Effect of Two Different Nozzle Arrangements on Control of Carrot Weevil, *Listronotus oregonensis* (LeConte), in Processing Carrots

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**Abstract**

Field studies were conducted during 2004-2005 at the Rutgers Agricultural Research and Extension Center, Bridgeton, NJ to determine the effect of two different nozzle arrangements on the control of the carrot weevil, *Listronotus oregonensis* (LeConte), in processing carrots (*Daucus carota* L.). Two drop nozzles per row directed at the base of the plant resulted in significantly fewer damaged carrots caused by carrot weevil feeding each year as compared with a single nozzle centered as a 15.2-cm band located 30.5 cm over the row. However, carrot weevil damage to carrots was high each year in all treatments even during and after multiple pesticide applications, suggesting that growers need to use other management tactics with their spray program. Crop rotation, weed control, and planting date may be as important as pesticide selection and application for effective management of the carrot weevil.

**Introduction**

The carrot weevil, *Listronotus oregonensis* (LeConte), is an important pest of carrots, *Daucus carota* L., in the northeastern United States (10). Adults overwinter in and near carrot fields where carrots were grown the previous year, emerging in late April to early May in New Jersey (9). The adults feed directly on the leaves and crowns of carrots, and females oviposit from the beginning of May until late June in carrot roots (9). Larvae tunnel extensively throughout the upper third of the roots (Fig. 1), damaging 80% or more of the carrots in untreated processing carrot fields (11). Pepper (7) reported two full broods with a partial third brood in northern New Jersey, and three full broods with a partial fourth in southern New Jersey.
Growers currently use multiple foliar sprays of either diazinon, esfenvalerate, cyfluthrin, or oxamyl, or a rotation of these, for control of carrot weevil. Control of the carrot weevil is difficult because the female deposits her eggs in cavities that she chews in the roots, thus eliminating the potential for larval control. Consequently, pesticide applications are directed at adult weevils to prevent or reduce oviposition. In New Jersey, most growers use a single nozzle over the row to deliver the spray when adult activity begins, and continue the sprays through mid-summer. However, during the past several years, carrot weevil damage has been increasing in New Jersey carrot farms, and damage has been as high as 90% loss on farms in Salem County (W. Kline, personal communication). These losses are partly due to the cancellation of broad-spectrum insecticides, such as parathion, azinphos-methyl, and phosmet during the early 1990s. Additional losses may also be due to failure in application equipment technology, where one nozzle over the row is ineffective in delivering a sufficient lethal dosage of pesticide spray to the base of the plant. As the carrot plant matures, the dense foliage may prevent the spray from reaching the soil at the base of the plant where the carrot weevil attacks the plant.

These trials were conducted to compare a single, over-the-row spray nozzle with a drop nozzle on each side of the row, directed at the base of the plant, for carrot weevil control in carrots.

Plant Propogation and Insecticide Application

‘Campbell’s SDC 1374’ carrots were seeded into a Sassafrass sandy loam (pH 5.9) field each year at the Rutgers Agricultural Research and Extension Center, Bridgeton, NJ with a JD Agricola Vacuum Seeder. Plots consisted of three rows of carrots, 38.1 cm apart, on a 1.5 m-wide bed that was 7.62 m long, replicated four times in a randomized complete block design. All rows were treated, but only the center row was used for data collection. All plots received a broadcast application of nitrogen at 67.2 kg/ha applied one week before planting, in the form of calcium nitrate and then incorporated into the soil. Calcium nitrate (136.1 kg/ha) was re-applied and incorporated approximately 4 and 6 weeks after planting each year. For weed control, trifluralin (Treflan, Dow Agrosciences, Indianapolis, IN) was applied pre-plant at a rate of 1.8 liter/ha, and linuron (Lorox, 1.12 kg/ha; Griffin LLC, Valdosta, GA) and sethoxydim (Poast, 1.17 liter/ha; Micro Flo Co., Memphis, TN) were applied post-emergence. The fungicides chlorothalonil (Bravo TM, Syngenta Crop Protection, Inc., Greensboro, NC) and maneb (Manzate F, Griffin LLC) were applied on a 7- to 10-day schedule in July and August, as per commercial recommendations for carrots grown in New Jersey (2). Treatments were nozzle arrangements, and consisted of either a single nozzle centered 30.5 cm over the row, or a drop nozzle on each side of the row with the nozzle directed at the base of the plant; the single nozzle was calibrated to deliver 308.7 liter/ha at 227.5 kPa, and the two drop nozzles were calibrated to deliver 617 liter/ha at 227.5 kPa, both nozzle arrangements applied at 3.2 kph. Plots were irrigated as needed with an overhead sprinkler.

Damage Assessments in 2004

Carrots were seeded on 22 April. Plots received either no pesticide application (the check plots), or the application of esfenvalerate (Asana XL, 0.7 liter/ha; E. I. du Pont de Nemours and Co., Wilmington, DE) on 2, 14 June and 2, 13, 26 July, and oxamyl (Vydate 2L, 4.7 liter/ha; E. I. du Pont de Nemours and Co.) on 22 June. On 28 May, 25 carrot seedlings in the center of each plot were counted and marked with a 15.2-cm wooden stake at the beginning and the end of those seedlings. The number of plants between the stakes was re-counted on 18 June to determine seedling loss. Twenty-five carrots from the center row of each plot were pulled on 14 July and again on 6 August, examined for carrot weevil injury, and the numbers of carrot-weevil damaged roots were recorded to determine percentage damaged carrots. Total weights of carrots from each treatment were recorded at harvest. Each year, the percentage damaged carrots were transformed using arcsine transformation before analysis. All data were
analyzed using a two-factor analyses of variance. Separation of the treatment means was determined by application of Tukey’s HSD Studentized Range Tests.

**Damage Assessments in 2005**

Carrots were seeded on 4 April. Plots received either no pesticide application, or applications of esfenvalerate (Asana XL, 0.7 liter/ha) on 7, 15 June, and 9 July, and oxamyl (Vydate 2L, 4.7 liter/ha) on 22 and 30 June. On 20 May, 25 carrot seedlings in the center of each plot were counted and marked with a 15.2-cm wooden stake at the beginning and the end of those seedlings. The numbers of plants between the stakes were re-counted on 1 July. Twenty-five carrots from the center row or each plot were pulled on 29 August, examined for carrot weevil injury, and the numbers of carrot-weevil damaged roots were recorded. Total weights of carrots for each treatment were recorded at harvest. Each year, the percentage damaged carrots were transformed using arcsine transformation before analysis. All data were analyzed using a two-factor analyses of variance. Separation of the treatment means was determined by application of Tukey’s HSD Studentized Range Tests.

**Insecticide Evaluations**

In both 2004 and 2005, the number of seedlings damaged early in the season (mid-June) by the carrot weevil was not significantly different ($F = 0.293, df = 2, P = 0.05$ and $F = 1.149, df = 2, P = 0.05$, respectively) among treatments (Tables 1 and 2). Carrot weevils are attracted to carrots when the plants reach the 6-leaf stage, but early damage is usually confined to slight minor feeding damage to the leaves and petioles (4). This damage would thus have little effect on yields as carrot roots are only starting to develop.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of seedlings per 25 ft</th>
<th>Percent CW-damaged carrots</th>
<th>Total yields per 25 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 nozzle, banded</td>
<td>22.8 ns</td>
<td>52.0 b</td>
<td>68.0 b</td>
</tr>
<tr>
<td>2 drop nozzles</td>
<td>23.8</td>
<td>22.0 a</td>
<td>33.0 a</td>
</tr>
<tr>
<td>Untreated check</td>
<td>24.0</td>
<td>66.0 b</td>
<td>78.0 b</td>
</tr>
</tbody>
</table>

Means within columns followed by the same letter or denoted ns are not significantly different (Tukeys HSD studentized test $P \leq 0.05$).

x 1 nozzle = 308.7 liter/ha at 227.5 kPa; 2 nozzles = 617 liter/ha at 227.5 kPa/ha.

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<th>Percent CW-damaged carrots</th>
<th>Total yields per 25 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 nozzle, banded</td>
<td>24.0 ns</td>
<td>89.8 b</td>
<td>23.2 ns</td>
</tr>
<tr>
<td>2 drop nozzles</td>
<td>24.5</td>
<td>73.5 a</td>
<td>23.8</td>
</tr>
<tr>
<td>Untreated check</td>
<td>23.0</td>
<td>94.2 b</td>
<td>21.6</td>
</tr>
</tbody>
</table>

Means within columns followed by the same letter or denoted ns are not significantly different (Tukeys HSD studentized test $P \leq 0.05$).

x 1 nozzle = 308.7 liter/ha at 227.5 kPa; 2 nozzles = 617 liter/ha at 227.5 kPa/ha.
In 2004, the percentage of damaged carrots was significantly (F = 19.870, df = 2, P = 0.05) lower in plots that were treated with a 2-nozzle sprayer as compared with the one-nozzle sprayer and the untreated (control) on each date recorded (Table 1); there were no significant differences for damaged carrots between the untreated check plots and the carrots that were treated with the one-nozzle sprayer on both sample dates recorded (Table 1). Damaged carrots in all plots were commercially unacceptable, and the damage increased from 14 July through 6 August by at least 11%, regardless of treatment, even though sprays were applied through 26 July. This suggests that inadequate control of the carrot weevil was obtained using esfenvalerate (0.7 liter/ha was applied to both insecticide-treated plots on 2, 13, and 26 July) with either one or two nozzles per row. However, laboratory assays and field trials have shown that the pyrethroids fenvalerate (8) and esfenvalerate (6) are toxic to adult carrot weevils. Anciso (1) reported that esfenvalerate has proven useful in managing a similar carrot weevil, *Listronotus texanus* (Stockton), in the field. The increase in damage during the scheduled sprays with esfenvalerate in our field trials suggests that the pesticide may not be penetrating the dense foliage of the carrots as well as desired. Increased volume and or pressure of the spray application may assist with this effort.

In 2005, carrot weevil pressure was extremely high, as shown by the percentage of damage to the carrots in the untreated plots (> 94% damage). Although damage was high in all plots (~ 94%, 90%, and 74% in the untreated, 1 nozzle and 2 nozzle plots, respectively), the plots treated with 2 nozzles per row had significantly (F = 18.895, df = 2, P = 0.05) less weevil damage than all other treatments.

In both years, there were no significant yield differences (total carrot weights) among plots (Tables 1 and 2). This is expected because carrots damaged by carrot weevils can still produce large carrots, although they may have extensive weevil tunneling within the root. Boivin (3) reported that adult feeding, oviposition punctures, and subsequent larval feeding of the carrot weevil in carrots did not decrease carrot stand significantly. Carrot weevil adults can feed on the seedlings in late spring, possibly resulting in yield losses, but the seedling count data shows that early weevil feeding on the seedlings was not significant in each year.

**Conclusions and Recommendations**

Our studies show that current grower spray applications using a single nozzle over the carrot row are not as effective in carrot weevil control as two drop nozzles directed at the base of the plant. However, multiple foliar sprays of insecticides using drop nozzles still resulted in high levels of carrot weevil damage at harvest, and growers will need to adopt other practices to reduce this damage. Boivin (3) reported that delayed planting reduced the number of carrot weevil eggs deposited in carrots. Grafius (5) stated that crop rotation combined with careful control of weed hosts, such as wild carrot (*Daucus carota* L.) is of great benefit in managing carrot weevil in carrots. Thus, a combination of delayed planting, crop rotation, weed control, and well-timed and directed insecticide sprays may be required to obtain effective management of the carrot weevil in New Jersey.

**Acknowledgments**

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Literature Cited