Effects of Foliar Surfactants on Host Plant Selection Behavior of Liriomyza huidobrensis (Diptera: Agromyzidae)

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**ABSTRACT**

The pea leafminer, *Liriomyza huidobrensis* (Diptera: Agromyzidae), is a highly polyphagous insect pest of global distribution. *L. huidobrensis* feeds and lays its eggs on leaf tissue and reduces crop marketability because of stippling and mining damage. In field insecticide trials, it was observed that stippling was reduced on plants treated with surfactant alone. The objectives of this study were to determine the effect of surfactants on host selection behaviors of female *L. huidobrensis* and to assess the phytotoxicity of two common surfactants to test plants. The application of the surfactant Sylgard 309 to celery (*Apium graveolens*) caused a significant reduction in stippling rates. The application of Agral 90 to cucumber leaves (*Cucumis sativus*) resulted in changes to the amount of effort invested by females in specific host plant selection behaviors, as well as causing a significant reduction in the amount of stippling damage. The recommended dose of Sylgard 309 does not induce phytotoxicity on celery over a range of age classes nor does Agral 90 cause a phytotoxic effect in 35-d-old cucumber. Thus, reductions in observed stippling and changes to host selection behaviors were caused by an antixenotic effect of the surfactant on *L. huidobrensis* rather than a toxic effect of the surfactant on the plant. The presence of surfactant on an otherwise acceptable host plant seems to have masked host plant cues and prevented host plant recognition. Results indicate that surfactants may be used to reduce leafminer damage to vegetable crops, potentially reducing the use of insecticides.

**KEY WORDS**

pea leafminer, Agral 90, Sylgard 309, preoviposition behaviors, antixenosis
trials, foliar applications of surfactants without an insecticide seemed to reduce stippling damage and impair normal host selection behaviors (Hallett et al. 2004). Surfactants lower the surface tension of a solvent and may be included as wetting agents in tank mixes of pesticide sprays to ensure proper foliar coverage (Jones and Atkins 2000). There are currently no known studies that specifically address the effect of surfactants on ovipositional behavior of L. huidobrensis. The objectives of this study, therefore, were to determine the effect of surfactants on host selection behaviors of female L. huidobrensis and to assess the phytotoxicity of surfactants on two host plants.

Materials and Methods

**Plants.** Celery and cucumber were selected for experimentation as representatives of field and greenhouse-grown vegetables, respectively, commonly infested by L. huidobrensis in Ontario. All cultivars used were obtained from Stokes Seeds (Thorold, Ontario, Canada). All plants were grown in Pro-Mix B (Premier Horticultural, Dorval, Quebec, Canada) and maintained at 25°C with a 16:8 light period and 50–70% RH. Celery cultivar Florida 683 was either seeded directly into 10-cm pots (experiments 1 and 2) or seeded in 128 cell plug trays and transplanted to 12.7-cm pots when seedlings reached ~8 cm in height (experiment 3). Cucumber cultivar Calypso 146A was grown in 128 cell plug trays and transplanted to 10-cm pots when seedlings reached ~5 cm in height (experiments 4–6). Plants were watered ad libitum and fertilized three times per week with 15–30–15 Miracle-Gro vegetable fertilizer (Miracle-Gro, Marysville, OH).

**Surfactants.** Surfactants were selected on the basis of the agricultural contexts in which they are registered for use in Canada. Sylgard 309 (siloxylated polyether 76%; Dow Corning Canada, Georgetown, Ontario, Canada) is registered for use with herbicides applied to field grown crops, i.e., including celery (Pest Management Regulatory Agency 2008b). Agral 90 (nonylphenoxypolyethoxyethanol 90%; Syngenta Crop Protection Canada, Guelph, Ontario, Canada) is registered for use with insecticides that are registered for use in greenhouse cucumbers (Pest Management Regulatory Agency 2008a). Neither surfactant had a detectable odor when applied to plants as described below.

**Insects.** Leafminers used in all experiments were obtained from a laboratory colony maintained according to procedures outlined in Martin et al. (2005). Four-day-old adults, reared primarily on lettuce (Lactuca sativa L. cultivar Ithaca M.I.), were used in experiments 1 and 2 (2004). Leafminers used in experiments 5 and 6 (2006–2007) were from colonies reared on lettuce, cucumber, peas (Pisum sativum L. cultivar Bolero), and Chinese broccoli (Brassica albo-lobra cultivar Guy Ron 422A). Three- to 4-d-old mated females (i.e., with abdomens visibly distended with eggs) were used in experiments 5 and 6.

**Experiment 1: Effect of Sylgard on Stippling.** A choice experiment was conducted to determine the effect of Sylgard on stippling by the pea leafminer. Ten pairs of celery plants (2 mo after seeding), selected for approximately equal size, were sprayed with either 6 ml of water or 6 ml of Sylgard solution (2.5 ml/liter; i.e., labeled rate) using hand-held spray bottles (E-Z Sprayer; Continental Industries, Brampton, Ontario, Canada) at a distance of 30 cm to cover the surface of the plant. Plants were left to dry for 20 min and pairs of plants were placed in 100 by 60 by 40-cm Plexiglas cages. Fifty adult leafminers were introduced into the cages by aspirator. After 5 d, the first and third petioles from the center were removed from each plant, all leaflets examined (five leaflets for first petioles and seven leaflets for third petioles) and the number of stipples counted on each leaflet.

**Experiment 2: Effect of Sylgard on Female Behavior.** To assess the effect of surfactant on preoviposition behavior, an observational choice study was conducted with individual females. Observation chambers were made from 1.7-liter white plastic buckets (15 cm diameter by 10 cm height), which had their lids replaced with a transparent sheet. The third oldest petiole was selected from celery plants of equal age and approximately equal size. One petiole was treated with 6 ml of Sylgard solution as above (2.5 ml/liter), and the other was sprayed with water. Both petioles were allowed to air dry for 20 min and placed inside the observation chamber. A single female was released into the observational chamber and observed for 1 h. The number of landings on control and treated petioles were recorded, along with the duration of the landing and whether or not probing and stippling occurred. Probing was defined as the extension of the female’s mouthparts to make physical contact with the plant surface. Eight replicates were conducted.

**Experiment 3: Phytotoxicity of Sylgard on Celery.** Five treatments of Sylgard (5.0, 2.5, 1.25, 0.63, and 0 ml/liter [control] were applied to celery plants that were 2, 4, and 8 mo old. Ten, three, and five replicates were conducted for the 2-, 4-, and 8-mo age classes, respectively. The three healthiest stalks on each plant were tagged before the experiment and a total of 6 ml of the treatment solution was applied to the entire plant surface with hand-held spray bottles from a distance of 30 cm. Plants were air dried and arranged in a completely randomized design.

Phytotoxicity was assessed every 3 d for a 21-d period using a foliar damage rating based on the percentage of chlorotic and/or necrotic leaf surface area with 0 = 0% damage, 1 = 1–20% damage, 2 = 21–40% damage, 3 = 41–60% damage, 4 = 61–80% damage, and 5 = 81–100% damage. Damage ratings were assessed visually by overlaying a leaf with a transparent grid with squares equal to 1 cm². Grid squares partially filled with necrotic foliar tissue were estimated to the nearest 0.25 cm².

**Experiment 4: Phytotoxicity of Agral on Cucumber.** Five treatments of Agral (0.6 ml/liter water, 0.3 ml/liter [labeled rate], 0.15, 0.08, and 0 ml/liter [control]) were applied to 35-d-old cucumber plants. The first three leaves of the vines were tagged before treatment. Experimental protocols were identical to
experiment 3, except that 10 replicates per treatment were conducted, and plants were assessed for damage every 3 d for 15 d, as normal senescence of cucumber leaves began before 21 d.

Experiment 5: Effect of Agral on Female Behavior on Cucumber. A no-choice experiment was conducted with 35-d-old cucumber plants treated with 0.3 ml/liter Agral (n = 25) and control plants treated with water (n = 25). After treatment, a single cucumber plant was placed in the center of a vented Plexiglas observation cage (30 by 30 by 30 cm). A single female was released into the cage, which was placed inside a white fabric tent (50 by 50 by 130 cm) to minimize external interference. Overhead lighting was provided by two 100-W spotlights placed outside of the tent and equidistant from the center of the tent. Observations of behavior were made every 20 s for 30 min through small windows cut into the fabric. Time to first plant contact and time spent on plant were recorded. Behaviors were recorded for 30 min; however, observation of the female continued as long as was needed for her to make initial contact with the plant. Between trials, air inside the cage was exchanged using a vacuum pump to ensure removal of any plant volatiles that might influence subsequent test subjects.

Observed behaviors were stippling, sitting, flying, walking, grooming, and push-ups. “Stippling” incorporated the previously described probing behavior and was defined as the puncturing of the leaf surface with the ovipositor and feeding and removal of tissue with the mouthparts because these behaviors occur together and result in formation of a stipple or wound on the plant. The term “grooming” was used to describe rubbing together of two or more appendages, including antennae. The term “push-up” was used to describe repeated lifting and lowering of the body.

Behavioral recordings made at 20-s intervals were compiled into six 5-min periods for each 30-min observation period, and data for number of observations per behavior, time until first contact, and time spent on plant were analyzed for differences between treated and control plants. Female behaviors were separated based on “on” and “off” plant observations. For this study, only female behaviors occurring while in contact with plants were analyzed. Because the time taken to contact plants varied by female, observations of on plant behaviors were standardized as percentages of the total number of 20-s time intervals each female spent on a plant.

Experiment 6: Effect of Agral on Female Host Preference. A choice experiment, with 25 replicates, was conducted with cucumber plants treated as in experiment 5. Treated and control plants were randomly assigned to each end of a vented Plexiglas cage (36 by 61 by 46 cm), which was placed within the white fabric tent, as above. Ten mated females were released at the center of the cage. After 2 h, plants were removed, and the number of stipples on each plant counted and recorded. The number of stipples on each plant was converted to proportion of total stipples to reduce variability arising from differences among females in stippling rates.

Table 1. Comparisons of the behavior of female pea leafminers (L. haidobrensis) on celery (A. graveolens) treated with Sylgard 309 (2.5 ml/liter) (treated) or with water (control)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>No. stipples per leaflet</th>
<th>Treated</th>
<th>Control</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>4.67 ± 0.28</td>
<td>29.14 ± 1.29</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Experiment 2</td>
<td>1.13 ± 0.23</td>
<td>5.75 ± 0.70</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>No. probing events</td>
<td>1.00 ± 0.19</td>
<td>3.75 ± 0.53</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>No. stippling events</td>
<td>0.13 ± 0.13</td>
<td>2.38 ± 0.42</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>Time on plant (s)</td>
<td>384.58 ± 115.52</td>
<td>1180.00 ± 246.93</td>
<td>0.0113</td>
<td></td>
</tr>
<tr>
<td>Time per landing</td>
<td>307.90 ± 57.97</td>
<td>205.22 ± 36.70</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

Data analysed by ANOVA, with α = 0.05. Values are means ± SE.

Statistical Analyses. Analyses of variance (ANOVA) were conducted using PROC GLM (SAS v 9.1; SAS Institute, Cary, NC) to examine differences in the number of stipples on treated and control celery plants in experiment 1, and differences in the number of landings, probes, and stipples and time spent on treated and control plants in experiment 2. Phytotoxicity (experiments 3 and 4) and behavioral data (experiments 5 and 6) were analyzed by ANOVA followed by means separations with Tukey’s studentized range (honestly significant difference [HSD]) test with α = 0.05. In experiment 6, proportion of stipples data were subject to arcsine transformation before analyses to satisfy the assumptions of ANOVA.

Results

Experiment 1: Effect of Sylgard on Stippling. The number of stipples per leaflet differed significantly between treated and control plants (Table 1). Replicate was found to be a significant source of variation (df = 9,455; F = 2.26; P = 0.018), but no significant treatment by replicate interaction was found (df = 4,455; F = 1.19; P = 0.32). Petioles were observed to be dying on treated plants at the time of stippling assessments; however, this observation was not quantified.

Experiment 2: Effect of Sylgard on Female Behavior. Statistically significant differences were found between treated and control plants in the number of landings, number of probing events, number of stipples, and time spent on the plant (Table 1). Replicate was not found to be a significant source of variation for any of these measures. No significant difference was found between treatments in time per landing event. Replicate was found to be a significant source of variation (df = 7,40; F = 3.85; P = 0.003) for this measure; however, no significant treatment by replicate interaction was found (df = 7,40; F = 1.56; P = 0.177).
Experiment 3: Phytotoxicity of Sylgard on Celery. The highest rate (5.0 ml/liter) of Sylgard caused significant damage to the leaves of 2- and 4-mo-old celery plants (Table 2). On 8-mo-old celery plants, the 5.0, 2.5, and 0.63 ml/liter treatments of Sylgard caused significantly more damage than the 1.25 and 0 ml/liter treatments over the 21 d of post-treatment assessments. No treatment by assessment day interaction was found for any of the plant ages examined.

Experiment 4: Phytotoxicity of Agral on Cucumber. The highest rate (0.60 ml/liter) of Agral caused significantly more damage to the leaves of 35-d-old cucumber plants than all other treatments (Table 2). Damage in the 0.60 ml/liter treatment was present on all leaves from 3 d after application but progressed more slowly on leaves in other treatments (data not shown). No treatment by assessment day interaction was found.

Experiment 5: Effect of Agral on Female Behavior on Cucumber. Significant differences in the frequency of behaviors across time periods were found largely within treatments, with significant differences in stippling occurring between control and treated plants in the later time periods (Fig. 1). On control plants, stippling was the most frequently observed behavior (as measured by percent of observations), followed by sitting across all time periods. On treated plants, stippling was the most common behavior with the exception of the final two time periods when sitting became the most common behavior. Grooming and push-ups were infrequent behaviors and each comprised <2% of observations in any 5-min time period. Replicate was found to be a significant source of variation in the first, second, third, and fourth 5-min time periods for control plants, as well as the second, fifth, and sixth 5-min time periods for the treated plants, and was attributed to variation among activity levels of individual females.

In the first 5 min, the only behaviors observed on control plants were stippling and walking. During this time, these behaviors occurred infrequently and were not significantly different from one another (df = 4.96; F = 1.00; P = 0.41; Fig. 1a). No behaviors were observed on treated plants during the initial 5 min.

From 5 to 10 min, stippling occurred more frequently than push-ups and walking on control plants (df = 4.96; F = 3.41; P = 0.012). Sitting, walking, and stippling all occurred at low, but equal, frequency on treated plants during this time (df = 4.96; F = 1.57; P = 0.122; Fig. 1b). No significant differences were found in the frequencies of individual behaviors between control and treated plants in this time period.

From 10 to 15 min, stippling occurred more frequently than all other behaviors, except sitting, on control plants (df = 4.96; F = 4.85; P < 0.002; Fig. 1c). A similar, but nonsignificant, pattern of behavioral frequencies was recorded on treated plants (df = 4.96; F = 1.50; P < 0.210). No significant differences were found in the frequencies of individual behaviors between control and treated plants in this time period.

From 15 to 20 min, stippling was the most frequent behavior on control plants (df = 4.96; F = 12.21; P < 0.001; Fig. 1d). A similar, but nonsignificant, pattern of behavioral frequencies was observed on treated plants within this time period (df = 4.96; F = 1.66; P = 0.165). There was no difference in the frequencies of individual behaviors between treatments.

From 20 to 25 min, stippling occurred more frequently than sitting, which occurred more frequently than all other behaviors on control plants (df = 4.96; F = 22.30; P < 0.001), whereas sitting occurred more frequently than all other behaviors on treated plants (df = 4.96; F = 9.20; P < 0.001; Fig. 1e). During this time period, stippling occurred significantly more often on control than on treated plants (df = 1.48; F = 13.06; P < 0.001). No other behaviors differed significantly in frequency between control and treated plants.

In the final time period (25–30 min), stippling was again the most frequently observed behavior on control plants, followed by sitting, which was more frequent than all other behaviors (df = 4.96; F = 27.34; P < 0.001). On treated plants sitting was the most frequent behavior (df = 4.96; F = 10.63; P < 0.001; Fig. 1f). Stippling was significantly less frequent on treated than control plants (df = 1.48; F = 22.38; P < 0.001), whereas no other significant differences occurred in the frequencies of all other behaviors.

Of the five observed behaviors exhibited on plants by female *L. huidobrensis*, the occurrence of stippling had the largest change in frequency across the 30-min observation period on control versus treated cucum-

### Table 2. Phytotoxicity ratings for three ages of celery (*A. graveolens*) plants 21 d after treatment with Sylgard 309 and for 35-d-old cucumber (*C. sativus*) plants 15 d after treatment with Agral 90

<table>
<thead>
<tr>
<th>Sylgard 309 (ml/L)</th>
<th>Foliar damage rating (mean ± SE)</th>
<th>Agral 90 (ml/liter)</th>
<th>Foliar damage rating (mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-mo celery&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4-mo celery&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8-mo celery&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>5.00</td>
<td>1.06 ± 0.06 a</td>
<td>2.25 ± 0.17 a</td>
<td>1.78 ± 0.06 a</td>
</tr>
<tr>
<td>2.50</td>
<td>0.78 ± 0.04 b</td>
<td>1.54 ± 0.11 b</td>
<td>1.63 ± 0.06 a</td>
</tr>
<tr>
<td>1.25</td>
<td>0.73 ± 0.07 b</td>
<td>1.22 ± 0.08 b</td>
<td>1.35 ± 0.07 b</td>
</tr>
<tr>
<td>0.63</td>
<td>0.71 ± 0.08 b</td>
<td>1.34 ± 0.08 b</td>
<td>1.72 ± 0.08 a</td>
</tr>
<tr>
<td>0</td>
<td>0.76 ± 0.09 b</td>
<td>1.38 ± 0.07 b</td>
<td>1.32 ± 0.05 b</td>
</tr>
</tbody>
</table>

Mean damage ratings within a column followed by the same letter are not significantly different (Tukey’s studentized range test, α = 0.05).

<sup>a</sup>ANOVA, df = 4.1031; F = 5.93; P < 0.001.

<sup>b</sup>ANOVA, df = 4.611; F = 11.43; P < 0.001.

<sup>c</sup>ANOVA, df = 4.861; F = 39.44; P < 0.001.
ber plants. Over the duration of the observation period, the frequency of stippling by females increased significantly on control but not treated plants (Fig. 2). Stippling on control plants began at a frequency of 0.2% and steadily increased to become the principal behavior exhibited in minutes 25–30 (38.8%). In contrast, stippling rates on treated plants were much lower than on control plants and never exceeded 7% of recorded observations. Sitting, rather than stippling, became the most engaged-in behavior for female \textit{L. huidobrensis} exposed to treated plants (18.9%).

Females took longer to make contact with treated (1,942.16 ± 290.41 s) than with control (1,120 ± 86.50 s) cucumber plants (df = 1,48; \( F = 4.69; P = 0.035 \)).

Experiment 6: Effect of Agral on Female Host Preference. After the 2-h exposure period, a significantly lower percentage of stipples were found on treated plants (34.1%) than on control plants (65.9%; df = 1,24; \( F = 15.06; P < 0.001 \)). Replicate was not a significant source of variation.

**Discussion**

Surfactants reduced normal preoviposition behaviors of \textit{L. huidobrensis} on otherwise acceptable celery host plants. This effect does not seem to be related to possible negative effects of surfactants on plant health, as recommended rates of the surfactants used did not
cause phytotoxicity. Petiole death was observed, but not quantified, in Sylgard-treated celery in initial experiments, and was likely caused by the enclosed conditions in which plants were housed for 5 d rather than to the surfactant alone. Phytotoxic effects of Sylgard were observed on 8-mo-old celery plants, but these plants were both overmature and became infested with thrips. Thrips vector many plant diseases that cause chlorosis and necrosis of foliar tissue (Jones 2005), possibly confounding foliar ratings. Symptoms of phytotoxicity observed on cucumber leaves treated with low doses of Agral were likely caused by leaf age and senescence rather than to the surfactant, as similar symptoms were observed on control plants.

The results of this study indicate that certain host plant selection behaviors of female *L. huidobrensis* may be altered by the presence of a surfactant on the foliage of a potential host plant. From this study, it seems the normal hierarchy of behaviors during host-plant interactions by *L. huidobrensis*, as indicated by behaviors on control cucumber plants, is stippling followed by sitting, walking, grooming, and finally push-ups. On treated plants, females exhibited this hierarchy of behaviors until the final two 5-min observation periods where females continued to engage more frequently in sitting, and less frequently, in stippling. In addition, the presence of a surfactant significantly altered the time taken for *L. huidobrensis* to make initial plant contact, the number of landings on a plant, the amount of time spent on a plant, stippling rates in both choice and no choice trials, as well as the frequency of stippling behavior. Because behavioral data were standardized based on the amount of time a female spent in contact with a plant, it is unlikely that differences in behavioral frequencies between control and treated cucumber plants across time is an artifact of the increased time taken for females to make initial plant contact or the reduced amount of time spent on treated plants. However, the low incidence of recorded behaviors in the initial 10 min of observation is likely caused by delayed plant contact by females exposed to either plant treatment. Thus, reductions in observed stippling and changes to host selection behaviors were apparently caused by an antixenotic effect of the surfactant on *L. huidobrensis* rather than a toxic effect of the surfactant on the plant.

Although somewhat more frequent on treated plants, the push-up behavior appears to be an irregular activity across time on both treated and control plants and is unaffected by the presence of a surfactant. It was noted that flight and walking behaviors were often preceded by a series of push-ups that lasted 1 or 2 s. In a stationary fly, push-ups may be a reaction to increasing neurological activity as part of a physiological and/or neurological sequence that is initiated before locomotion (Dethier 1976).

Chemical detection and recognition allows insects to locate optimal feeding areas (Desouhant et al. 2005, Kendrick and Raffa 2006, Hjalten et al. 2007), seek mating opportunities (Carazo et al. 2004, Bengtsson et al. 2006, Segura et al. 2007, Witzgall et al. 2008), avoid natural enemies (Ferris and Rudolf 2007), and select suitable oviposition sites (Bengtsson et al. 2006, Tasin et al. 2006, Steiner et al. 2007). Chemical cues present in plants are a major determinant for host plant identification in many insects, and plants that do not have the correct chemical signature may be ignored as oviposition sites (Wallin and Raffa 2000, Clausen et al. 2002, Cunningham and Floyd 2004). Foliar applications of plant extracts have resulted in reduced damage to crops because of decreased oviposition by *L. huidobrensis* (Banchio et al. 2003). The surfactants used here did not seem to repel *L. huidobrensis* from the plant because there was no difference in the time spent per landing on control and treated plants. In addition, flight activity in both treatment and control contexts was at its maximum during the 15- to 20-min period (data not shown); however, the time to first plant contact occurred nearly 14 min later on treated than control plants, suggesting that the surfactant may...
surfactants may help to reduce<br>on celery. Preliminary field evidence suggests that<br>protecting certain vegetable crops from<br>surfactants in pest management programs directed at<br>Hallett et al. (2004) and support the potential use of<br>quent reduction in stippling damage.

Successful feeding and oviposition can be depend-<br>ent on the successful execution of a series of host<br>acceptance activities (Mowry et al. 1989, Henderson<br>et al. 2004). Martin et al. (2005) have suggested that<br>L. huidobrensis feeding and oviposition cues are overlapped or that oviposition is dependent on positive feeding cues. Dethier (1976) states that flies that are in no immediate need of nutrition and are not concerned with reproduction are “going nowhere, doing nothing.” However, the females selected for use in this study were all gravid and therefore should have had an urge to oviposit on plants deemed to be acceptable. On control plants, stippling was the most frequent behavior of female L. huidobrensis as time progressed; however, on treated plants, females engaged more frequently in sitting. This result suggests that they were unable to identify the plant as an acceptable host because of the coating of surfactant. An inability of L. huidobrensis to properly detect host-plant chemistry could deter the initiation of feeding and also ovipositional behavior. If these behaviors are interrupted, L. huidobrensis may revert to an activity that is most energetically favorable, such as sitting, with a conse-<br>quent reduction in stippling damage.

The results from this study agree with those of<br>Hallett et al. (2004) and support the potential use of<br)surfactants in pest management programs directed at protecting certain vegetable crops from L. huidobrensis damage. In the laboratory setting, surfactants were shown to deter L. huidobrensis stippling over a 2-h period on cucumber and over a 5-d laboratory period on celery. Preliminary field evidence suggests that surfactants may help to reduce L. huidobrensis stippling for periods of up to 7 d (Hallett et al. 2004). However, considerable further study is needed to ex-<br>amine the interactions between L. huidobrensis and surfactant-treated crops in field settings, as well as the effect of environmental conditions on surfactant per-<br>formance. Surfactants may have the highest potential to be of use for crop protection in the hydroponic greenhouse vegetable industry. Typically, the growing environment within these greenhouses is highly regulated with no natural precipitation that may wash-off surfactants applied to crops, possibly extending the effectiveness of the surfactant’s protective properties. Although further studies are needed to test the appli-<br>cability of crop protection by surfactants, available evidence suggests that potential exists for surfactants, or similar products, to be integrated into a pest management regimen for L. huidobrensis.

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