10.10–14.76)	54.74 (41.52–79.69)	4.08 (0.13)
		WA22-00	610	3.01 (0.25)	15.59 (13.90–17.54)	41.54 (34.69–52.66)	2.08 (0.56)
		WA17-00b	500	1.77 (0.16)	19.93 (16.38–24.22)	105.24 (77.83–157.40)	2.75 (0.25)
		WA16-00a	480	2.82 (0.24)	19.95 (17.05–23.21)	56.74 (46.74–72.56)	1.77 (0.41)
		WA14-00	530	2.91 (0.24)	21.46 (18.43–24.77)	59.25 (49.37–74.64)	1.70 (0.43)
		WA15-00	640	2.69 (0.25)	25.35 (22.19–28.00)	75.94 (61.96–100.11)	2.17 (0.54)
		WA20-00	480	1.97 (0.16)	25.37 (20.90–30.97)	113.56 (85.10–165.43)	1.98 (0.37)
		WA21-00	600	2.52 (0.20)	30.11 (25.50–35.06)	97.11 (80.60–122.25)	3.70 (0.30)

BC, British Columbia; WA, Washington.

significantly ($P > 0.05$). An examination of LC_{90} values suggests approximate diagnostic doses for *A. pomi* and *A. spiraecola* of ≈5 ppm (AI) and 19 ppm (AI), respectively.

Susceptibilities to Dimethoate. Compared with pirimicarb, dimethoate was less toxic to both aphid species (Table 2). LC_{50} values ranged from 4.81 ppm (AI) to 55.44 ppm (AI) for third instars of *A. pomi*, and from 6.27 ppm (AI) to 30.11 ppm (AI) for *A. spiraecola.* For this material, there was greater variability (11.5-fold) among the clones of *A. pomi* compared with *A. spiraecola* (4.8-fold), but the two species differed little in average susceptibility to dimethoate. Based on the highest LC_{90} value (121.35 ppm [AI]), a useful diagnostic dose for both *A. pomi* and *A. spiraecola* would be ≈125 ppm (AI). For both species combined, clones from Washington were more than twice as tolerant to dimethoate than those from BC; LC_{50} values averaged 23.19 ppm (AI) versus 10.35 ppm (AI), respectively.

Susceptibilities to Lambda-Cyhalothrin. Only four clones were tested for susceptibility to lambda-cyhalothrin, but the results suggest little difference between Washington and British Columbia sites and a significant difference between species (Table 3). For both species, there was no significant difference ($P > 0.05$) between LC_{50} values based on overlapping 95% CI for the clones from WA versus BC, but the values for *A. pomi* were significantly ($P < 0.05$) lower compared with *A. spiraecola.* The difference in susceptibility between the two species based on this limited sample size is only about three-fold, however, which is similar to the four-fold difference shown for pirimicarb. Establishment of accurate diagnostic doses would require testing of additional clones, but examination of LC_{90} values suggests doses in excess of five ppm (AI) of lambda-cyhalothrin for *A. pomi* and 10 ppm (AI) for *A. spiraecola.*

Table 3. Determination of lethal concentrations (ppm AI) of lambda-cyhalothrin applied to leaf disks of apple to third instars of *A. pomi* and *A. spiraecola* from south central British Columbia and central Washington based on probit analyses of mortality after 48 h

Province/state	Yr	Code	*n*	Slope (SE)	LC_{50} (95% CI)	LC_{90} (95% CI)	χ^2 (*P*)
A. pomi							
BC	2001	BC12-01	630	1.87 (0.17)	0.47 (0.37–0.58)	2.27 (1.72–3.24)	3.12 (0.21)
WA	2000	WA19-00	480	1.51 (0.14)	0.58 (0.44–0.75)	4.15 (2.93–6.61)	0.24 (0.89)
A. spiraecola							
WA	2000	WA20-00	480	1.67 (0.13)	1.29 (1.04–1.61)	7.58 (5.50–11.42)	0.13 (0.94)
		WA17-00b	480	1.71 (0.14)	1.73 (1.39–2.15)	9.72 (7.05–14.69)	1.31 (0.52)

BC, British Columbia; WA, Washington.

Table 4. Determination of lethal concentrations (ppm AI) of pymetrozine applied to leaf disks of apple to third instars of *A. pomi* and *A. spiraecola* from south central British Columbia and central Washington based on probit analyses of mortality after 5 d

Province/state	Yr	Code	*n*	Slope (SE)	LC_{50} (95% CI)	LC_{90} (95% CI)	χ^2 (*P*)
A. pomi							
BC	2001	BC12-01	440	0.68 (0.13)	2.30 (0.88–4.50)	173.53 (58.62–1,489)	0.10 (0.32)
WA	2000	WA19-00	630		≈27		20.69 (<0.01)
A. spiraecola							
WA	2000	WA17-00b	480		≈80		10.42 (<0.01)
		WA20-00	320	0.28 (0.09)	≈2,100	n.a.	1.25 (0.27)

BC, British Columbia; n.a., not applicable; WA, Washington.

Susceptibilities to Pymetrozine. Pymetrozine is thought to act primarily as a feeding inhibitor, with mortality largely resulting from starvation (Denholm et al. 1998). Perhaps because this material does not act as a typical neurotoxin, the data from only two of the clones fit the probit model (Table 4). Of these two, the LC_{50} value for *A. pomi* clone BC12-01 of 2.30 ppm (AI) is nearly 1,000 times lower than the value of 2,097 ppm (AI) determined for *A. spiraecola* clone WA20-00. Even though the data for this latter clone fit the probit model ($\chi^2 = 1.25$, $P = 0.27$), the very low slope casts some doubt on the validity of the results.

Discussion

Susceptibilities to Pirimicarb. Using leaf disks dipped in solutions of pirimicarb, Barber et al. (1999) determined LC_{50} values for susceptible laboratory strains of the aphid *Nasonovia ribisnigri* Mosley; green peach aphid, *Myzus persicae* (Sulzer); and cotton aphid, *Aphis gossypii* Glover, of ≈6, 8, and 69 ppm (AI), respectively. Testing of additional strains of *N. ribisnigri* from lettuce in the United Kingdom resulted in LC_{50} values as high as 62 ppm (AI), for a nearly 11-fold level of resistance. Compared with these previous results, *A. pomi* is marginally more susceptible to pirimicarb, whereas the largest LC_{50} value for *A. spiraecola* of 6.3 ppm (AI) (Table 1) is not statistically different from those for the susceptible strains of *N. ribisnigri* and *M. persicae.* Considering that we used third instars and Barber et al. (1999) tested alate adults, differences in susceptibility are even less than indicated.

A. gossypii is known to be highly tolerant to pirimicarb because of a mutant form of acetylcholinesterase that is less sensitive to inhibition (Devonshire 1989). The same nonmetabolic resistance mechanism has been demonstrated in certain populations of several other aphid species, conferring high levels of resistance to many carbamate and organosphosphate insecticides (Moores et al. 1994, Rufinger et al. 1999). Resistance ratios as high as 42, largely because of decreased sensitivity of acetylcholinesterase, were determined for clones of *N. ribisnigri* (Rufinger et al. 1999). Resistance to pirimicarb also conferred resistance to propoxur. The range in susceptibility to pirimicarb for clones of *A. pomi* of less than 5-fold (Table 1) likely represents natural variation within this species. The maximum 11-fold difference in LC_{50} values between clones of *A. spiraecola* suggests the possibility of low levels of resistance to this material. Pirimicarb is not registered for the control of insects on apple in the United States. Increased tolerance or resistance to this material for *A. spiraecola* on apple in Washington could have resulted, however, from exposure to other insecticides that confer cross-resistance to pirimicarb. Characterization of carboxylesterase activity and insecticide resistance levels for clones of *M. persicae* collected from several field crops in the United Kingdom showed that elevated esterase-4 levels that resulted in resistance to the organophosphates dimethoate and demeton-S-methyl also conferred resistance to pirimicarb, although at a lower level (Sawicki et al. 1978).

Susceptibilities to Dimethoate. Feeding of 4- to 5-d-old *A. spiraecola* nymphs for 24 or 72 h on an artificial diet containing dimethoate resulted in LC_{50} values of 6.16 ppm (AI) and 2.95 ppm (AI), respectively (Manulis et al. 1981). Although the method of exposing aphids to the insecticide differed between this study and ours, the LC_{50} value after 24 h feeding did not differ significantly ($P > 0.05$) from the two lowest values determined for *A. spiraecola* fed for 24 h on treated leaf disks of apple (Table 2) based on overlapping 95% CI. Bioassays conducted over 3 d resulted in a significantly lower LC_{50} value for *A. spiraecola*, which is not surprising considering that Manulis et al. (1981) added the dimethoate directly to the diet. Even though dimethoate has good systemic activity, aphids reared on artificial diet would undoubtedly have been exposed to higher amounts of insecticide compared with treatment of leaf disks.

Barber et al. (1999) studied the susceptibility of *N. ribisnigri* to dimethoate in bioassays by using dipped leaf disks. The LC_{50} value for a susceptible laboratory strain was 5.5 ppm (AI); for a strain collected from lettuce in the field, it was 13 ppm (AI). In another study, confining red and green color morphs of *M. persicae* on small lettuce plants that had been dipped in test solutions of dimethoate resulted in LC_{50} values ranging from 1,145 ppm (AI) to 4,275 ppm (AI) (Kerns et al. 1998). Compared with these previous findings, the susceptibilities of *A. pomi* and *A. spiraecola* to dimethoate were comparable with those for *N. ribisnigri*, whereas *M. persicae* seems to be much more resistant than all three of these species. It should be noted that the outcome of these bioassays could be influenced somewhat by differing techniques and variable uptake of the test materials by the different plant species.

Our results suggest that low levels of resistance to dimethoate might be present in populations of *A. pomi.* The range in LC_{50} values from <5 ppm (AI) to >55 ppm (AI) represents more than an 11-fold difference. Until recently, control of insects on apple in the Pacific Northwest relied heavily on a number of organophosphate insecticides, such as azinphosmethyl. By caging aphids produced in the laboratory on treated apple, Hogmire et al. (1992) determined that *A. pomi* could be controlled effectively with the recommended field rate of azinphosmethyl, but poor control of *A. spiraecola* was likely even at twice the rate. Contrary to this finding, Hogmire et al. (1990) had shown an ≈7-fold greater tolerance to azinphosmethyl for field-collected *A. pomi* compared with *A. spiraecola.* In light of our findings, the differing results might best be explained by the range in susceptibilities to insecticides within populations of both species.

Susceptibilities to Lambda-Cyhalothrin. Rearing adult *N. ribisnigri* on leaf disks of lettuce treated with lambda-cyhalothrin for 3 d, Barber et al. (1999) determined LC_{50} values of 0.1 ppm (AI) and 0.15 ppm (AI) for two strains with characterized resistance to other insecticides. In another study, spraying of leaf disks of cabbage that had adult turnip aphids, *Lipaphis erysimi* (Kaltenbach), confined on them resulted in an LC_{50} value of 0.017 ppm (AI) (Liu et al. 2001). These values are significantly lower than those for field-collected red and green color morphs of *M. persicae* reared on small lettuce plants that had been dipped in lambda-cyhalothrin (Kerns et al. 1998), which ranged from ≈481 ppm (AI) to >8,000 ppm (AI). High levels of resistance to many insecticides, including pyrethroids, is widespread in many populations of *M. persicae* throughout the world (Devonshire 1989). Taking the different treatment methods into account, the susceptibilities of *A. pomi* and *A. spiraecola* to lambda-cyhalothrin (Table 3) is similar to that documented previously for *N. ribisnigri* and *L. erysimi.*

Susceptibilities to Pymetrozine. The largest difference in susceptibility to an insecticide for *A. pomi* and *A. spiraecola* occurred after exposure to pymetrozine. The LC_{50} value for one clone of *A. spiraecola,* 2,097 ppm (AI) was ≈1,000-fold higher than that for a clone of *A. pomi,* 2.3 ppm (AI) (Table 4). Foster et al. (2002) used a dipped leaf disk bioassay system to evaluate the susceptibilities of a large number of clones of *M. persicae* with known insecticide resistance mechanisms. Assessment of first instar mortality after 96 h produced LC_{50} values ranging from 420 ppm (AI) to 2,812 ppm (AI). The susceptibility of *A. spiraecola* is similar to that for *M. persicae,* whereas *A. pomi* seems to be very sensitive to this material. Although testing of the second clone of *A. pomi* from Washington did not result in data that fit the probit model ($\chi^2 = 20.69$, $P < 0.01$), the statistical program was able to generate an approximate LC_{50} value of 27 ppm (AI).

In conclusion, our results support the previous findings of Hogmire et al. (1990, 1992) that *A. spiraecola* and *A. pomi* differ in susceptibility to a number of insecticides. In our study, we have shown that *A. spiraecola* is on average four-fold less susceptible to pirimicarb, three-fold less susceptible to lambda-cyhalothrin, and nearly 1,000-fold less susceptible to pymetrozine than *A. pomi.* There was little difference in susceptibility to dimethoate between the two species. In a previous article, we reported that, depending on the bioassay method, *A. spiraecola* was from 4.4- to 5.8-fold more tolerant to imidacloprid compared with *A. pomi* (Lowery et al. 2005). Development of new products for the control of aphids on apple should consider the differing responses of these two species to insecticides.

Acknowledgments

Special thanks go to Cheryl Zurowski (Agriculture and Agri-Food Canada [AAFC]–Pacific Agri-Food Research Centre [PARC] Summerland) for technical assistance and for the statistical analyses. Funding for this project was provided by the Washington Tree Fruit Research Commission and AAFC through the Matching Investment Initiative.

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Received 12 September 2005; accepted 24 February 2006.