Activity of conventional and reduced-risk insecticides for protection of grapevines against the rose chafer, *Macrodactylus subspinosus* (Coleoptera: Scarabaeidae)

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Abstract: Bioassays were conducted to compare the residual toxicity and leaf protection activity of conventional broad-spectrum and reduced-risk insecticides against the rose chafer, *Macrodactylus subspinosus*. Insecticides were applied to a *Vitis labrusca* (F.) vineyard and residues were aged for 1, 3 or 7 days before leaves were collected and exposed to beetles in no-choice tests. Azinphosmethyl caused rapid knockdown and mortality for up to 1 week after application, with 1-day-old residues providing 95.6% protection against feeding, dropping to 51.6% when residues were a week old. Fenpropathrin caused mortality and knockdown after beetles had been exposed to fresh residues for 72 h. Although these effects diminished as residues aged, this compound provided the best protection of leaves against beetle feeding, with 77.9% reduction in feeding compared with the control after 7 days of aging in the vineyard. Of the reduced-risk insecticides, imidacloprid caused the greatest initial mortality and knockdown of beetles, providing protection against feeding that was equivalent to azinphosmethyl. Exposure to azadirachtin caused a low level of knockdown and mortality when residues were 1- and 3-days old. Protection against feeding was also low, lasting for only 3 days. Beetles were minimally affected by capsaicin and kaolin, with mortality and knockdown seen only when beetles were exposed to 1-day-old residues for 72 h. Foliage protection from these compounds was minimal, with between 10 and 15% reduction in feeding injury. Results are discussed in relation to development of semi-field bioassay methods for evaluating reduced-risk insecticides, and the management of *M. subspinosus* within grape pest management programs.

Key words: beetle, bioassay, insecticide, knockdown, mortality, viticulture

1 Introduction

Sporadic outbreaks of insect pests in vineyards may require intervention to protect foliage and fruit from economic damage. The rose chafer, *Macrodactylus subspinosus*, is a univoltine scarab beetle that is a pest of many horticultural crops and flowers in eastern North America, particularly in areas with sandy soils (Chittenden, 1916; McLeod and Williams, 1990). Adult beetles emerge in the spring when grapevine clusters are in bloom and when foliage is tender during rapid growth. Because of their relatively thin leaves, vineyards of *Vitis vinifera* L. and hybrid grape varieties are at greater risk than *V. labrusca* L. vineyards, although clusters of all varieties are attacked. Abundance of this beetle varies greatly between years and from vineyard to vineyard, but vines with over 100 rose chafer beetles per plant have been observed (R. Isaacs, unpublished data), and in thin-leaved varieties this degree of pest pressure results in almost total loss of photosynthetically active leaf area. Recent studies on potted *V. labrusca* plants have shown that feeding early in the growing season by rose chafer can negatively affect subsequent root growth and can increase susceptibility of vines to injury by other foliar herbivores later in the growing season (Mercader and Isaacs, in press). When valuable parts of the crop are attacked by rose chafer, commercial fruit growers require insecticides that will provide protection from defoliation and fruit injury.

Conventional broad-spectrum insecticides such as carbamate and organophosphate compounds can provide good protection of grapevines from feeding by rose chafer and other insects (Williams, 1979; Wise et al., 2002). These neurotoxins have activity through contact and ingestion, and cause rapid knockdown and death in the target insects. Increased restrictions on insecticides in these classes are expected in grapes and other food crops in the United States because of implementation of the Food Quality Protection Act (FQPA) of 1996 by the US Environmental Protection Agency (US EPA). Revocation of some tolerances for use of insecticides in vineyards and extension of re-entry intervals for others are likely to limit the utility of these types of insecticides for this crop, where
hand labour activities are required at multiple stages throughout the growing season. New insecticide chemistries that are achieving registration within the current regulatory environment of the US EPA include compounds that are designated as ‘reduced-risk’ and that may reasonably be expected to result in one or more of: reduced pesticide risk to human health, reduced pesticide risk to non-target organisms, reduced potential for contamination of valued environmental resources, or broadened adoption of integrated pest management (IPM) (Anonymous, 1996). Reduced-risk insecticides generally have less immediate toxicity to pest insects than conventional insecticides, but they may have sublethal activity such as repellency or antifeedant effects. These types of insecticides are potential new tools for use against rose chafer and other insects in fruit crops because of their suitability for inclusion in IPM programs. Evaluation of these types of compounds is a priority for many pest management research programs in the United States because their use is likely to survive implementation of the FQPA.

This study compared conventional and reduced-risk insecticides registered for use in grapes to determine their immediate and residual activity against adult *M. subspinosus*, using a field based bioassay method recently reported by Liberd et al. (2003), which is similar to the bioassay method of Williams et al. (1990). We tested two conventional insecticides; azinphosmethyl, an organophosphate insecticide with broad activity against insect pests that is used widely in fruit crops and fenpropathrin, a pyrethroid insecticide and miticide recently registered for use on grapes with activity against a broad spectrum of insects as well as certain phytophagous and predaceous mites. Reduced-risk insecticides tested in this study included imidacloprid, capsaicin, azadirachtin, and kaolin clay. Imidacloprid is a neonicotinoid in the chloronicotinyl subclass, registered on US grapes for control of sucking insect pests such as leafhoppers, mealybugs, and aphids. The short duration of residue on the leaf surface results in low activity of this insecticide on pest insects than conventional insecticides, but they may have sublethal activity such as repellency or antifeedant effects. These types of insecticides are potential new tools for use against rose chafer and other insects in fruit crops because of their suitability for inclusion in IPM programs. Evaluation of these types of compounds is a priority for many pest management research programs in the United States because their use is likely to survive implementation of the FQPA.

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Percent mortality of adult rose chafer beetles after 24 or 72 h exposure to leaves with residues of different insecticides aged under vineyard conditions for 1, 3, or 7 days.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Age of residue (days)</th>
<th>1</th>
<th>3</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 h</td>
<td>72 h</td>
<td>24 h</td>
<td>72 h</td>
</tr>
<tr>
<td>Azinphosmethyl</td>
<td>69.0 ± 6.0 a</td>
<td>99.0 ± 1.0 a</td>
<td>9.0 ± 2.8 a</td>
<td>48.0 ± 9.8 a</td>
</tr>
<tr>
<td>Fenpropathrin</td>
<td>14.0 ± 3.4 b</td>
<td>53.0 ± 3.9 b</td>
<td>6.0 ± 3.4 a</td>
<td>21.0 ± 7.4 ab</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>8.0 ± 2.5 bc</td>
<td>38.0 ± 5.7 c</td>
<td>5.0 ± 1.7 ab</td>
<td>17.0 ± 3.7 ab</td>
</tr>
<tr>
<td>Azadirachtin</td>
<td>11.0 ± 3.5 c</td>
<td>57.0 ± 6.2 b</td>
<td>5.0 ± 2.7 ab</td>
<td>33.0 ± 8.9 ab</td>
</tr>
<tr>
<td>Capsaicin</td>
<td>3.0 ± 2.1 bc</td>
<td>30.0 ± 3.7 c</td>
<td>1.0 ± 1.0 ab</td>
<td>12.0 ± 2.9 b</td>
</tr>
<tr>
<td>Kaolin</td>
<td>5.0 ± 3.0 bc</td>
<td>42.0 ± 5.9 c</td>
<td>1.0 ± 1.0 ab</td>
<td>4.0 ± 1.6 b</td>
</tr>
<tr>
<td>Untreated</td>
<td>2.0 ± 1.3 c</td>
<td>14.0 ± 3.0 d</td>
<td>0.0 ± 0.0 b</td>
<td>18.0 ± 4.2 ab</td>
</tr>
</tbody>
</table>

Values are mean ± SE, and values within a column followed by the same letter are not significantly different (P < 0.05).
The area of leaf feeding by rose chafer beetles was reduced by insecticide treatments for each of the residue ages tested ($F_{6,63} > 12.21$, $P < 0.0001$), with some treatments providing long-term protection against defoliation (table 3). Feeding damage by rose chafer was reduced by over 90% in the presence of 1-day-old residues of azinphosmethyl, fenpropathrin, and imidacloprid, compared with the untreated leaves. When residues were 1-day old, leaves with kaolin or capsaisin residues had significantly less feeding damage than the untreated leaves but allowed greater feeding than leaves treated with azinphosmethyl, fenpropathrin, or imidacloprid. Thereafter, kaolin and capsaisin afforded no protection of leaves from feeding under these bioassay conditions. Azadirachtin residues provided some protection for the first 3 days, but their activity was gone by 1 week after application. The high degree of feeding protection afforded by 1-day-old residues of imidacloprid was much reduced by 3 days after application, and by 1 week after application, imidacloprid reduced feeding by 40.2% compared with the untreated leaves. Residues of azinphosmethyl maintained leaf protection for 7 days, as shown by a 51.6% reduction of feeding compared with the untreated. Fenpropathrin was the most consistently active residue for protecting leaves against feeding by rose chafer, providing 78% reduction of feeding damage after 7 days of aging under vineyard conditions.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Age of residue (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Azinphosmethyl</td>
<td>1.36 ± 1.78 d</td>
</tr>
<tr>
<td>Fenpropathrin</td>
<td>0.94 ± 0.97 d</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>3.81 ± 3.38 d</td>
</tr>
<tr>
<td>Azadirachtin</td>
<td>16.90 ± 2.67 c</td>
</tr>
<tr>
<td>Capsaisin</td>
<td>28.45 ± 4.52 b</td>
</tr>
<tr>
<td>Kaolin</td>
<td>26.82 ± 3.79 b</td>
</tr>
<tr>
<td>Untreated</td>
<td>39.15 ± 2.45 a</td>
</tr>
</tbody>
</table>
| Average area of grape leaves: 1 day: 154.45 ± 2.97 cm²; 3 day: 125.29 ± 1.87 cm²; 7 day: 158.13 ± 2.58 cm². | Values within a column followed by the same letter are not significantly different ($P < 0.05$).

4 Discussion

The relationships between mortality, knockdown and leaf feeding reported above provide insights into differences in activity characteristics of the insecticides tested, and provide information on potential options for control of rose chafer beetles in vineyards. Both the pyrethroid and the organophosphate insecticides provided a high degree of foliage protection, but they differed in how this effect was reached. Azinphosmethyl primarily caused mortality of beetles, which increased with the duration of exposure. Beetles in this treatment were observed to be exhibiting sublethal effects soon after their placement in the chamber. The volatility of this insecticide may have contributed to its high activity in the confines of the bioassay chamber. The combined effect of the mortality and knockdown resulted in little feeding on fresh residues, but as the residues aged and the immediate mortality declined, feeding levels increased. In contrast, the initial activity of fenpropathrin was primarily through strong knockdown activity, as reported for other pyrethroids against beetle pests (Pree et al., 1996). Beetles in this treatment were quickly affected by the fresh residues, and although the level of knockdown declined after 3 days of aging, beetles were still highly unlikely to feed on leaves that were treated 7–10 days earlier.

Imidacloprid was the most active reduced-risk insecticide tested, providing immediate and sustained mortality and knockdown, and protection of leaves from feeding. This product is currently used in grapes primarily for leafhopper control. However, because the perceived spectrum of activity for this insecticide is restricted to homopteran insects, it has been considered of limited use to grape growers seeking coincident protection against insects from different families. The activity against Coleoptera demonstrated here may provide for greater use of this reduced-risk insecticide rather than broad-spectrum alternatives in eastern US vineyards, particularly if antifeedant sublethal effects can achieve pest management goals (e.g. Nauen et al., 1998). The primary need may be around the time of bloom, when rose chafer and leafhoppers may require control at the same time. Additionally, vines in many areas of eastern North America are fed upon by adult Japanese beetles, Popillia japonica Newman, during periods when leafhoppers require control. Given the results presented here on a related member of the Melolonthinae, activity against Japanese beetles in vineyards would be expected. Recent bioassay and field evaluations in highbush blueberry, Vaccinium corymbosum, support this expectation, with foliar application of imidacloprid providing rapid knockdown and mortality followed by residual antifeedant activity (J. Wise and R. Isaacs, unpublished data). Imidacloprid and other neonicotinoids, such as acequinocid, that has recently received registration in US
grape production, are expected to play an expanded role in future viticultural crop protection, and may help minimize the ecological impact of pest management programs.

Azadirachtin’s activity against rose chafer for 1–3 days provides evidence that this biological insecticide can be incorporated into pest management programs for short-term activity against this pest. This was the most promising treatment that can be used in organic production, and although there was little evidence of knockdown activity, 1-day-old residues caused a moderate level of mortality and reduction in feeding damage. Antifeedant activity of this compound has been reported previously for other insects (Morde, and Blackwell, 1993; Morde et al., 1998; Enriz et al., 2000). The very low level of activity against the beetles exhibited by capsaicin and its minimal protection against feeding by adult beetles indicates that this is not an effective option for control of this pest. Capsaicin was also ineffective as an olfactory repellent against the cabbage maggot, Delia radicum, in trials where it was added to a physical barrier placed around the base of cabbage plants (Hoffmann et al., 2001).

Kaolin particle films have has been shown to be an effective alternative approach for some pest management needs (Glenn et al., 1999; Knight et al., 2000; Unruh et al., 2000), but results from our assays provided little evidence of activity against rose chafers. However, more repeated applications may be required to achieve sufficient coverage of the leaves to deter feeding by this pest, and the compound’s activity may be greater under field conditions where beetles can disperse from treated areas. Application of a coating to the plant may be expected to have detrimental horticultural impacts. Although benefits in terms of reduced sun scald and less overheating in fruit have been reported (Glenn et al., 2002), reduced carbon assimilation and yield have been found in apples treated with kaolin (Glenn et al., 2003). The short growing season and relatively low light intensity in many eastern US grape growing regions indicates that the horticultural effects of kaolin should be determined before widespread use of this product on grapes.

The vineyard-based bioassay approach described here, similar to that of Williams (1979), provided an effective method for comparison of lethal and sublethal activities of different insecticides against this pest, and should find utility for other crop–pest combinations. Conducting bioassays in this way, with controlled laboratory evaluation of mortality, knockdown and feeding on residues aged under field conditions provided insight into the activity characteristics of different compounds under evaluation. Azinphosmethyl provided the overall highest and consistent levels of lethal activity, but as residues aged in the field, longer exposure time and ingestion were increasingly important for causing beetle mortality. The lethal activity of fenpropatrin was comparatively short-lived, but its knockdown effect was significant across all of the aged residue tests. This finding, along with the consistently best protection from defoliation, suggests that the knockdown activity is caused by beetle contact with surface residues, rather than ingestion. The imidacloprid data trends suggest that freshly applied surface residues will kill the beetles before defoliation can occur, but later as residues are absorbed into the plant, ingestion is important to attaining lethal or sublethal responses. This also indicates that the beetle knockdown from imidacloprid is sublethal poisoning rather than true repellency. Capsaicin and kaolin provided limited lethal and sublethal activity and only after the maximum exposure periods. A similar trend in defoliation and knockdown data suggests that these compounds do not act as repellents to the rose chafer, but that ingestion may play a role in mortality. Although residues of azadirachtin were lethal only when 1-day old, knockdown effects persisted for up to 3 days. The high initial mortality required extended exposure and was accompanied by relatively high defoliation (compared with imidacloprid), suggesting that ingestion may be important for lethal activity.

If further restrictions on broad-spectrum insecticides are implemented for this sector of the US fruit industry, some of the reduced-risk insecticides tested here can be integrated into management programs to protect vines against defoliation by this pest when populations reach damaging levels.

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