Characterization of Stink Bug (Heteroptera: Pentatomidae) Damage to Mid- and Late-Season Apples1, 2

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ABSTRACT

Stink bugs (Heteroptera: Pentatomidae) were found to feed on apples in mid- to late season, from late July until harvest. Stink bug-feeding damage has been confused with cork spot, but differs in three ways: 1) the edge of the depression on the fruit surface from stink bug feeding is gradual instead of abrupt as in cork spot, 2) the corky flesh is always immediately beneath the skin in stink bug damage but may not be in contact with the skin in cork spot, and 3) the presence of a puncture site from stink bug feeding. Application of foliar calcium chloride did not affect the occurrence of corking damage related to stink bug feeding, and the fruit flesh immediately below the skin in stink bug damaged fruit had the same concentration of calcium and boron as fruit flesh from undamaged fruit. Damage caused by stink bugs was eliminated by caging fruit in early July, whereas damage was higher on fruit caged with stink bugs for a two-week period between late July and harvest than on fruit that were not caged. Most stink bug damage occurred from 26 to 60 days before harvest.

KEY WORDS Pentatomidae, calcium chloride, boron, cork spot, bitter pit

Stink bugs (Heteroptera: Pentatomidae) are well-known pests of rice (Bowling 1979), legumes (Nilakhe et al. 1981), nuts (Yates et al. 1991, Shearer & Jones 1996), and fruits (Mundinger & Chapman 1932, Borden et al. 1952). Feeding on seeds or the fruiting structures surrounding seeds of these and other crops causes economic damage. Stink bugs penetrate the plant’s protective structures to feed through a combination of mechanical pressure exerted by the mouthparts and saliva-containing enzymes that dissolve components of the cell wall and intercellular matrix (Miles 1958, Miles 1959). Damage to temperate, deciduous tree fruit appears as two different defects. Feeding on apple early in the season causes a dimple on the surface of the fruit with a trail into the fruit flesh toward the seeds or calyx (Solymar 1999). In peaches, early damage develops into cat-facing injury, as a result of the surrounding undamaged fruit flesh growing around the damaged feeding site (Rings 1958). Later season damage to peach appears as a depressed area on the fruit surface, a water-soaked lesion, or gummosis (Rings

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2This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or a recommendation by the USDA for its use.
1958), apparently as a result of loss of cell contents from many cells (Mundinger & Chapman 1932). In peaches and pear, the flesh has a white or brown, pithy appearance (Mundinger & Chapman 1932) but in apple the damaged flesh is brown and corky (Krupke & Brunner 2001). In eastern North America, mid to late season stink bug damage has been reported in peach and pear, but generally has not been considered to be an economic problem for apple (Mundinger & Chapman 1932, Solymar 1999).

Disorders associated with nutrient deficiencies in apple, especially cork spot and bitter pit, can be confused with stink bug feeding (Brown 2001a). In particular, calcium-related deficiency can cause symptoms that include a corky appearance of apple flesh under a depressed and discolored area on the fruit skin (Faust & Shear 1968). The variety ‘York Imperial’ is especially susceptible to a corking disorder (Simons et al. 1971, Miller 1980) that is related to calcium deficiency. A number of studies (Faust & Shear 1968, Shear 1972, Raese & Drake 1993) have demonstrated that the application of foliar calcium can reduce the occurrence of this disorder in apple. Other factors such as crop load, defoliation, water relations, and storage conditions also can contribute to cork spot and bitter pit development (Faust & Shear 1968).

This study was conducted to characterize stink bug feeding damage to apples during the mid-season to harvest stages of fruit development. Experiments were conducted to determine if the observed damage could be prevented by excluding stink bugs and to eliminate the possibility of calcium deficiency as a contributing cause.

Materials and Methods

Experimental orchard. Experiments on stink bug feeding damage to apple were superimposed on an existing study examining the effect of increasing plant diversity on arthropod pest management conducted at the Appalachian Fruit Research Station, Kearneysville, West Virginia (Brown 2001b). Four 0.5-ha orchards were planted in April 1997 with ‘Loring’/Lovell peach (Prunus persica Batsch), and ‘Granny Smith’/EMLA.26 and ‘Royal Empire’/M.9/EMLA.111 apple (Malus x domestica Borkh.) at a spacing of 3.7 × 4.9 m (560 trees/ha). The control (C) orchard was planted with a contiguous block of peach adjacent to a contiguous block of apple. The interplanted (I) orchard was planted with alternating pairs of apple and peach trees within and among tree rows. The ground cover (GC) orchard was planted with contiguous plantings of apple and peach as in orchard C. Alternating strips of dill (Anethum graveolens L.), buckwheat (Fagopyrum esculentum Moench), purple tansy (Phacelia tanacetifolia Benth.), and a mixture of 16 wildflowers (partial shade mix, American Meadows, Williston, Vermont) were planted under each side of the tree row in 0.75-m wide strips extending from 1.25 to 2.00 m from the center line of the row. The final orchard, interplanted/ground cover (I/GC), had the highest plant diversity combining interplanting of fruit trees and flowering annual plants under the trees as described above. Orchard C was treated with a conventional insecticide application schedule, and the other three orchards received a reduced insecticide schedule (Table 1).

Cage studies. Thirty individual branches of each apple cultivar were caged with 10 × 50 threads/cm screen (BioQuip Products, Gardena, California) to ex-
clude insects after 11 July 2001. Branches were pruned before caging so that at least five fruit were within each 1.0-m long by 0.5-m diameter cage. Six cages per cultivar were randomly assigned to one of five treatments, four receiving two stink bugs for approximately two-week periods and one a control with no stink bugs. Exposure to stink bugs on 'Empire' branches was 48 to 36 days, 35 to 26 days, 25 to 16 days, and 15 to 0 days before harvest (7 September 2001). Exposure to stink bugs on 'Granny Smith' branches was 60 to 46 days, 45 to 32 days, 31 to 18 days, and 17 to 0 days prior to harvest (16 October 2001). Stink bugs were field collected in Jefferson County, West Virginia, during the summer and maintained in laboratory cages containing a mixture of flowering annual plants. Cages were kept in a growth chamber at 16:8 (L:D) photoperiod at 24–26°C. Five of the six cages per treatment and cultivar were exposed to the stink bug _Euschistus servus_ (Say). One cage of each treatment contained one of the other species: _E. tristigmus_ (Say), _Acrosternum hilare_ (Say), and _Brochymena quadrapustulatus_ (F.). The most abundant stink bug in West Virginia apple orchards is _E. servus_ (personal observation, MWB) but the other species were included in small numbers to ascertain if there was a complex of species causing damage or just the one species. Two individuals of the same species were added per cage as called for in the experimental design. At harvest, the fruit were picked from inside the cage and brought to the laboratory for evaluation. Stink bug damage was identified by a sunken discolored area on the surface of the fruit, a corky appearance to the flesh below the discolored area, and the presence of a feeding puncture site. Data on percent fruit with stink bug damage were transformed using arcsine (square root) then analyzed with Proc Mixed (SAS Institute 1996) testing for effects of cultivar, treatment, and the cultivar by treatment interaction.

The cage design used in 2001 was not sufficient to prohibit feeding completely by stink bugs from outside the cage. Several stink bugs were seen on the outside of the cage feeding through the mesh on fruit inside the cage (personal observation, MWB). To exclude stink bug feeding completely, a revised cage design was used in 2002. Cage diameter was increased to 0.75 m and bamboo stakes were taped to the apple branches to form a support to keep the cage mesh off of the

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**Table 1. Insecticide treatments in conventional and reduced program orchards for characterizing stink bug damage to apple fruit, Kearneysville, West Virginia, 2001.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Conventional program</th>
<th>Reduced program</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 8</td>
<td>Indoxacarb</td>
<td>Indoxacarb</td>
</tr>
<tr>
<td>May 17</td>
<td>Phosmet</td>
<td><em>Bacillus thuringiensis</em></td>
</tr>
<tr>
<td>June 4</td>
<td>Phosmet</td>
<td></td>
</tr>
<tr>
<td>June 20</td>
<td>Methomyl</td>
<td></td>
</tr>
<tr>
<td>July 2</td>
<td>Methomyl</td>
<td></td>
</tr>
<tr>
<td>July 27</td>
<td>Esfenvalerate</td>
<td></td>
</tr>
<tr>
<td>August 16</td>
<td>Phosmet</td>
<td></td>
</tr>
<tr>
<td>September 18</td>
<td>Phosmet</td>
<td></td>
</tr>
</tbody>
</table>

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Thirty 'Empire' trees were selected randomly and, because of a low fruit load, only five 'Granny Smith' trees were selected randomly. Two branches were selected on each tree for caging. One branch had two stink bugs introduced for a two-week period between mid-July and harvest, and the other cage received no stink bugs as a control. A third branch on each tree, with a similar fruit load, also was selected and left uncaged as a control exposed to natural levels of stink bug feeding. Stink bugs were collected and maintained as in 2001. Approximately 80% of the cages with stink bugs contained *E. servus*, with the rest containing *E. tristigmus* or *E. variolaris* (Palisot de Beauvois). At harvest (5 September 2002, for ‘Empire’ and 30 September 2002 for ‘Granny Smith’) the fruit from the three sample branches were picked and evaluated for damage as in 2001. Because of an inability to normalize the data because of a large number of zeros, the effect of caging on the percent of fruit with stink bug damage was analyzed with the nonparametric median test (Conover 1971).

**Nutrient content.** Beginning at the first cover spray and continuing at about biweekly intervals, calcium chloride was applied with an airblast sprayer to orchards C and I/GC in 2001. A total of 43.7 kg/ha (39 lbs/acre) calcium chloride was applied to ‘Empire’ trees and 52.7 kg/ha (47 lbs/acre) to ‘Granny Smith’ in 2001. Twenty randomly selected fruit from each of 15 randomly selected apple trees of each cultivar and from each orchard (a total of 1200 fruit of each cultivar) were picked on 7 September 2001 (‘Empire’) and 16 October 2001 (‘Granny Smith’) for evaluation in the laboratory. Damage was categorized as caused by stink bug feeding based on morphology of the depression and corky flesh based on descriptions of Mundinger & Chapman (1932) and Rings (1958). If there was doubt about the cause of damage, the damaged area was examined under a dissecting microscope for the presence of a feeding puncture. Percent fruit with stink bug damage was transformed with the arcsine (square root) and analyzed with Proc Mixed (SAS Institute 1996) testing for effects of cultivar, orchard, and the cultivar by orchard interaction.

An additional 40 fruit were collected from ‘Granny Smith’ trees in orchard C on 19 October 2001. Two stink bug-damaged fruit and two undamaged fruit were collected from each of 10 trees randomly distributed in the orchard. No fruit in these orchards exhibited symptoms of cork spot for comparison with stink bug damage. To obtain fruit flesh for nutrient analysis, a hand-operated apple peeler (Back to Basics, Inc., Draper, Utah) was used to first remove the peel and then a sample strip of flesh, 1.5-mm deep × 10-mm wide. The fruit flesh was frozen in glass vials covered with parafilm at −80°C until chemical analyses were conducted. Before analysis, the samples were lyophilized for five days, crushed, and transferred to a plastic bag. A 0.5-g subsample was placed in a 15-ml test tube. The subsample was ashed in a muffle furnace for 14 h at 510 to 520°C. After cooling the subsamples to room temperature, 5 ml of 6N HCl was added to digest the subsample and then diluted with 10 ml of deionized water. Subsamples were held in Pyrex tubes covered with parafilm until analysis.

Calcium concentration was determined with an atomic absorption mass spectrometer (Leco, St. Josephs, Michigan) under flame (absorption) mode. The equipment was recalibrated against a standard after every 10 samples. An average of three readings was used for analysis. Boron concentration was determined by adding 5 ml concentrated H2SO4 to a 1-ml aliquot from the subsample. The tube was agitated and then 5 ml of carmine solution (0.92 g carmine in 1000 ml of
concentrated H₂SO₄) was added and allowed to react for 45 min. Three 1-ml subsamples were taken and placed into polystyrene cuvettes for analysis with an Ultraspec 3000 UV/Visible Spectrophotometer (Pharmacia Biotech, Piscataway, New Jersey). Readings were taken at 600 nm absorbance and compared with freshly prepared boron standards with an average of the three subsamples used for analysis. Calcium and boron concentrations, no transformation of data was needed, were analyzed with Proc Mixed (SAS Institute 1996) to test for differences between damaged and undamaged fruit.

**Results and Discussion**

**Characterization of damage.** The damage caused by stink bug feeding on apples in the mid- to late season is a depressed, discolored area on the fruit skin. The discoloration appears as a water-soaked to dark green area on both red and green colored cultivars. On red-colored fruit, the discoloration sometimes appears darker red. The area of discoloration is approximately 1 cm in diameter for each feeding site and is roughly circular, but in the case of multiple feeding on the same fruit, the damage may appear larger and irregular. Immediately beneath the depressed, discolored fruit surface is dark, corky flesh that extends about 0.5 to 1 cm into the fruit as shown in Fig. 1A. Although there is a puncture site that provides proof of feeding, this may often be visible only under magnification (Fig. 2). Krupke & Brunner (2001) found that feeding damage to apple by *Euschistus conspersus* Uhler in Washington was evident within one day of feeding.

Stink bug feeding damage differs from cork spot, a calcium related symptom. Corking only occurs immediately adjacent to the fruit skin in stink bug damage (Fig. 1A), whereas in cork spot the damage may occur separate from the skin with healthy flesh between the corking and the skin (Fig. 1B) (Faust & Shear 1968). Corking of the flesh appears more diffuse in cork spot (Fig. 1B), whereas in stink bug damage the corking is uniform within the affected area (Fig. 1A). The fruit surface of cork spot is irregular in outline compared with a more circular appearance in stink bug damage. The depression in cork spot is shallow compared with that in stink bug damage and the edge of the depression is more abrupt in cork spot. Stink bug damage can occur as a single blemish or as multiple sites which often are clustered anywhere on the fruit. Cork spot generally occurs as multiple sites on a fruit, generally more randomly distributed as opposed to clustered, and often is more abundant near the calyx end of the fruit (Faust & Shear 1968).

Bitter pit, another calcium deficiency symptom, is different from stink bug damage. Bitter pit most often occurs during storage, whereas stink bug damage does not develop or progress after harvest. Bitter pit appears as small, shallow, irregularly shaped black depressions with only a small extent (2 to 3 mm) of corky flesh under the skin (Faust & Shear 1968).

**Cage studies.** During both years of exclusion cage studies, no stink bug damage was observed on fruit in the orchard prior to caging in early July. Cages made of the same mesh and with similar design were previously shown to have no microclimate effects in the shade, and in full sunlight increased the enclosed branch temperature by only 1°C (Brown 2003). In the 2001 study, treatment effect was significant ($F = 9.60; \text{d.f.} = 4, 50; P < 0.0001$) but there was no significant effect of cultivar ($F = 1.77; \text{d.f.} = 1, 50; P = 0.1898$) or a cultivar by treatment interaction ($F = 1.38; \text{d.f.} = 4, 50; P = 0.2549$), therefore, data were
Fig. 1. Cross section of stink bug feeding damage, A, and cork spot, B, on an unnamed New York cultivar (bars = 1 cm).
pooled for both cultivars. A total of 568 caged fruit were evaluated ranging from 108 to 122 fruit per treatment. The most damage occurred in the two earlier exposure periods: from 48 to 26 days (’Empire’) and 60 to 32 days (’Granny Smith’) before harvest (Table 2). Apparently, fruit between one and two months before harvest either are more susceptible to damage or are more attractive to stink bugs. Damage to fruit exposed to stink bugs for the 15 days (’Empire’) or 17 days (’Granny Smith’) before harvest was nearly twice as high as the control without stink bugs (Table 2), but this was not significantly different due to high variability in damage among cages within each treatment. Similar damage to apples was observed in cages containing all species of stink bugs tested and damage seemed to occur with the same frequency for each species.

In 2002, the modified cages were effective at excluding stink bugs and there was no damage on any of the 191 fruit evaluated from the control cages, confirm-
ing that this damage occurs only in the presence of stink bugs (median test, \( P < 0.01 \), d.f. = 1). Significantly more damage occurred (median test, \( P < 0.05 \), d.f. = 1) when stink bugs were enclosed with fruit for a two week period (median = 40% fruit damage, range 0 to 100, \( n = 164 \)) as compared with natural infestation levels (median = 0% fruit damage, range 0 to 50, \( n = 133 \)). All three species of stink bug tested in 2002 caused similar fruit damage at a similar frequency.

**Nutrient content.** Orchard C, which received CaCl applications, had the greatest amount of stink bug damage, and orchard I, which did not receive CaCl, had the least amount of damage (Table 3). Application of foliar calcium did not reduce this form of damage (\( F = 10.15; \) d.f. = 3,98; \( P < 0.0001 \)) as it does for cork spot and bitter pit (Shear 1972, Raese & Drake 1993). Fruit flesh just below the skin from damaged and undamaged fruit showed no difference in either calcium (\( F = 0.30; \) d.f. = 1.18; \( P = 0.5910 \)) or boron (\( F = 0.18; \) d.f. = 1.18; \( P = 0.6756 \)) concentration (Table 4), further indicating that this damage is not related to deficiencies in these nutrients.

**Table 2. Effect of timing of exposure to stink bugs on percent fruit damage from 2001 cage experiment, data for ‘Empire’ and ‘Granny Smith’ pooled, Kearneysville, West Virginia.**

<table>
<thead>
<tr>
<th>Days before harvest exposed to stink bugs (no. fruit)</th>
<th>‘Empire’</th>
<th>‘Granny Smith’</th>
<th>Percent damage ± SEM&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>48–36 (103)</td>
<td>60–46 (37)</td>
<td>49.0 ± 5.39a</td>
<td></td>
</tr>
<tr>
<td>35–26 (71)</td>
<td>45–32 (38)</td>
<td>53.2 ± 5.74a</td>
<td></td>
</tr>
<tr>
<td>25–16 (65)</td>
<td>31–18 (43)</td>
<td>33.5 ± 5.62b</td>
<td></td>
</tr>
<tr>
<td>15–0 (68)</td>
<td>17–0 (48)</td>
<td>23.9 ± 5.39bc</td>
<td></td>
</tr>
<tr>
<td>Stink bugs excluded (73)</td>
<td>Stink bugs excluded (40)</td>
<td>11.9 ± 5.62c</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Untransformed means presented, analysis done on arcsine (square root) transformed data; mean separation by L.S.D., \( P = 0.05 \).

**Table 3. Percent stink bug damage to fruit by orchard management, 600 fruit per orchard, (only conventional had a standard insecticide program, the others had a reduced program, see Table 1) and calcium chloride treatment, Kearneysville, West Virginia, 2001.**

<table>
<thead>
<tr>
<th>Orchard</th>
<th>Calcium</th>
<th>Percent damage&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Applied</td>
<td>32.4a</td>
</tr>
<tr>
<td>Interplanted peach and apple</td>
<td>Not applied</td>
<td>16.7c</td>
</tr>
<tr>
<td>Ground cover flowers under trees</td>
<td>Not applied</td>
<td>25.6b</td>
</tr>
<tr>
<td>Interplanted and with flowers</td>
<td>Applied</td>
<td>24.8b</td>
</tr>
</tbody>
</table>

<sup>a</sup>Untransformed means presented, analysis done on arcsine (square root) transformed data; pooled SEM = 2.14; mean separation by L.S.D., \( P = 0.05 \).
The presence of flowering plants in the ground cover of two of the orchards did not have a consistent effect on the amount of stink bug damage to fruit (Table 3). In New Jersey peach orchards, Atanassov et al. (2002) found more stink bugs, and in one year more fruit damage, in orchards with broadleaf weeds than in orchards with better broadleaf weed control. However, I previously found no increase in stink bug damage to peach fruit due to the presence of the same flowering plant species as used in this study (Brown 2002). The ineffectiveness of the insecticide schedule used in this study to reduce stink bug damage, as demonstrated by the highest rate of damage being in the only orchard to receive conventional insecticides, orchard C (Table 3), indicates alternative management tactics may be needed.

Stink bugs do cause damage to apples in the mid- to late season. This damage superficially resembles cork spot, a calcium deficiency–related problem, but can be distinguished by the external appearance of the damage site, the nature of corking in the fruit flesh, and the presence of a feeding puncture. Proper recognition of stink bug damage to apple fruit in the mid- to late season is becoming more important because of the recent appearance of a potentially serious fruit pest in Pennsylvania, the exotic stink bug *Halyomorpha halys* (Stål) (Hoebeke & Carter 2003). As a result of the potential confusion of stink bug damage with the symptoms of calcium deficiency (cork spot), monitoring techniques and methods for stink bug population management are needed to properly manage both stink bug damage and cork spot. Because damage is caused by highly mobile adults and there is a complex of at least five species (*E. servus*, *E. tristigmus*, *E. variolaris*, *Acrosternum hilare*, and *Brochymena quadrapustulatus*), management of these pests is likely to be difficult.

**Acknowledgments**

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**References Cited**


