Evaluation of New Approaches for Management of Japanese Beetles in Highbush Blueberries

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SUMMARY. The Japanese beetle, *Popillia japonica*, can be a pest of highbush blueberries because of direct feeding on berries and leaves, and the risk of contaminating harvested fruit. To determine where beetles are most abundant and whether cultural controls have potential for use against *P. japonica* in blueberry, soil was sampled for grubs during 2001 and 2002 in and around fifteen blueberry fields. Densities of

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overwintering *P. japonica* were greater under permanent sod outside fields than in the soil between the rows. When grub density inside the fields was compared between clean-cultivated rows and those with sodded row middles, cultivated rows had significantly lower grub densities than those with sod. Bioassays with pyrethrum insecticides against adult beetles indicated their potential for removal of beetles from bushes just prior to harvest. An integrated strategy including elimination of suitable habitat by cultivation and use of chemical controls to remove beetles before harvest is under development for reducing populations and minimizing contamination of blueberry by this pest.

KEYWORDS. Japanese beetle, *Popillia japonica*, blueberry, cultural control, integrated pest management

INTRODUCTION

The Japanese beetle, *Popillia japonica* Newman (Coleptera: Scarabaeidae) was introduced accidentally from Japan to the eastern coast of North America in 1916 (Fleming, 1972). Since its arrival in southern New Jersey, this mobile insect has gradually increased in geographic distribution. *P. japonica* has become established as far west as Minnesota and Kansas (Anonymous, 2000) and has been sporadically detected and eradicated in some western US states (Fleming, 1972; Potter and Held, 2002). Adult beetles can cause extensive feeding damage to a broad range of ornamental and fruit plants by feeding on their leaves and fruit (Fleming, 1972; Potter and Held, 2002), and this species has become a major pest of managed turf due to the preference of larval stages (grubs) for feeding on grass roots (Vittum et al., 1999). Beetles can cause feeding damage on leaves and ripe berries of highbush blueberries, *Vaccinium corymbosum* L. if other plants are not present. However, it is the presence of adult beetles on plants at harvest that is of greatest concern, due to the risk of contamination of harvested berries.

Japanese beetles were first detected in Michigan in the early 1930s near Detroit and even though early eradication programs included lead arsenate applications at 1000 pounds per acre, the beetle has increased in range and is now found throughout the lower tier of Michigan (Cappaert and Smitley, 2002), including some regions with highbush blueberry production. Insecticide applications continue to be the foundation of management strategies for Japanese beetle in blueberries and many other fruit crops, as growers strive to meet the market's demand for contamination-free fruit. Broad-spectrum insecticides are effective against beetles that are treated directly (Wise and Isaacs, unpublished data), but most of these products have long pre-harvest intervals creating a potential for immigrating beetles to re-infest fields as residue activity declines. Over 70% of Michigan's 7,285 ha (18,000 acres) of blueberry is harvested mechanically, and because beetles can be present on bushes at the time of harvest, strategies that eliminate the risk of adult beetles contaminating the fruit are needed.

Conditions in and around crop fields can favor development of this insect if primary requirements for Japanese beetle population development are met (Vittum et al., 1999). Ground covers of seeded grass or the naturally-invading mix of grass and broadleaved weeds are commonly used in blueberry fields to maintain soil structure, provide conditions for agricultural machinery to drive across during wet conditions, and reduce soil erosion. Japanese beetle grubs feed on the roots of grasses and some broadleaved weeds (Crutchfield and Potter, 1995) and blueberry fields often have areas with these ground covers within and around the bushes. In addition, sufficient soil moisture for development of first instar grubs is present in many commercial blueberry fields in July and August because of natural rainfall and irrigation, and soil temperatures above -9.4°C in winter allow grub survival. These conditions are not unique to Michigan, and Japanese beetle has become established in most of the eastern US states (Allsopp, 1996). Although biological control agents could provide population suppression, a recent survey indicates that natural enemies are at extremely low levels in the Michigan population of Japanese beetle (Cappaert and Smitley, 2002), compared to those found in areas near to the original site of introduction. This is presumably because native and introduced biological control agents have yet to become established in this leading edge of the beetle's expanding geographic distribution.

Use of a short-lived insecticide with rapid 'knock-down' activity, such as a pyrethrum may be an effective approach for removing live beetles from bushes immediately before harvest. Extracted from chrysanthemum flowers, pyrethrums create immediate paralysis in treated insects, causing them to drop from plants (Casida and Quistad, 1995). With their short residual activity combined with minimal pre-harvest and re-entry restrictions, pyrethrums may provide growers with a tool for meeting the target of insect-free fruit, even in situations where immigrating Japanese beetles are challenging the performance of broad-spectrum insecticides.

Recent experience indicates that one-dimensional strategies based solely on conventional insecticides may not be an effective long-term approach for achieving the required pest management goals for Japanese beetle in blueberry. The combination of market demands and pest abundance makes it imperative that management strategies include approaches for reduction of overall beetle populations. An integrated Japanese beetle management program should include (1) consideration of the surrounding habitat as part of the production system, (2) reducing the attraction of blueberry crop habitats to adult beetles, (3) establishing a suppressive habitat for grub development, (4) use of effective insecticides at the appropriate time in the production cycle, and (5) optimizing post-harvest beetle removal. Biological control should also be included as part of a long-term strategy, and future introductions may be one approach to aid in the long-term suppression of populations of *P. japonica* within the blueberry production landscape.

As part of our research toward developing the integrated program outlined above, this study aimed to determine the relative abundance of Japanese beetles in and around blueberry fields. Within fields, the effect of tillage for control of Japanese beetle was determined by comparing grub abundance in row middles that were rotovated with those covered by permanent sod. In addition, we report on bioassays to compare the activity of biological insecticides that can be applied immediately before harvest to remove beetles from bushes before harvest.

MATERIALS AND METHODS

Grub sampling. During April 2001 and May 2002, soil samples were taken at 15 commercial blueberry farms in southwest Michigan (in Allegan, Berrien, Muskegon, Ottawa, and Van Buren counties) to evaluate the density of Japanese beetle larvae. Soil was sampled to 15 cm depth from the perimeter and from row middles at each of the farms using a golf cup cutter (10 cm^2 area). Eighty perimeter samples were taken from between the edge of the blueberry field and the woods. To sample grubs within each field, a row was selected at random from each of ten equal sections across the field width. Within each selected row, grubs were sampled from the mid-point of the row middle, at six positions spaced along the length of the field. Soil cores were examined in the field for white grubs, and all grubs were placed in plastic bags with a small amount of soil and transported back to the laboratory for species identification using the diagnostic rastral pattern in which Japanese beetle has 14 or fewer hairs in a V-shaped pattern near the anus (Vittum et al., 1999). The number of Japanese beetle grubs was recorded and the number per unit area was calculated for each sample. Data were analyzed to compare abundance in the interior and the perimeter of the fields. Row middle samples were analyzed separately to compare larval densities in rotovated and sodded row middles. Due to the non-normality of the data, statistical comparisons were made using a Mann-Whitney U test.

Bioassays. To test the effect of pyrethrin insecticides on Japanese beetle, blueberry shoots were cut from untreated *V. corymbosum* cv. Rubel bushes at the Trevor Nichols Research Complex, Fennville, MI (TNRC), and brought to the laboratory. Shoots were adjusted to a standard size of 10 leaves and 5 berries, and these were treated by spraying to runoff with aqueous solutions of either Pyganic EC 1.4 (1.4% pyrethrum) or Evergreen EC 60-6 (6% pyrethrum and 60% piperonyl butoxide). Solutions were prepared to be equivalent to a 0.473 L/ha rate of Pyganic (16 oz/acre) or 0.118 L/ha of Evergreen (4 oz/acre), to provide nearly equivalent rates of active ingredient in the two solutions (7% difference). Solutions of these insecticides were prepared at the appropriate rate, placed into spray bottles, and mixed thoroughly before application. After shoots were treated to runoff, they were shaken to remove excess solution, then placed into bioassay chambers (1.8 L plastic cups with ventilation holes in the wall) containing 5 cm depth of floral oasis on the bottom that was covered with paraffin wax. Adult beetles were collected during the two hours prior to bioassays from an unsprayed grassy field at TNRC using baited Japanese beetle traps (Trecé Inc., Salinas, CA). Beetles were then held on blueberry foliage in a ventilated container until needed. Ten beetles were placed in the bottom of each chamber immediately after foliage was in place, and the cups were sealed with a lid punctured with holes for ventilation. The beetles' position and behavior within the chamber was observed after 1, 24, and 120 hours of exposure. Beetles were scored for mobility, and whether they exhibited sub-lethal toxicity symptoms. After the 120 h observations, chambers were opened, and visual assessments were made of feeding damage by the beetles to foliage and fruit, using 5% increments. Bioassay data were analyzed by analysis of variance on arcsine transformed percentages, followed by Fisher's protected least square difference test to compare between treatments.

RESULTS AND DISCUSSION

A majority of the blueberry fields at farms in this study had a mix of grass and broad leaf weeds in the row middles, showing that this is a common ground cover in Michigan blueberry fields where Japanese beetle is reported. All sampled blueberry fields were surrounded by grass or a grass-weed mix in the area where spraying and harvesting machinery are driven. These fields varied in whether rotovated soil or permanent sod was between the rows of blueberry bushes. Soil sampling for Japanese beetle grubs within and around blueberry fields showed that grub abundance was significantly greater in the ground cover surrounding fields than in the row middles inside fields (Table 1). A similar pattern of greater grub abundance outside managed fields was documented in ornamental crops by Smitley (1996) and in soybean and cornfields by Hammond and Stinner (1987). Grass is the optimal habitat for survival of Japanese beetle grubs, and female beetles select grassy areas near their feeding sites for egglaying (Fleming, 1972). In the absence of grass, grubs can survive on a diet of weeds, though they perform less well (Crutchfield and Potter, 1995). Because of this, the presence of a grass and weed mix ground cover around all fields is a significant risk factor for Japanese beetle infestation. In a recent study of movement by Japanese beetles, recapture of marked beetles released from the surrounding headlands was greatest on nearby blueberry border rows, indicating that some beetles do not move far into fields once an acceptable plant host has been found (Z. Szendrei, unpublished data). This further indicates the importance of removing habitats suitable for grub development near to blueberry fields to minimize the risk of beetle immigration into fields.

When grub abundance was compared between samples taken from rotovated row middles and those covered permanently with plant cover,

TABLE 1. Abundance of Japanese beetle grubs (average grubs per square meter ± S.E.) in soil samples taken from the perimeter and from the row middles of blueberry fields (n = 15) during spring 2001 and 2002. Values in a column are not significantly different if followed by the same letter ($P \leq 0.05$).

Sampling position	Spring 2001	Spring 2002
Field perimeter	44.45 ± 8.07 a	28.95 ± 5.06 a
Row middle	11.03 ± 3.44 b	10.33 ± 4.52 b

grubs were significantly more abundant in the latter habitat (Table 2). At rotovated sites, row middles were kept without any ground cover by using mechanical soil management techniques. Row middles that were rotovated as a cultural control had over 90% fewer Japanese beetle grubs in the soil during 2001 when the study started. During 2001-2, some of the study sites that had previously had permanent sod were changed to clean cultivation by the growers, although some weeds remained in these transitional sites. Because of this, the difference was not as great between the row middle types as previously found, though the difference remained significant (Table 2). Using a similar control strategy, Chittenden (1916) showed that cultural disruption of the rosechafer, *Macrodactylus subspinosus*, during the pupation period led to significant control of this pest in vineyards. The relative impact of direct mortality from rotovation and from removal of host plants remains to be determined. Previous studies have reported that cultivation causes significant mortality of eggs (Smith, 1924) and grubs (Cory and Langford, 1955; Smith, 1924) of Japanese beetle, though the impact of host plant removal on Japanese beetle oviposition remains unknown. Timing of rotovation for maximum impact on this pest has been reported to be in the early fall and late spring when grubs are near the surface (Fleming, 1976), and curative management may require tillage at both timings.

Permanent removal of host plants is a potentially effective strategy for reducing beetle infestation, but negative horticultural impacts may reduce the likelihood of adoption. Bare ground can be wet in spring, preventing tractor access to the field, and bare ground can be dusty at the time of harvest, potentially reducing fruit quality. In addition, erosion and pesticide leaching are also likely to be greater when soil is cultivated (Elliot et al., 2000). Rather than constant clean cultivation, acid-tolerant cover crops are a potential method of maintaining soil structure after tillage. Although the impact of planted cover crops on

TABLE 2. Abundance of Japanese beetle grubs (average grubs per square meter ± S.E.) in row middles that had permanent plant cover or were rotovated to create clean cultivation, during spring 2000 and 2001. Values in a column are not significantly different if followed by the same letter ($P < 0.05$).

Row middle type	Spring 2001	Spring 2002
Permanent sod	16.36 ± 4.63 a	11.84 ± 0.65 a
Clean cultivation	1.08 ± 0.43 b	8.93 ± 0.11 b

Japanese beetle is not well understood (Potter and Held, 2002), variation in grub abundance under different plant covers has been reported (Hawley, 1944), indicating that this could be exploited to reduce beetle abundance within and around blueberry fields. Planting cover crops in blueberry row middles is currently under evaluation to provide a component of a sustainable approach to Japanese beetle control in blueberries by targeting the most vulnerable stages of this insect's life cycle.

Application of soil insecticides to infested grassy areas within the blueberry field is an alternative non-cultural control approach for grub control, and various insecticides have been shown to have activity against Japanese beetle in nursery crops (Mannion et al., 2001) and turf (Potter, 1998). New selective insecticides such as imidacloprid from the neonicotinoid class show promise because of their high activity against young grubs of Japanese beetle and their relatively low environmental impact (Potter and Held, 2002), though registration is still pending for use in blueberry.

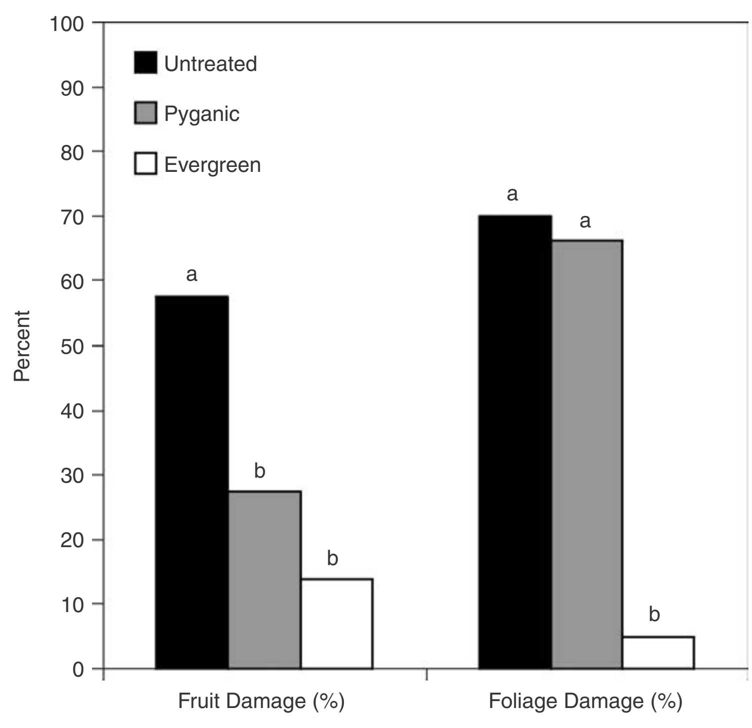
Both pyrethrum insecticide formulations tested caused over 90% of beetles to drop from the blueberry foliage within one hour after application (Table 3). However, after 24 h, beetles had recovered from exposure to the Pyganic treatment, whereas the effect of the Evergreen treatment remained. Five days after exposure to the residues, the activity of both treatments had declined to the point where only 20% of beetles were immobile in the containers containing Pyganic-treated foliage, compared to over 50% in the Evergreen treated foliage. This greater activity of Evergreen compared to Pyganic, and its extended period of activity, was likely caused by the presence of piperonyl butoxide rather than the difference in amount of active pyrethrum because there was only a 7% difference in the rates of pyrethrum between the two treatments. Although there was no significant difference between the insecticide treatments on the number of beetles found alive on the container, the numeric values increased over time, becoming twice as large after 120 h on the untreated and Pyganic-treated containers than in containers with Evergreen-treated shoots, suggesting that there is some difference in the rate of recovery by adult beetles from the two treatments. The number of live beetles on blueberry shoots were significantly reduced by the initial application of both pyrethrum compounds, and no beetles were found on the shoots within 1 and 24 h after application. After 5 d of exposure to the residues, a small number of beetles had begun to move back onto the foliage, though there was still no significant difference between the treatments tested.

TABLE 3. Response of adult Japanese beetle to residues of two pyrethrum insecticides on blueberry foliage, at different times after initial exposure. Data are average percent beetles observed in the different categories of mortality and sub-lethal response at 1, 24, and 120 hours after initial exposure.

Treatment	Rate (L/Ha)	Immobile on container			Live on the container			Live on the plant		
		1 h	24 h	120 h	1 h	24 h	120 h	1 h	24 h	120 h
Untreated	0	0.0 ± 0.0 b	12.5 ± 12.5 b	0.0 ± 0.0 a	5.0 ± 2.9 a	2.5 ± 2.5 a	65.0 ± 17.6 a	95.0 ± 2.9a	72.5 ± 24.3 a	35.0 ± 17.6 a
Pyganic	0.473	92.5 ± 4.8 a	27.5 ± 13.8 b	25.0 ± 15.0 a	0.0 ± 0.0 a	2.5 ± 2.5 a	65.0 ± 21.8 a	0.0 ± 0.0b	0.0 ± 0.0 b	2.5 ± 2.5 a
Evergreen	0.118	97.5 ± 2.5 a	82.5 ± 7.5 a	52.5 ± 13.8 b	0.0 ± 0.0 a	0.0 ± 0.0 a	27.5 ± 4.8 a	0.0 ± 0.0b	0.0 ± 0.0 b	7.5 ± 4.8 a

In addition to the direct effects on the beetles, fruit treated with both pyrethrum formulations received significantly less damage after 5 d of exposure to beetles than did the untreated fruit (Figure 1). Although the reason for this result is not known, only Evergreen was able to protect the foliage over this same period, while the level of beetle feeding on leaves was not significantly affected by residues of Pyganic. During the 5 d of exposure, more beetles were observed to recover from their initial sub-lethal knockdown symptoms after exposure to the Pyganic-treated, compared to the Evergreen-treated foliage (Table 3). These end-point results show that addition of the agonist piperonyl butoxide is an important component of effectively using pyrethrums for control of *P. japonica* and protection of the crop from feeding damage. From data presented

FIGURE 1. Percent feeding (by area) on foliage and fruit of blueberry treated either with Pyganic, Evergreen, or a water only control after five days of exposure to ten Japanese beetles. Damage to fruit or foliage was significantly different between treatments ($P \leq 0.05$) if bars are topped by different letters.



above, formulations that contain piperonyl butoxide are expected to provide the required short-term protection against beetle presence if applied the day before harvest, and trials are underway at commercial farms to verify this expectation under field conditions.

CONCLUSION AND GROWER BENEFITS

Effective in-field management of Japanese beetle in highbush blueberry requires that growers implement an integrated strategy across their farms. This should include attention to areas around and within fields that have habitat for Japanese beetle grub development. It is expected that this will have the double benefit of reducing the pest pressure and enabling foliar insecticides to perform more effectively due to the lower levels of beetle immigration. Use of foliar treatments for adult control should remain a component of this integrated strategy, with selection of pyrethrum products or other insecticides with short pre-harvest intervals if beetles must be removed from the bushes prior to harvest. Although not discussed above, post-harvest strategies for removing contaminants are an additional step that should be considered to ensure that growers can meet the market's demand for contaminant-free berries.

LITERATURE CITED

Allsopp, P.G. 1996. Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae): Rate of movement and potential distribution of an immigrant species. The Coleopt. Bull. 50: 81-95.

Anonymous 2000. National Agricultural Pest Information System: Japanese beetle (http://ceris.purdue.edu/napis/pests/jb/index.html).

Cappaert, D.L. and D.R. Smitley. 2002. Parasitoids and pathogens of Japanese beetle (Coleoptera: Scarabaeidae) in Southern Michigan. Environ. Entomol. 31: 573-580.

Casida, J.E. and G.B. Quistad. 1995. Pyrethrum flowers: Production, chemistry, toxicology and uses. Oxford Univ. Press, New York.

Chittenden, F.H. 1916. The rose chafer: A destructive garden and vineyard pest. USDA Farmer's Bull. 712: 1-8.

Cory, E.N. and G.S. Langford.1955. The Japanese beetle retardation program in Maryland. Maryland Univ. Ext. Bull. 156.

Crutchfield, B.A. and D.A. Potter. 1995. Feeding by Japanese beetle and southern masked chafer grubs on lawn weeds. Crop Sci. 35:1681-1684.

Elliott, J.A., A.J. Cessna, W. Nicholaichuk, and L.C. Tollefson. 2000. Leaching rates and preferential flow of selected herbicides through tilled and untilled soil. J. Environ. Quality 29:1650-1656.

Fleming, W.E. 1972. Biology of the Japanese beetle. USDA Tech. Bull. 1449. U.S. Gov. Print. Office, Washington, DC.

Fleming, W.E. 1976. Integrating control of the Japanese beetle–a historical review. USDA Tech. Bull. 1545. U.S. Gov. Print. Office, Washington, DC.

Hammond, R.B. and B.R. Stinner. 1987. Soybean foliage insects in conservation tillage systems: Effects of tillage, previous cropping history, and soil insecticide application. Environ. Entomol. 16:524-531.

Hawley, I.M. 1944. Notes on the biology of the Japanese beetle. U.S. Bur. of Entomol. Plant Quarratine E-615.

Mannion, C.M., W. McLane, M.G. Klein, J. Moyseenko, J.B. Oliver, and D. Cowan. 2001. Management of early instar Japanese beetle (Coleoptera:Scarabaeidae) in field-grown nursery crops. J. Econ. Entomol. 94:1151-1161.

Potter, D.A. 1998. Destructive turfgrass insects. Biology, diagnosis, and control. Ann Arbor Press, Chelsea, MI.

Potter, D.A. and D.W. Held. 2002. Biology and management of the Japanese beetle. Ann. Rev. Entomol. 47:175-205.

Smith, L.B. 1924. The Japanese beetle. New Jersey Dept. Agr. Bul. 41:55-63.

Smitley, D. 1996. Incidence of *Popillia japonica* (Coleoptera: Scarabidae) and other scarab larvae in nursery fields. Hort. Entomol. 89:1262-1266.

Vittum, P.J., M.G. Villani, and H. Tashiro. 1999. Turfgrass insects of the United States and Canada. Cornell University Press, Ithaca, NY.