Phytophagous Preferences of the Multicolored Asian Lady Beetle (Coleoptera: Coccinellidae) for Autumn-Ripening Fruit

R. L. KOCH,[1] E. C. BURKNESS, S. J. WOLD BURKNESS, AND W. D. HUTCHISON

Department of Entomology, 219 Hodson Hall, 1980 Folwell Avenue, University of Minnesota, St. Paul, MN 55108

J. Econ. Entomol. 97(2): 539–544 (2004)

ABSTRACT The objective of this study was to assess the potential pest status of *Harmonia axyridis* (Pallas) on autumn-ripening fruit. In autumn, *H. axyridis* has been observed feeding on pumpkins, apples, grapes, and raspberries in Minnesota. To determine whether *H. axyridis* can inflict primary feeding damage to fruit (i.e., breaking the skin of the fruit), we conducted laboratory feeding experiments with undamaged pumpkins, apples, grapes, and raspberries. The only fruit that *H. axyridis* was able to damage directly was raspberry. Laboratory choice tests were conducted to determine whether *H. axyridis* exhibits a preference between damaged and undamaged fruit, between cultivars of fruit, and between sugar water and water alone. For all fruits tested, *H. axyridis* showed a preference for damaged fruits over undamaged fruits. *H. axyridis* also exhibited a strong preference for sugar water over water alone. However, few differences were exhibited in preference between cultivars of fruit. In autumn, it seems that *H. axyridis* is an opportunist, taking advantage of previously damaged fruit, caused by other agents.

KEY WORDS *Harmonia axyridis*, apple, grape, raspberry, pumpkin

THE MULTICOLORED ASIAN LADY beetle, *Harmonia axyridis* (Pallas), was released into North America for classical biological control (Gordon 1985). In its native Asian range, *H. axyridis* is a well-known predator of aphids and other small soft-bodied pests (Yasumatsu and Watanabe 1964, Hukusima and Kamei 1970, Wang 1986). In North America, *H. axyridis* has proven effective at mitigating some pest problems, such as the pecan aphid complex (Tedders and Schaefer 1994).

Unfortunately, the introduction of *H. axyridis* into North America may result in adverse impacts to the environment and humans. Evidence is accumulating to indicate that *H. axyridis* may be adversely impacting native coccinellids (Cottrell and Yeargan 1998, Michaud 2002). Koch et al. (2003) also identified *H. axyridis* as a potential hazard to immature monarch butterflies, *Danaus plexippus* L., developing in agricultural systems. Humans have been adversely affected by *H. axyridis* through the tendency of the beetle to form fall aggregations on homes and other buildings (Kidd et al. 1995, Huelsman et al. 2002). Subsequent entry of *H. axyridis* into homes through cracks or holes may result in a nuisance for homeowners (Huelsman et al. 2002). Furthermore, some people have developed an allergic rhinoconjunctivitis from exposure to *H. axyridis* (Yarbrough et al. 1999). Finally, *H. axyridis* has attained status as a potential pest in fruit production (Koch 2003). Despite numerous extension fact sheets addressing the issue of *H. axyridis* as a potential pest to fruit production (Ratcliffe 2002), we are unaware of any published data confirming *H. axyridis* feeding activity on damaged or undamaged fruit.

In Minnesota, we have observed *H. axyridis* adults feeding on pumpkins, apples, grapes, and raspberries in autumn (Koch and Hutchison 2003a; R.L.K. unpublished data). However, the ability of *H. axyridis* to inflict primary feeding damage to these fruits (i.e., breaking the skin of the fruits) has remained uncertain. The blossoming wine-making industry in Minnesota is seriously threatened by *H. axyridis.* Adult *H. axyridis* are difficult to remove from clusters of grapes during harvest. Subsequently, some *H. axyridis* may be processed with the grapes, resulting in unmarketable, tainted wine (Ejbich 2003). The objective of these studies was to assess the pest potential of *H. axyridis* to autumn-ripening fruit, such as raspberries, grapes, apples, and pumpkins. We conducted laboratory feeding studies on undamaged fruit, as well as choice tests between previously damaged and undamaged fruit, between popular Minnesota cultivars of fruit, and between sugar water and water alone.

Materials and Methods

Undamaged Fruit Feeding Studies. To determine whether *H. axyridis* can cause feeding damage to pumpkins, apples, grapes, and raspberries, we conducted feeding studies with undamaged fruit in the laboratory. In 2002, individual small pumpkins ('Magic

[1] E-mail: koch0125@umn.edu.

Lantern') with unbroken skins were placed into 14-liter clear plastic containers (Sterilite, Townsend, MA). Twenty-five *H. axyridis* adults were then released into each container with pumpkins. The undamaged pumpkin feeding study was replicated in eight plastic containers. Pumpkins were checked for feeding damage after 72 h. The pumpkin feeding study was started on 1 October. For raspberries, two berries (proprietary cultivar, Driscoll's, Watsonville, CA) with no apparent surface damage were placed into 100 by 15-mm petri dishes. Five *H. axyridis* adults were released into each petri dish with raspberries. The undamaged raspberry feeding study was replicated in 15 petri dishes. Raspberries were checked for damage after 48 h. The raspberry feeding study was started on 6 October. *H. axyridis* adults used in the pumpkin and raspberry feeding studies were collected on 1 October from exterior walls of storage sheds at the Rosemount Research and Outreach Center, University of Minnesota, Rosemount, MN. For grapes, groups of three berries ('Crimson Seedless') with unbroken skins and stems attached were placed into 1.96-liter plastic containers (Pioneer Plastics, Inc., Dixson, KY). Twenty *H. axyridis* adults were then released into each plastic container with grapes. The undamaged grape feeding study was replicated in five plastic containers. Grapes were checked for feeding damage after 72 h. Individual apples ('Honeycrisp') with unbroken skins were placed into 14-liter Sterilite plastic containers. Twenty *H. axyridis* adults were released into each plastic container with apples. The apple feeding study was replicated in five plastic containers. Apples were checked for feeding damage after 72 h. The apple and grape feeding studies were started on 8 November. *H. axyridis* adults used in the grape and apple feeding studies were collected on 7 November from the same location as beetles used in the pumpkin and raspberry feeding studies.

In 2003, *H. axyridis* adults used in the undamaged fruit feeding studies were collected on 26 September with a sweep net from soybean, *Glycine max* (L.) Merr., at the research farm where *H. axyridis* were collected in 2002. Individual pumpkins ('We-Be-Little') and apples ('Fireside') with unbroken skins were placed into separate 1.96-liter plastic containers (Pioneer Plastics, Inc.). Twenty *H. axyridis* adults were then released into each plastic container with apples or pumpkins. The pumpkin and apple feeding studies were replicated in three and five containers, respectively. Pumpkins and apples were checked for damage after 72 h. The apple and pumpkin feeding studies were started on 27 and 28 September, respectively. For the grape feeding studies, two cultivars ('Frontenac' and 'St. Pepin') were tested separately. Groups of three berries with stems attached and unbroken skins were placed into 100 by 15-mm petri dishes with filter paper. Five *H. axyridis* adults were then released into each petri dish with grapes. Each grape cultivar was replicated in 10 petri dishes, and checked for damage after 72 h. 'Frontenac' and 'St. Pepin' grape feeding studies were started on 27 and 29 September. Pairs of raspberries, one 'Heritage' and one 'Kiwi Gold,' with no apparent surface damage were placed into 100 by 15-mm petri dishes with filter paper. Five *H. axyridis* adults were then released into each petri dish with raspberries. The pairs of raspberries were replicated in 10 petri dishes. Raspberries were checked for feeding damage after 48 h. The raspberry feeding study was started on 27 September. For 2002 and 2003, all undamaged fruit feeding studies were conducted on a laboratory bench at temperatures ranging from 25 to 27°C with constant light.

Choice Test Feeding Studies. To determine whether *H. axyridis* adults show any preference between damaged and undamaged fruit, we conducted laboratory choice test feeding studies. In 2002, we tested damaged versus undamaged grapes and apples. Two groups of three grapes ('Crimson Seedless') were placed at opposite ends of 14-liter Sterilite plastic containers. One of the groups of grapes in each container was damaged by punching one 0.75-cm-diameter hole ≈0.25 cm in depth into each grape. The other group of grapes in each container remained undamaged. Six *H. axyridis* adults were then released into each container with grapes. The damaged versus undamaged grape choice test was replicated in ten containers. After 2, 6, and 28 h, the number of *H. axyridis* on each group of grapes was recorded. Two apples ('Honeycrisp') were placed at opposite ends of 14-liter Sterilite plastic containers. One of the apples in each container was damaged by punching six 0.75-cm holes ≈0.25 cm in depth. The other apple in each container remained undamaged. Six *H. axyridis* were then released into each container. The damaged versus undamaged apple choice test was replicated in 10 containers. After 2, 6, and 28 h, the number of *H. axyridis* on each apple was recorded. The damaged versus undamaged grape and apple choice test feeding studies were started on 8 November, by using beetles that were collected on 7 November from the exterior walls of storage sheds near Rosemount, MN.

In 2003, we tested damaged versus undamaged raspberries, grapes, and apples. *H. axyridis* adults used in the damaged versus undamaged fruit choice test studies were obtained as in the 2003 undamaged fruit feeding studies, except *H. axyridis* used in the apple choice test were collected on 29 September. Damaged fruit and undamaged fruit were placed at opposite ends of 5.7-liter Sterilite plastic containers. For raspberries and grapes, groups of three berries were used. One group of berries from each container was damaged by repeatedly pinching approximately a 1-cm^2 area at the tip of each berry with a forceps. The other group of berries in each container remained undamaged. For apples ('Fireside'), damage was created as in the 2002 damaged versus undamaged apple study. Ten *H. axyridis* were then released into each container with raspberries, grapes, or apples. The damaged versus undamaged choice tests for raspberries, grapes, and apples were each replicated in ten containers. After 2, 6, and 24 h, the number of *H. axyridis* on damaged and undamaged fruits was recorded. The damaged versus undamaged grape, raspberry, and apple choice test feeding studies were started on 27, 28, and 29 September, respectively, by using beetles collected on 26 September from soybean near Rosemount, MN.

In 2003, to determine whether *H. axyridis* adults show any preference between cultivars of damaged raspberries, grapes, and apples, we conducted laboratory choice test feeding studies. *H. axyridis* used in the cultivar choice test studies were collected as in the other 2003 laboratory feeding studies, except *H. axyridis* used in the apple choice test were collected on 29 September. For raspberries and grapes, two groups of three damaged berries were placed into 5.7-liter Sterilite plastic containers. The fall-ripening raspberry (primocane-bearing) cultivars 'Heritage' and 'Kiwi Gold' were compared, and the grape cultivars 'Frontenac' and 'St. Pepin' were compared. Berries were damaged as in the 2003 damaged versus undamaged fruit choice tests. The apple cultivars 'Haralson' and 'Fireside' were compared. One damaged apple from each cultivar was placed into each 5.7-liter Sterilite plastic container. Apples were damaged as in the 2002 damaged versus undamaged apple choice tests. Ten *H. axyridis* were then released into each container. Each of these choice test studies was replicated in ten containers. At 2, 6, and 24 h, the number of *H. axyridis* on each cultivar was recorded. The raspberry, apple, and grape cultivar choice test feeding studies were started on 27, 28, and 29 September.

To determine whether *H. axyridis* exhibits a preference between sugar water and water alone, we conducted a choice test feeding experiment. Bottoms of two 60 by 15-mm petri dishes were placed at opposite ends of 5.7-liter Sterilite plastic containers. One-half of a cotton prepping ball (Kendall Curity, Mansfield, MA) was placed into each petri dish bottom. The cotton in one petri dish from each container was wetted with 8 ml of a 20% (by mass) solution of granular sugar (American Crystal Sugar Company, Moorhead, MN) in deionized water. Cotton in the other petri dish was wetted with 8 ml of water. Ten *H. axyridis* adults were then released into each container. The sugar water versus water choice test was replicated in 15 containers. At 2, 6, and 24 h, the number of *H. axyridis* in each dish was recorded. *H. axyridis* used in the sugar water versus water choice test were collected as in the apple choice test studies of 2003. The sugar water versus water choice test was started on 1 October. All choice test feeding studies were conducted on a laboratory bench at temperatures ranging from 25 to 27°C with constant light. The side of the container into which each choice was placed was randomized for each replication.

Measurement of Soluble Solids and Titratable Acidity. In 2003, soluble solids (i.e., sugar content) of apples ('Fireside' and 'Haralson') and raspberries ('Heritage' and 'Kiwi Gold') were measured using a handheld refractometer. Soluble solid values in °Brix provide an industry standard estimate of sugar content (El-Shiekh et al. 2002). A small piece was cut from each apple and manually squeezed to produce juice for the measurement. Measurements were taken from 10 'Fireside' and six 'Haralson' apples. For raspberries, groups of four berries were crushed with a mortar and pestle. This product was centrifuged to separate the juice from the rest of the berry. Measurements were taken from five groups of four berries for 'Heritage' and 10 groups of four berries for 'Kiwi Gold' raspberries. For grapes, soluble solids and titratable acidity were measured by the wine makers at the Horticultural Research Center, University of Minnesota.

Data Analysis. For the 2003 undamaged raspberry feeding study, a two-sample t-test on the mean difference in percentage of berries with damage for 'Heritage' versus 'Kiwi Gold' was used to test for any preference between these two cultivars. The mean difference was compared with zero, which would indicate no preference. For all choice test feeding studies, data were analyzed by time period by using a two-sample t-test on the mean difference between the number of *H. axyridis* on one choice versus the other choice. The mean difference was compared with zero, which would indicate no preference (Koch et al. 2004).

Results

Undamaged Fruit Feeding Studies. *H. axyridis* adults did not cause any obvious feeding damage to pumpkins, apples, or grapes. However, *H. axyridis* did cause obvious feeding damage to raspberries. In 2002, 73% of replications for the proprietary raspberry cultivar had obvious feeding damage. In 2003, 70 and 40% of the replications for 'Heritage' and 'Kiwi Gold' raspberries, respectively, had obvious feeding damage. The percentage of replications with damage to 'Heritage' versus 'Kiwi Gold' did not differ significantly (t = 1.96, df = 9, P = 0.08). Damage to raspberries seemed to be localized to individual drupelets and was characterized as small punctures in the drupelet, a hole in the drupelet and the drupelet being hollowed out, or a shriveled appearance of the drupelet. Damage to raspberries ranged from only one to seven drupelets damaged per berry. Feeding on raspberries was further evidenced by reddish purple stains on the filter paper under the feces of the beetles.

Choice Test Feeding Studies. Significantly more *H. axyridis* adults were found on damaged fruit compared with undamaged fruit for all observation times of all cultivars of fruit (Table 1). For apples, after 2 h, significantly more *H. axyridis* adults were found on 'Fireside' compared 'Haralson' (Table 2). The difference in the abundance of *H. axyridis* on 'Fireside' compared with 'Haralson' apples decreased through time; the difference was only marginally significant at 6 h and was not significant at 24 h (Table 2). For grapes, no significant differences were found in the abundance of *H. axyridis* between cultivars (Table 2). For raspberries, significantly more *H. axyridis* were found on 'Kiwi Gold' at 6 h (Table 2). At all observation times, the difference in the abundance of *H. axyridis* in dishes with sugar water compared with water was highly significant, with *H. axyridis* preferring sugar water (Table 2).

Table 1. Mean abundance of adult *H. axyridis* on damaged and undamaged fruits in a laboratory choice test, 2002–2003

Fruit	Cultivar	Year	Time postinfestation (h)	Damaged Mean ± SEM	Undamaged Mean ± SEM	t^a	df	*P*
Apple	'Honeycrisp'	2002	2	2.4 ± 0.34	0.1 ± 0.10	6.27	9	0.0002
			6	2.1 ± 0.35	0.4 ± 0.22	3.15	9	0.012
			28	1.6 ± 0.40	0.3 ± 0.21	2.90	9	0.017
	'Honeycrisp'	2003	2	3.2 ± 0.55	0.2 ± 0.13	6.06	9	0.0002
			6	5.0 ± 0.37	0.2 ± 0.13	11.52	9	<0.0001
			24	3.1 ± 0.64	0.3 ± 0.15	5.05	9	0.0007
Grape	'Crimson Seedless'	2002	2	1.5 ± 0.40	0.2 ± 0.13	3.07	9	0.013
			6	1.2 ± 0.29	0	4.13	9	0.0026
			28	1.5 ± 0.45	0	3.31	9	0.0091
	'Frontenac'	2003	2	4.3 ± 0.37	0.1 ± 0.10	10.80	9	<0.0001
			6	6.6 ± 0.50	0.1 ± 0.10	14.33	9	<0.0001
			24	5.3 ± 0.47	0.3 ± 0.15	11.17	9	<0.0001
Raspberry	'Heritage'	2003	2	5.5 ± 0.62	0.3 ± 0.15	8.26	9	<0.0001
			6	6.1 ± 0.57	0.4 ± 0.22	9.85	9	<0.0001
			24	4.2 ± 0.53	0.5 ± 0.17	6.39	9	<0.0001

[a] Two-sample *t*-test on the mean difference between the number of *H. axyridis* on damaged and undamaged fruit. The mean difference was compared to zero, which would indicate no preference.

Measurement of Soluble Solids and Titratable Acidity. The concentration of soluble solids (i.e., primarily sugar concentration) was greater in 'Fireside,' 14.4 °Brix, compared with 'Haralson' apples, 11.8 °Brix. The amount of soluble solids was similar between 'Heritage,' 14.0 °Brix, and 'Kiwi Gold' raspberries, 13.8 °Brix. For grapes, the concentration of soluble solids of 'St. Pepin' and 'Frontenac' was 22.5 and 23.5 °Brix, respectively. Titratable acidity for 'St. Pepin' and 'Frontenac' was 0.94 and 1.43%, respectively.

Discussion

In North America, *H. axyridis* seems to be bivoltine (LaMana and Miller 1996, Koch and Hutchison 2003b). In autumn, adults of the second generation of *H. axyridis* seek out overwintering locations (LaMana and Miller 1996). A period of time may exist between the crash of summer aphid populations and the movement of *H. axyridis* to overwintering locations, when food is scarce for *H. axyridis.* In times of food shortage, phytophagous behaviors have been observed for aphidophagous coccinellids. For example, in early spring, *Adalia bipunctata* (L.) will feed on pollen before the buildup of aphid populations (Hemptinne and Desprets 1986). Similarily, *H. axyridis* has been documented feeding on pollen and nectar (Hukusima and Itoh 1976, LaMana and Miller 1996). The phenomenon of fruit feeding is not limited to *H. axyridis.* In Europe, fruit feeding has been documented for *Coccinella septempunctata* L. on pears and peaches, and *A. bipunctata* on cherries and plums (Hodek and Honêk 1996).

The fruit-feeding behavior of *H. axyridis* may be a strategy for attaining simple carbohydrates before overwintering. We found that *H. axyridis* exhibited a strong preference for sugar water compared with water alone (Table 2). This preference for sugar water indicates that *H. axyridis* is not just looking for moisture in autumn but that *H. axyridis* is seeking simple carbohydrates. The preference for sugar may explain some of the differences seen in our choice tests with different fruit cultivars. In the apple cultivar choice test, 'Fireside', which had a higher concentration of soluble solids (i.e., sugar concentration) than 'Haralson' (El-Shiekh et al. 2002), was more preferred by *H. axyridis* (Table 2), whereas the cultivars of the

Table 2. Mean abundance of adult *H. axyridis* on different damaged fruit cultivars, and 20% sugar water versus water, 2003

Choices	Time postinfestation (h)	Choice 1 Mean ± SEM	Choice 2 Mean ± SEM	t^a	df	*P*
Apple: 'Fireside' vs. 'Haralson'	2	4.4 ± 0.40	2.1 ± 0.41	3.14	9	0.012
	6	4.5 ± 0.58	2.4 ± 0.45	2.24	9	0.052
	24	2.7 ± 0.30	3.5 ± 0.52	−1.44	9	0.18
Grape: 'St. Pepin' vs. 'Frontenac'	2	3.5 ± 0.56	3.2 ± 0.51	0.33	9	0.75
	6	3.6 ± 0.60	3.0 ± 0.47	0.69	9	0.51
	24	3.1 ± 0.43	3.2 ± 0.36	−0.14	9	0.89
Raspberry: 'Kiwi Gold' vs. 'Heritage'	2	2.8 ± 0.39	1.9 ± 0.41	1.33	9	0.22
	6	3.8 ± 0.39	2.0 ± 0.37	3.04	9	0.014
	24	2.5 ± 0.50	2.4 ± 0.52	0.12	9	0.91
water + sugar vs. water	2	5.7 ± 0.43	0.1 ± 0.09	11.15	14	<0.0001
	6	8.4 ± 0.38	0.1 ± 0.07	21.57	14	<0.0001
	24	5.4 ± 0.47	0	11.59	14	<0.0001

[a] Two-sample *t*-test on the mean difference between the number of *H. axyridis* on the first choice and the second choice. The mean difference was compared to zero, which would indicate no preference.

other fruit crops had very similar concentrations of soluble solids, and little difference in preference was observed (Table 2). However, for apples and other fruits, sugar content may not be the only variable influencing the preference of *H. axyridis.* For example, the acidity of apples varies greatly between cultivars. The titratable acidity (percentage of malic acid) of 'Haralson' is more than twice that of 'Fireside' (El-Shiekh et al. 2002). Further research is needed to elucidate the factors influencing the preference of *H. axyridis* for several fruits.

Our results indicate that with the exception of raspberries, *H. axyridis* is unable to inflict primary feeding damage (i.e., breaking the skin of the fruit) to fruits, such as pumpkin, apples, and grapes. The skins of these fruits may be too tough for *H. axyridis* to penetrate with its mandibles or provide insufficient feeding stimuli on the unbroken surfaces of the fruits. However, if another agent damages the fruits, *H. axyridis* is attracted to the wounded tissue and feeds. For example, feeding by wasps (e.g., Vespidae) and birds may cause breaks in the skin of fruits, such as grapes and apples (Chang 1968, Boudreau 1972, Tobin et al. 1989). Furthermore, physiological processes, such as excessive absorption of water through roots or osmotic absorption of water through the skin of the fruit, may also break the skin of fruits (Opara et al. 1997). For crops such as pumpkins, apples, and grapes, if the presence of *H. axyridis* on the ripening fruit is not tolerated, control measures may be taken against the agents that cause the primary feeding damage to fruit in an attempt to reduce the number of wounds that may attract *H. axyridis.* Heavy infestations of *H. axyridis* on fruit such as raspberries, which can be directly damaged by *H. axyridis,* may necessitate use of a short residual insecticide. Given the high value of fruit crops, insecticide use may seem to be an attractive option. However, there is a paucity of data to support the use of insecticides as an effective control tactic for *H. axyridis* on fruit. Further work is needed to evaluate the efficacy of insecticides and other control tactics for *H. axyridis* in various fruit systems.

Acknowledgments

We thank P. Hemstad (University of Minnesota), D. Bedford (University of Minnesota), and J. Jacobson (Pine Tree Apple Orchard) for sharing their opinions with us about the potential pest status of *H. axyridis* on fruits, and for providing fruit for our experiments. We also thank C. Tong (University of Minnesota) and J. Luby (University of Minnesota) for assistance in measuring soluble solids and titratable acidity. We are grateful to J. Luby and E. Hodgson (University of Minnesota) for reviewing earlier versions of this paper. This research was funded by the University of Minnesota Doctoral Dissertation Fellowship Program, and the University of Minnesota Experiment Station.

References Cited

Boudreau, G. W. 1972. Factors related to bird depredations in vineyards. Am. J. Enol. Viticult. 23: 50–53.

Chang, S. C. 1968. The wasps destructive to pears and apple fruits in Taiwan. Plant Prot. Bull. Taiwan 10: 49–51.

Cottrell, T. E., and K. V. Yeargan. 1998. Intraguild predation between an introduced lady beetle, *Harmonia axyridis* (Coleoptera: Coccinellidae), and a native lady beetle, *Coleomegilla maculata* (Coleoptera: Coccinellidae). J. Kans. Entomol. Soc. 71: 159–163.

Ejbich, K. 2003. Producers in Ontario and northern U.S. bugged by bad odors in wine. Wine Spectator 15 May: 16.

El-Shiekh, A. F., C.B.S. Tong, J. J. Luby, E. E. Hoover, and D. S. Bedford. 2002. Storage potential of cold-hardy apple cultivars. J. Am. Pomol. Soc. 56: 34–45.

Gordon, R. D. 1985. The Coleoptera (Coccinellidae) of America north of Mexico. J. N.Y. Entomol. Soc. 93: 1–912.

Hemptinne, J. L., and A. Desprets. 1986. Pollen as a spring food for *Adalia bipunctata,* pp. 29–35. *In* I. Hodek [ed.], Ecology of Aphidophaga. Dr. W. Junk, Dordrecht, The Netherlands.

Hodek, I., and A. Honêk. 1996. Ecology of Coccinellidae. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Huelsman, M. F., J. Kovach, J. Jasinski, C. Young, and D. Eisley. 2002. Multicolored Asian lady beetle (*Harmonia axyridis*) as a nuisance pest in households in Ohio, pp. 243–250. *In* Proceedings of 4th International Conference on Urban Pests, Charleston, SC, 7–10 July 2002. Pocahontas Press Inc., Blacksburg, VA.

Hukusima, S., and K. Itoh. 1976. Pollen and fungus as food for some coccinellid beetles. Res. Bull. Fac. Agric. Gifu Univ. 39: 31–37.

Hukusima, S., and M. Kamei. 1970. Effects of various species of aphids as food on development, fecundity and longevity of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). Res. Bull. Fac. Agric. Gifu Univ. 29: 53–66.

Kidd, K. A., C. A. Nalepa, E. R. Day, and M. G. Waldvogel. 1995. Distribution of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in North Carolina and Virginia. Proc. Entomol. Soc. Wash. 97: 729–731.

Koch, R. L. 2003. The multicolored Asian lady beetle, *Harmonia axyridis*: a review of its biology, uses in biological control, and non-target impacts. J. Insect Sci. 3: 1–16 (http://www.insectscience.org/3.32).

Koch, R. L., and W. D. Hutchison. 2003a. Multicolored Asian lady beetle. Vegetable pest fact sheets, VegEdge Web site, Dept. of Entomology, University of Minnesota Extension Service, St. Paul, MN (http://www.vegedge.umn.edu/vegpest/harmonia/harmonia.htm).

Koch, R. L., and W. D. Hutchison. 2003b. Phenology and blacklight trapping of the multicolored Asian lady beetle (Coleoptera: Coccinellidae) in a Minnesota agricultural landscape. J. Entomol. Sci. 38: 477–480.

Koch, R. L., E. C. Burkness, and W. D. Hutchison. 2004. Confirmation of bean leaf beetle (Coleoptera: Chrysomelidae) feeding on cucurbits. J. Insect Sci. 4: 1–6 (http://www.insectscience.org/4.5).

Koch, R. L., W. D. Hutchison, R. C. Venette, and G. E. Heimpel. 2003. Susceptibility of immature monarch butterfly, *Danaus plexippus* (Lepidoptera: Nymphalidae: Danainae), to predation by *Harmonia axyridis* (Coleoptera: Coccinellidae). Biol. Control 28: 265–270.

LaMana, M. L., and J. C. Miller. 1996. Field observations on *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) in Oregon. Biol. Control 6: 232–237.

Michaud, J. P. 2002. Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea.* Environ. Entomol. 31: 827–835.

Opara, L. U., C. J. Studman, and N. H. Banks. 1997. Fruit skin splitting and cracking. Hort. Rev. 19: 217–262.

Ratcliffe, S. 2002. National pest alert: multicolored Asian lady beetle. U.S. Dep. Agric. CSREES Regional Integrated Pest Management Program and the Pest Mangement Centers (http://www.pmcenters.org/northcentral/MALB/).

Tedders, W. L., and P. W. Schaefer. 1994. Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the southeastern United States. Entomol. News 105: 228–243.

Tobin, M. E., R. A. Dolbeer, and P. P. Woronecki. 1989. Bird damage to apples in the mid-Hudson Valley of New York. HortScience 24: 859.

Wang, L. Y. 1986. Mass rearing and utilization in biological control of the lady beetle *Leis axyridis* (Pallas). Acta Entomol. Sinica 29: 104.

Yarbrough, J. A., J. L. Armstrong, M. Z. Blumberg, A. E. Phillips, E. McGahee, and W. K. Dolen. 1999. Allergic rhinoconjunctivitis caused by *Harmonia axyridis* (Asian lady beetle, Japanese lady beetle, or lady bug). J. Allergy Clin. Immunol. 104: 705.

Yasumatsu, K., and C. Watanabe. 1964. A tentative catalogue of insect natural enemies of injurious insects in Japan – Part 1. Parasite-predator host catalogue. Entomological Laboratory, Faculty of Agriculture Kyushu University, Fukuoka, Japan.

Received 13 October 2003; accepted 9 December 2003.