Relative Susceptibility of Red and Green Color Forms of Green Peach Aphid to Insecticides

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Abstract

Field populations of green peach aphid, Myzus persicae (Sulzer), were collected from five produce fields near Yuma, Arizona. Three of the fields sampled contained both red and green-colored forms, while the remaining two fields contained only green-colored green peach aphids. Red-colored aphids were consistently more resistant to dimethoate and lambda-cyhalothrin, and usually more resistant to endosulfan than green-colored aphids collected from the same field. Slight differences in susceptibility to imidacloprid suggest that development of resistance is a possibility and justifies close resistance monitoring. Susceptibility to imidacloprid was not influenced by color form. We detected little or no differences in susceptibility to acephate, mevinphos or bifenthrin.

Introduction

Green peach aphid, *Myzus persicae* (Sulzer), is a cosmopolitan pest infesting over 40 plant families including ornamental, vegetable and stone fruit crops (Blackman and Eastop 1984, Quaglia et al. 1993). In the western United States, green peach aphid is a common pest of lettuce, leafy greens and cole crops (Anonymous 1992). Green peach aphids cause damage to these crops through direct injury, virus transmission and contamination (Blackman and Eastop 1984, Mackauer and Way 1976, Reid and Cuthbert 1977, Hinsch et al. 1991, Palumbo and Kerns 1994).

Green peach aphid produces two distinct color forms, green-yellow and red. Color variation among green peach aphids is common, and appears to be interclonal and sympatric in occurrence (Takada 1981, Miyazaki 1987). Although the benefit of color dimorphism in green peach aphid is not known, red-colored aphids may be better able to absorb solar radiation and warm themselves than green-colored aphids (Markkula and Rautapää 1967). Prior to 1993, the green color form of green peach aphid appeared to be most prevalent in Arizona. However, by 1994 occurrence of the red color form was common.

In 1994, pest control advisors in Yuma, AZ, reported difficulty controlling green peach aphids in lettuce with foliar insecticides, particularly when the aphid population contained large numbers of the red-colored form. Many pest control advisors questioned whether the red form of the green peach aphid in Yuma, were resistant to commonly used foliar aphicides. Green peach aphid has a well-documented history of resistance to a variety of insecticide classes throughout the world (Miyata 1983). In the United States, resistance has been reported to carbamate, organophosphate, cyclodiene, chlorinated hydrocarbon and pyrethroid insecticides (Georghiou 1963, Sudderuddin 1973, McClanahan and Founk 1983, Metcalf 1986, Unruh et al. 1996). In a closely related aphid species, the tobacco aphid, *Myzus nicotinae* (L.), previously described as a tobacco form of the green peach aphid (Blackman 1987), the red-colored form was found to consistently express resistance to malathion and acephate while resistance in the green form was inconsistent (Harlow and Lampert 1990).

Because of the difficulty controlling aphids in lettuce and cole crops with foliar aphicides, most produce growers in Yuma, opted to use pre-plant in-furrow applications of imidacloprid for aphid control in 1995. Green peach aphid control with imidacloprid has proven to be very effective (Palumbo and Kerns 1994, Natwick et al. 1996). However, because aphids do not always reach economically damaging levels in produce in southwestern Arizona, and prophylactic applications of imidacloprid are costly, there is still much interest in the effectiveness of using foliar aphicides.

The objective of this study was to determine if green peach aphids collected from produce grown in southwestern Arizona were resistant to foliar aphicides, and if resistance was more pronounced in the red color form. An additional objective was to develop base-line toxicity data for imidacloprid to green peach aphid, and determine if aphids resistant to foliar aphicides were cross resistant to imidacloprid.

Materials and Methods

Green peach aphid populations were collected from cabbage, spinach and lettuce growing in Yuma County, AZ, during 1995 and 1996. On 2 February 1995, red and green color forms of green peach aphid were collected from a single cabbage field, and on 7 March 1995, green-colored green peach aphids were collected from spinach located at the University of Arizona Yuma Agricultural Center. Red and green-colored aphids were collected from a lettuce field near Roll, AZ, on 17 March 1995. During 1996, green-colored aphids were collected from lettuce near Yuma and Tacna, AZ, on 15 and 25 February, respectively; and on 3 March, red and green-colored aphids were collected from a single lettuce field located near Roll, AZ.

Because of their scarcity, aphids collected from lettuce were not immediately tested for resistance but were cultured on 'Empire' lettuce plants, *Lactuca sativa*, in a growth chamber held at 20 ± 2 C and a 14:10 (L:D) photoperiod, until sufficient aphids were available for testing. Six foliar and one soil-injected insecticide were bioassayed. Of the foliar insecticides evaluated, three were organophosphates [acephate (Orthene 90S, Valent USA Corp., Walnut Creek, CA)], dimethoate (Dimethoate E267, Gowan Comp., Yuma, AZ) and mevinphos (Phosdrin 4EC, Amvac Chem. Corp., Los Angeles, CA)], two were pyrethroids [bifenthrin (Capture 2EC, FMC Corp., Philadelphia, PA) and lambda-cyhalothrin (Karate, Zeneca Inc., Wilmington, DE)], and one was a cyclodiene [endosulfan (Gowan Endosulfan 3EC, Gowan Comp.,Yuma, AZ)]. The systemic insecticide bioassayed was imidacloprid (Admire 2F, Bayer Corp., Kansas City, MO). Imidacloprid is classified as a chloronicotynal insecticide. Commercially formulated insecticides were used in all bioassays.

Three-leaf stage 'Empire' lettuce seedling, singly grown in flats divided into 2.0-cm^2 cells, were used in all bioassays. Plants were removed from their cells and the soil was washed from the root using de-ionized water. Foliar insecticides were evaluated using a plant-dip method. Foliar portions of lettuce seedlings were dipped in six to eight concentrations of each insecticide for 5 sec. Plants were allowed to dry at room temperature for approximately 30 min and then transferred to cup cages. Cup cages were prepared by melting 1.0-cm diameter holes in the bottoms of 300-ml T-10 Comet Brand clear plastic cups. Plants were placed in these cups with the roots protruding from the hole in the bottom. The lettuce plants were then secured in place by molding gray-green modeling clay about the stem of the plant and filling the hole. The cups containing the plants were then placed into a 230 ml T-8T Comet Brand clear plastic cup forming a hydroponic reservoir containing approximately 30 ml of de-ionized water. Ten adult green peach aphids were placed on each plant and the cups were sealed with ventilated clear plastic lids. Cups were then transferred to a growth cabinet set at 20 ± 2 C and a 14:10 (L:D) photoperiod. After 24 hrs, mortality was determined by removing the aphids from the cups and determining if they could walk. Aphids that could not walk were considered dead.

Imidacloprid was bioassayed using techniques similar to the foliar insecticides except plants were not dipped, but treated by varying concentrations of imidacloprid in the hydroponic reservoir. Imidacloprid treated plants were held at ambient room temperature for 48 hrs to allow systemic movement of the insecticide from the roots to the leaves before introducing the aphids.

Dosage-mortality curves for all bioassays were estimated using Probit's analysis (SAS Institute Inc. 1989). Dosages required to kill 50% (LD_{50}) and 95% (LD_{95}) of the populations were estimated using the Probit regression, 95% confidence limits were used to separate differences.

Results and Discussion

The only organophosphate insecticide evaluated that exhibited definitive mortality responses among green peach aphid populations was dimethoate (Table 1). Red-colored aphids consistently had significantly higher LC_{50} values than the green-colored. On average, red-colored aphids were 3.18-fold less susceptible than green aphids collected from the same field. Although, a 3.18-fold increase in resistance does not suggest a large difference, there does appear to be a trend for higher levels of resistance to dimethoate in the red-colored populations. Whether or not a 3.18-fold increase in resistance to dimethoate would result in a field control problem is not certain. When evaluated for dose-mortality response to acephate, there were no significant differences among any of the populations. However, both red and green-colored forms of the YC95 had flatter slope values than the other populations, suggesting the presence of a few resistant individuals. Differences in response to mevinphos between red and green-colored aphids was inconsistent. The only difference detected was for the red-colored YC95 population, which had a significantly lower LC_{50} than the green-YC95 and the red-TL96 populations. Additionally, the red-YC95 population had a significantly flatter slope than the other populations evaluated, suggesting that this population probably had a greater number of highly susceptible individuals.

Among the pyrethroids bioassayed, differences in susceptibility among aphid populations was detected only for lambda-cyhalothrin (Table 2). The red-colored populations YC95, RL95 and TL96 were 5.5, 1.4 and 6.5-fold more resistant to lambda-cyhalothrin, respectively, than the green-colored aphids collected from the same fields. Although there was no difference among the red-colored populations, there were differences in susceptibility to lambda-cyhalothrin among the green-colored populations. The population collected from spinach, YS95, was significantly most susceptible, and RL95 was least susceptible to lambda-cyhalothrin relative to the other green-colored populations evaluated.

Similarly, to dimethoate and lambda-cyhalothrin, red-colored green peach aphids had a tendency to be less susceptible to endosulfan than green-colored (Table 3). However, the red-colored TL96 population did not significantly differ from the green-colored TL96 population, nor did the green-colored TL96 populations significantly differ from the red RL95 population. Among the green-colored populations, the YS96 and the TL96 populations were significantly most and least susceptible to endosulfan, respectively. Among the red populations evaluated, YC95 was significantly most resistant.

There were few differences among aphid populations in response to imidacloprid (Table 3). However, the YS95 population was significantly more susceptible to this insecticide than any of the other populations evaluated. There were no detectable differences in response to imidacloprid among the remaining aphid populations, nor was there any clear evidence for cross resistance between imidacloprid and the other insecticides. Because imidacloprid had not been used in Arizona produce crops prior to 1995, we did not expect to detect any differences in tolerance to this insecticide. Although there has been no aphid control failures in produce crops treated with imidacloprid, a 4 to 5-fold difference in tolerance indicates that there is potential for selecting more tolerant green peach aphids. Unlike dimethoate, lambda-cyhalothrin and endosulfan, resistance to imidacloprid was not more pronounced in the red-colored aphids than in green aphids. This suggests that differences in susceptibility to imidacloprid does not involve mechanisms linked with color. Additionally, because imidacloprid tolerance was greater in aphids collected from cabbage or lettuce than from spinach, tolerance may be influenced by host.

Resistance to organophosphate, carbamate and pyrethroid insecticides in green peach aphid is common, and has been attributed to increased levels of a single carboxylesterase (E4) which express activity towards a broad range of insecticides (Devonshire and Sawicki 1979, Devonshire and Moores 1982). Although, the relationship between red-colored green peach aphids and insecticide resistance has not previously been documented, it has been reported for a similar aphid species. Harlow and Lampert (1990) classified tobacco aphids from North Carolina into three resistance categories based on their color and response to malathion resistant red-colored, resistant green-colored and susceptible green-colored aphids. They reported that red-colored tobacco aphids were consistently 3.3 to 4.3-fold more resistant than a susceptible population. Because we did not make comparisons to a known insecticide-susceptible population, we cannot definitively determine the magnitude of the resistances detected. However, the YS95 population had the lowest LC_{50} values for lambda-cyhalothrin, endosulfan and imidacloprid. Designating YS95, as an insecticide-susceptible population for comparison reasons, statistically significant resistance ratios for dimethoate range from 3.41 to 3.68-fold, similar to malathion resistant ratios reported for tobacco aphid (Harlow and Lampert 1990). Dimethoate and malathion belong to the same organophosphate sub-class, phosphorodithioate (Ware 1994), which may explain the similarity in response.

In red-colored tobacco aphids, insecticide resistance has been attributed to a single resistance-associated esterase (RAE), 1-napthyl acetate esterase (Wolff et al. 1994). RAE from tobacco aphid and E4 from green peach aphid have identical molecular weights and isoelectric points, suggesting structural similarity between these two proteins (Wolff et al. 1994). The cross resistance between dimethoate, lambda-cyhalothrin and endosulfan is consistent with the activity of carboxylesterase E4, but may also suggest the presence of multiple mechanisms of resistance. Although carboxylesterase E4 affects a broad range of insecticides, it appears to have highly specific binding requirements. Carboxylesterase E4 hydrolyzes the (1*S*)*trans* enantiomer of permethrin but has no activity on (1*RS*)*cis*-permethrin, and only 50% hydrolysis of (1*RS*)*trans*-permethrin (Devonshire and Moores 1982). Lambda-cyhalothrin is composed of *cis* isomers; green peach aphids have been reported to express resistance to *cis* isomers of other pyrethroids, but resistance was not attributed to increased expression of carboxylesterase (Büchi 1981). In Washington State, there is evidence that multiple mechanisms of resistance may exist in green peach aphid. Although high levels of carboxylesterase E4 have been detected in populations of green peach aphid, resistance to endosulfan resistance did not appear to involve carboxylesterase E4 (Unruh et al. 1996).

Based on our data, we cannot be certain of the mechanism of insecticide resistance in green peach aphid infesting Arizona produce crops. However, it is certain that significant differences in insecticide susceptibility exists. Arizona growers and pest control advisors should avoid using dimethoate, lambda-cyhalothrin or endosulfan when treating green peach aphid populations with substantial numbers of the red-colored form. Additionally, although soil applications of imidacloprid appear to be highly effective in controlling green peach aphid in produce (Palumbo and Kerns 1995, Natwick et al. 1996), and no control failures have been reported, the fact that we detected differences in tolerance to imidacloprid suggests that developing resistance is a distinct possibility. Efforts should be made to find alternatives to imidacloprid for aphid control in produce to reduce selection pressure.

Literature Cited

Anonymous 1992. Integrated pest management for cole crops and lettuce. Univ. Calif. Statewide IPM Proj., Publication 3307. 112 pp.

Blackman, R. L. 1987. Morphological discrimination of a tobacco-feeding form from *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), and a key to New World *Myzus* (*Nectarosiphon*) species. Bull. Entomol. Res. 77: 713-730.

Blackman, R. L. , and V. F. Eastop. 1984. Aphids on World's Crops: An Identification Guide. John Wiley & Sons, New York. 406 pp.

Büchi, R. 1981. Evidence that resistance against pyrethroids in aphids *Myzus persicae* and *Phorodon humuli* is not correlated with high carboxylesterase activity. Z. Pflanzenkrankheiten Pflanzenschutz 88: 631-643.

Devonshire, A. L., and G. D. Moores. 1982. A carboxylesterase with broad substrate specificity causes organophosphorus, carbamate and pyrethroid resistance in peach-potato aphids *(Myzus persicae)*. Pest. Biochem. Physiol. 18: 235-246.

Devonshire, A. L., and R. M. Sawicki. 1979. Insecticide-resistant *Myzus persicae* as an example of evolution by gene duplication. Nature (Lond.) 280: 140-141.

Georghiou, G. P. 1963. Comparative susceptibility to insecticides of two green peach aphid populations, collected 16 years apart. J. Econ. Entomol. 56: 655-657.

Harlow, C. D., and E. P. Lampert. 1990. Resistance mechanisms in two color forms of the tobacco aphid (Homoptera: Aphididae). J. Econ. Entomol. 83: 2130-2135.

Hinsch, R. T., P. V. Vail, J. S. Tebbets, and D. F. Hoffman. 1991. Live insects and other arthropods on California iceberg head and shredded lettuce. Southwest. Entomol. 16: 261-266.

Mackauer, M., and M. J. Way. 1976. *Myzus persicae* Sulz., an aphid of world importance, pp. 51-119. *In* V. Delucchi [ed.], Studies in Biological Control. Cambridge University Press, Cambridge.

Markkula, M., and J. Rautapää. 1967. The effect of light and temperature on the colour of the English grain aphid, *Macrosiphum avenae* (F.) (Hom., Aphididae). Annales Entomologici Fennici. 33: 1-13.

McClanahan, R. J., and J. Founk. 1983. Toxicity of insecticides to the green peach aphid (Homoptera: Aphididae) in laboratory and field tests, 1971-1982. J. Econ. Entomol. 76: 899-905.

Metcalf, R. L. 1986. The ecology of insecticides and the chemical control of insects, pp. 251-297. *In* M. Kogan [ed.], Ecological Theory and Integrated Pest Management Practice. John Wiley & Sons, New York.

Miyata, T. 1983. Detection and monitoring for resistance in arthropods based on biochemical characteristics, pp. 99-116. *In* G. Georghiou and T. Saito [eds], Pest Resistance to Pesticides. Plenum Press, New York.

Miyazaki, M. 1987. Forms and morphs of aphids, pp. 27-50. *In* A. Minks and P. Harrewijn [eds.], Aphids, Their Biology, Natural Enemies and Control, Vol. 2A. Elsevier, Amsterdam.

Natwick, E. T., J. C. Palumbo, and C. E. Engle. 1996. Effects of imidacloprid on colonization of aphids and silverleaf whitefly and growth, yield and phytotoxicity in cauliflower. Southwest. Entomol. 21: 283-292.

Palumbo, J. C., and D. L. Kerns. 1994. Effects of imidacloprid as a soil treatment on colonization of green peach aphid and marketability of lettuce. Southwest. Entomol. 19: 339-346.

Quaglia, F., E. Rossi, R. Petacchi, and C. E. Taylor. 1993. Observations on an infestation by green peach aphids (Homoptera: Aphididae) on green house tomatoes in Italy. J. Econ. Entomol. 86: 1019-1025.

Reid, Jr., W. J. and F. P. Cuthbert, Jr. 1977. Aphids of leafy vegetables. USDA-ARS Bull. No. 2148. 27 pp.

SAS Institute Inc. 1989. SAS/STAT User's Guide, Ver. 6, Fourth Ed., Vol. 2. SAS Institute Inc., Cary, North Carolina, 846 pp.

Sudderuddin, K. I. 1973. Studies of insecticide resistance in *Myzus persicae* (Sulz.0 (Hem., Aphididae). Bull. Entomol. Res. 62: 533-539.

Takada, H., 1981. Inheritance of body colour in *Myzus persicae* (Sulzer) (Homoptera: Aphididae). App. Entomol. Zool. 16: 557-573.

Unruh, T., A. Knight, and M. R. Bush. 1996. Green peach aphid (Homoptera: Aphididae) resistance to endosulfan in peach and nectarine orchards in Washington State. J. Econ. Entomol. 89: 1067-1073.

Ware, G. W. 1994. The Pesticide Book, 4th Ed. Thomson Publications, Fresno, CA. pp. 386.

Wolff, M. A., Y. A. I. Abdel-Aal, D. K. S. Goh, E. P. Lampert, and R. M. Roe. 1994. Organophosphate resistance in the tobacco aphid (Homoptera: Aphididae): purification and characterization of a resistance-associated esterase. J. Econ. Entomol. 87: 1157-1164.

TABLE 1. Dose-Response Curves of Green Peach Aphids to Three Organophosphate Insecticides.[a]

		Acephate			Dimethoate			Mevinphos		
Population	Color	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)
YC95	green	213	1.05 (0.39)	414.40 (168.81-651.90)	234	3.69 (0.48)	1,297 (1,118-1,472)	338	4.34 (0.59)	678.19 (623.04-743.08)
YC95	red	223	1.87 (0.40)	464.42 (348.39-589.17)	266	2.78 (0.43)	4,152 (3,509-4,800)	240	2.00 (0.39)	435.22 (311.80-541.21)
RL95	green	234	3.36 (0.45)	388.82 (327.16-447.62)	236	3.56 (0.47)	1,345 (1,161-1,530)	239	4.92 (0.57)	486.25 (429.19-542.34)
RL95	red	234	3.09 (0.43)	377.81 (312.96-436.46)	274	2.15 (0.40)	4,275 (3,438-5,125)	240	3.56 (0.45)	556.06 (479.82-633.15)
YS95	green	239	2.48 (0.41)	356.02 (276.28-427.26)	240	2.12 (0.31)	1,162 (899.07-1,433)	238	5.13 (0.68)	532.14 (481.88-582.44)
TL96	green	236	3.67 (0.47)	389.77 (333.25-444.33)	239	3.93 (0.49)	1,247 (1,084-1,407)	237	4.29 (0.51)	509.36 (444.85-572.63)
TL96	red	239	3.30 (0.45)	348.29 (288.55-403.47)	269	2.68 (0.43)	3,957 (3,285-4,595)	235	3.81 (0.48)	622.38 (543.19-704.55)
RL96	green	234	3.51 (0.45)	405.45 (345.83-463.94)	240	3.86 (0.50)	1,145 (982.90-1,298)	235	4.23 (0.50)	492.79 (429.93-554.86)

[a]Populations within an insecticide that have LC_{50}s with overlapping 95% confidence limits are not significantly different.

TABLE 2. Dose-Response Curves of Green Peach Aphids to Two Pyrethroid Insecticides.[a]

		Bifenthrin			Lambda-cyhalothrin		
Population	Color	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)
YC95	green	234	1.81 (0.24)	69.09 (50.71-89.25)	222	3.46 (0.48)	1,287 (1,116-1,479)
YC95	red	237	1.74 (0.32)	71.41 (52.52-91.24)	211	3.11 (0.61)	7,135 (5,404-8,409)
RL95	green	233	1.88 (0.25)	62.87 (46.32-80.88)	277	4.21 (0.54)	5,967 (5,198-6,665)
RL95	red	236	1.80 (0.24)	82.44 (62.08-106.06)	237	3.76 (0.54)	8,040 (6,916-9,087)
YS95	green	311	1.40 (0.21)	53.01 (33.48-72.43)	235	2.84 (0.43)	481.13 (390.62-565.26)
TL96	green	240	1.64 (0.24)	79.57 (57.98-104.09)	238	3.63 (0.46)	1,068 (920.67-1,214)
TL96	red	239	1.36 (0.23)	88.93 (61.72-121.92)	230	3.79 (0.65)	6,936 (5,628-7,939)
RL96	green	236	2.12 (0.26)	68.71 (53.06-86.20)	224	2.41 (0.44)	866.71 (640.30-1,057)

[a]Populations within an insecticide that have LC_{50}s with overlapping 95% confidence limits are not significantly different.

TABLE 3. Dose-Response Curves of Green Peach Aphids to a Cyclodiene and a Chloronicotynl Insecticide.[a]

		Endosulfan			Imidacloprid		
Population	Color	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)	*n*	Slope (±SE)	LC_{50} (ppm) (95% CL)
YC95	green	238	4.20 (0.57)	1,323 (1,178-1,479)	223	2.13 (0.40)	44.98 (32.96-55.65)
YC95	red	234	4.23 (0.63)	6,912 (6,144-7,681)	235	2.57 (0.42)	45.42 (35.58-54.25)
RL95	green	274	4.45 (0.56)	1,508 (1,325-1,671)	240	2.86 (0.43)	40.79 (32.23-48.33)
RL95	red	307	5.74 (0.72)	2,843 (2,614-3,046)	236	2.12 (0.40)	45.09 (32.97-55.58)
YS95	green	239	2.09 (0.32)	173.39 (125.65-218.25)	238	2.18 (0.34)	9.27 (7.00-11.46)
TL96	green	268	4.32 (0.56)	2,252 (2,042-2,678)	219	2.24 (0.41)	45.75 (34.30-56.14)
TL96	red	318	5.90 (0.72)	2,764 (2,542-2,957)	233	2.51 (0.42)	37.16 (27.50-45.32)
RL96	green	280	3.89 (0.52)	1,656 (1,455-1,841)	227	2.83 (0.42)	44.27 (35.46-52.23)

[a]Populations within an insecticide that have LC_{50}s with overlapping 95% confidence limits are not significantly different.