# Screen Hole Size and Barriers for Exclusion of Insect Pests of Glasshouse Crops[1]

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**ABSTRACT** Laboratory trials were conducted to determine the effectiveness of screens as barriers to five major greenhouse pests. Four screen types with a range of hole sizes were tested: high density polyethylene sheets perforated with holes that were in the center of an indentation on one side and a corolla of material on the opposite side; a woven mesh of polyethylene strands; a filter of unwoven polyester; and woven brass strainer cloth. *Liriomyza trifolii* (Burgess), *Aphis gossypii* Glover, *Myzus persicae* (Sulzer), *Bemisia tabaci* (Gennadius), or *Frankiniella occidentalis* (Pergande) were placed in a cage with a test screen separating them from a source of light and food. The insects' ability to pass through any barrier could not be predicted solely from thoracic width and hole size. Hole geometry or the way in which holes were formed were important elements in insects' exclusion. The most effective barriers to insect penetration correspondingly reduced air flow. The unwoven polyester filter designed specifically as an insect barrier did not restrain any of the insects under the methodology used. Results suggest that the maximum hole sizes for exclusion were: *L. trifolii* (640 µm), *A. gossypii* (341 µm), *B. tabaci* (462 µm) and *F. occidentalis* (192 µm).

**KEY WORDS** *Bemisia tabaci, Liriomyza trifolii, Aphis gossypii, Myzus persicae, Frankliniella occidentalis,* exclusion, screen, ornamentals.

Aphids, whiteflies, thrips, and leafminers are among the most important pests of glasshouse crops (Hussey 1985) not only because of direct feeding damage but many also transmit phytopathogenic organisms (Smith 1972, McLean et al. 1986). Most of these pests are becoming more difficult to control due to pesticide resistance. Consequently, management practices that rely on remedial control actions are growing increasingly less effective, and environmentally and economically inappropriate. Exclusion of insect pests from the greenhouse may become both a necessary alternative to pesticide use and provide a valuable addition to current control practices (Parrella and Jones 1987, Mears 1990).

However, there are potential limitations for the use of barriers for pest exclusion. Screens can restrict air flow which may increase both temperature and humidity, as well as reducing light transmission which may affect plant growth rates (Parrella and Jones 1987, Robb and Parrella 1988, Mears 1990). Also, the specific pest complex, plant culture condition, and the proximity to immigrating insect populations must be considered in selection of the type of barrier.

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Absolute exclusion of key arthropod pests with barriers may be important in specific circumstances (e.g. preventing access of insect vectors of disease-causing pathogens to susceptible crop plants). In other cropping systems, a barrier may only be needed to deter an insect from entering the greenhouse. That is, the insect may be able to eventually cross the barrier, but the presence of the obstacle may be adequate to divert colonization to more readily available alternate hosts outside the greenhouse. The objective of the study reported here was to characterize the potential for key greenhouse insect pests to pass through a range of barrier types when strong stimuli were provided.

## Materials and Methods

**Pest Source.** Insects used in this trial were obtained from existing colonies at the University of California Riverside. *Liriomyza trifolii* (Burgess) was reared on chrysanthemums, *Dendranthema grandiflora* Tzvelev (Parrella et al. 1983). The melon aphid, *Aphis gossypii* Glover and the green peach aphid, *Myzus persicae* (Sulzer) also were reared on chrysanthemum (Vehrs 1989). The sweetpotato whitefly, *Bemisia tabaci* (Gennadius), was reared on poinsettia, *Euphorbia pulcherrima* Willd (Bethke unpubl. data). Western flower thrips, *Frankliniella occidentalis* (Pergande) was reared on roses, *Rosa* spp. (Robb 1989).

Twenty pairs of each insect species were sexed and measured at the widest point of the thorax with an ocular micrometer. The thorax was assumed to be the least flexible part of the insect's body. Differences in thorax widths within each species were determined by analysis of variance (SAS Institute 1985, Proc GLM) and Duncan's new multiple range test (Duncan 1975).

**Exclusion Barriers.** Four types of barriers were used to test the insect movement. High density polyethylene sheets with 62 (#4) (Clear Screen) and 248 (#2) (VisPore) holes per cm$^2$ (Tredegar Film Products, Richmond, VA) constituted one barrier type . The manufacturing method produced a depression around the hole on one side (female side of the barrier) and a corolla of sheet material around the hole on the other side (the male side of the barrier). Because of the asymmetrical form of the material, both sides of these sheets were evaluated as barriers. Another barrier type was made of woven strands of high density polyethylene (Chicopee, Gainesville, GA). Two types of weave were used, a regular weave [350 (#3) or 135 (#7) holes per cm$^2$] and a 2-1 twill weave [240 (#5) holes per cm$^2$]. Five sizes of brass strainer cloth (C. O. Jellif, Southport, CT) were also used: 1552 (#1), 557 (#6), 388 (#8), 246 (#9), and 139 (#10) holes per cm$^2$. A fibrous filter of unwoven polyester (#11) (Hygro-Gardens Inc., Colorado Springs, CO), was also tested. Twenty holes of each screen type were arbitrarily selected and the size measured with an ocular micrometer. Differences in screen hole sizes were analyzed using the previously described statistical methods.

**Cage Design.** A cage design was developed to test the ability of the insects to cross different barriers (Figure 1). Holes were formed in the lids and bottoms of disposable plastic culture dishes. Either two dish lids or two dish bottoms were placed back-to-back and a test barrier (screen or sheet material) was glued over the formed hole in betweeen the sections. Insects were placed into a bottom section of a culture dish. A sandwich of dish lids with a layer of screening between was fitted on top of the release chamber. The process was repeated using pairs of dish bottoms and dish tops creating a stack of chambers separated by four screen

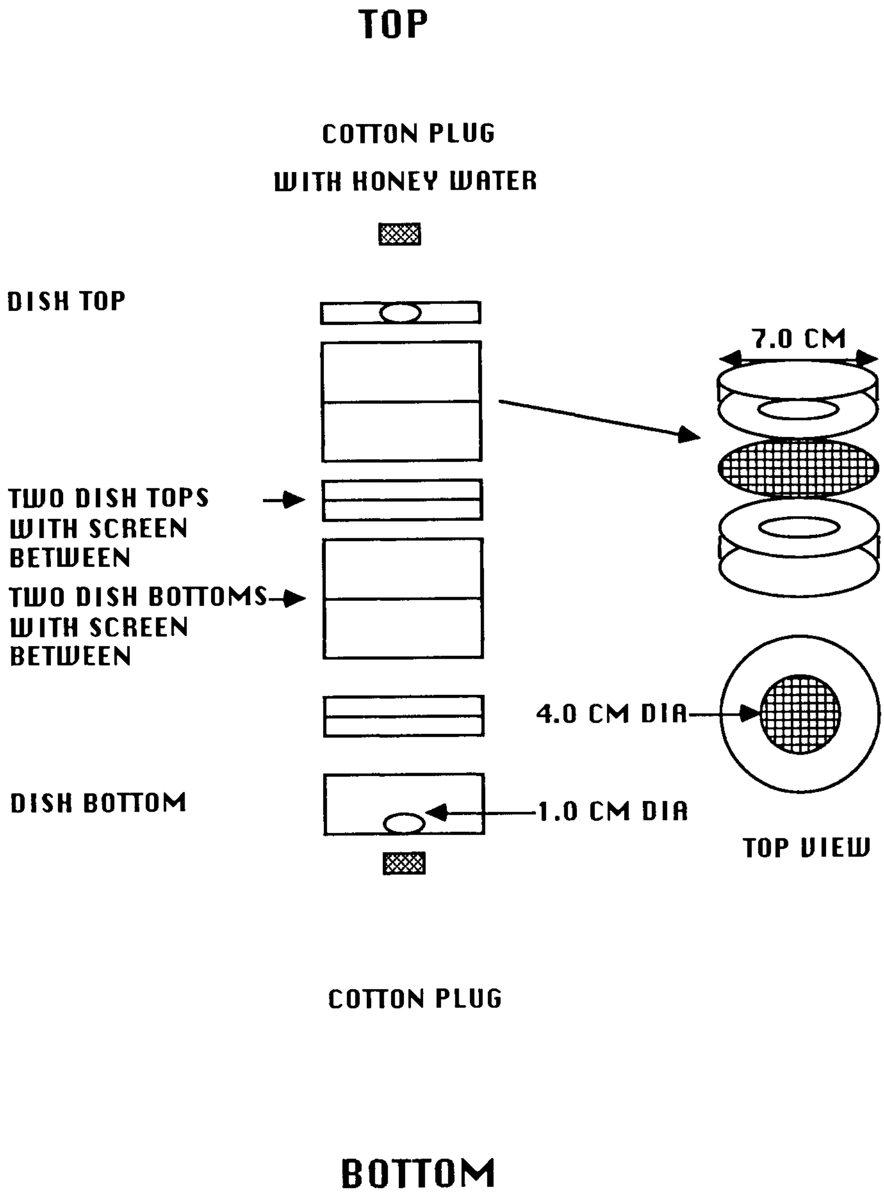


Fig. 1. Cage design for testing insect movement through barriers with different size holes.

barriers. A friction-sealed dish lid with a hole fitted with a cotton dental wick soaked in honey and water solution (50:50) was placed at the top of the stack. For each species, approximately 35 unsexed insects were arbitrarily selected from the existing colonies and placed in the bottom of a cage. Three replicates of each were conducted so that approximately 100 individuals of each species were tested. After introduction of the insects, the cages were placed vertically in an environmental chamber at 26.7°C, 14:10 (L:D) photoperiod with the release end down. The combination of stimuli, light, food, and negative geotropism, were used to encourage upward movement through the barriers. After 24 h, cages were frozen to kill the insects, fixing their positions within the arenas. Total numbers of insects in each level were counted and percentages of the total to reach the second and higher levels were calculated. Differences in ability of each species to move through one or more than one section of the different screen types were determined by Chi squared analysis (SAS Institute 1985, PROCFREQ) and means were separated by least significant difference test.

**Porosity.** Changes in air flow caused by the barriers were measured with a hot wire anemometer (Anemotherm, Hot Wire Anemometer #60). A seven-cm hole was cut in the center of the bottom of a 3.8 liter ice cream container (Fonda Group Inc., Union, NJ). The container was placed so that a stream of air blown by fan (2 - 3 m/sec) was directed through the hole and into the container. The aenemometer's sensor was inserted through a small hole on the side of the ice cream container perpendicular to the air flow. A cage section without the test barrier was placed in the hole in the bottom of the carton to obtain a control reading of the air flow. Sections with barriers in the center were then inserted and a second reading was taken. Two cage sections of each barrier type were each tested twice and in both directions to test if air flow was affected more from one direction than the other. Percent decrease in air flow was calculated by dividing the difference in air flow with and without barrier by the air flow without the barrier (multiplied by 100). No significant differences were observed in air flow between sides of the barriers, and consequently, the values were pooled for subsequent analyses. Differences in percent decrease in air flow through barriers were analyzed using previously described methods.

## Results

The mean thorax widths of the insect pest species tested differed significantly ($F = 356.2$, $df = 7, 138$, $p \leq .0001$) (Table 1). No male *M. persicae* or *A. gossypii* were measured as they are uniparental under greenhouse conditions. In addition to significant differences between species, conspecific males were smaller than females.

There were significant differences in percent decrease in air flow among screens (Table 2). Larger holes caused less reduction in the air movement. However, for barriers with smaller hole sizes, the polyethylene sheet barriers (#2 and 4) reduced air flow more significantly than did the woven or twill materials. The polyethylene sheets are asymmetrical by sides but the reduction in air flow was similar regardless which side faced the directed air stream.

*Myzus persicae* was the only insect species tested that did not pass through any barrier, including the unwoven polyester filter that every other species passed

**Table 1. Thorax width of five pests of greenhouse crops.**

| | Width (μm) ($\bar{x} \pm$ SE) | |
|---|---|---|
| Species | Male | Female |
| *Liriomyza trifolii* | 562.5 ± 14.2b | 653.8 ± 8.6a |
| *Myzus persicae* | N/A | 433.8 ± 13.4c |
| *Aphis gossypii* | N/A | 355.0 ± 7.2d |
| *Bemisia tabaci* | 215.8 ± 2.8f | 261.3 ± 4.6e |
| *Frankiniella occidentalis* | 184.4 ± 3.1g | 245.5 ± 8.1e |

Means followed by the same letter are not significantly different (p = .05, Analysis of Variance and Duncan's New Multiple Range Test).

**Table 2. Hole size and mean percent decrease in air flow compared to control of four screen types.**

| Screen | Material | Hole Size (μm²) ($\bar{x} \pm$ SE) | Mean % Decrease (± SE) In Air Flow† |
|---|---|---|---|
| 1 Brass Weave | 1552 Holes/cm² | 192.5 ± 2.6i | 46.8 ± 1.9cd |
| 2 Polyethylene Sheet | 248 Holes/cm² | 270.5 ± 11.0h | 72.9 ± 1.7a |
| 3 Polyethylene Weave | 350 Holes/cm² | 308.7 ± 2.9g | 49.1 ± 2.2c |
| 4 Polyethylene Sheet | 62 Holes/cm² | 337.5 ± 15.8fg | 73.5 ± 1.8a |
| 5 Polyethylene Twill | 240 Holes/cm² | 341.2 ± 4.9f | 60.2 ± 3.1b |
| 6 Brass Weave | 557 Holes/cm² | 462.5 ± 2.9e | 35.6 ± 3.0e |
| 7 Polyethylene Weave | 135 Holes/cm² | 530.0 ± 2.9d | 37.6 ± 1.7e |
| 8 Brass Weave | 388 Holes/cm² | 537.5 ± 4.3cd | 35.0 ± 1.5e |
| 9 Brass Weave | 246 Holes/cm² | 640.0 ± 5.6b | 35.1 ± 5.6e |
| 10 Brass Weave | 139 Holes/cm² | 938.8 ± 13.6a | 21.9 ± 2.2f |
| 11 Polyester | Unwoven | N/A | 40.6 ± 3.1de |

Means followed by the same letter are not significantly different (p = .05, Analysis of Variance and Duncan's New Multiple Range Test).

* Arcsin square root transformation performed on the data prior to analysis. F = 49.6; df = 13.70; $p \leq .0001$.

† F = 384.08; df = 11, 229; $p \leq .0001$.

through insignificant numbers (Table 3). The mean thorax width of *M. persicae* was 433.8 μm and there were five barriers (#6 - 10) with larger holes. Either the stimuli used in this test were inappropriate to encourage the aphid to move through the holes or the aphids do not readily pass through openings that are more than twice the size of the insect thorax.

*Liriomyza trifolii* were only able to pass through the unwoven filter (#11) and the brass weave (#10) cloth with holes (938.8 mm) which are 1.4 times larger than either sex (Table 3). Male *L. trifolii* were slightly smaller than holes in the brass weave (#9) with 640 μm holes, but no individuals penetrated that barrier. The holes had to be almost 1.5 times larger than the thorax width for individuals to pass through the barriers.

The second aphid species, *A. gossypii*, was significantly restricted by nine of the barriers. All barriers with holes smaller than the thorax width were unpenetrable. The percentage of melon aphids passing through the polyethylene weave (#7)

**Table 3. Proportion of insects (X ± SE) successful in penetrating one or more barrier sections.**

| Screen* | *L. Trifolii* | | | *A. Gossypii* | | |
|---|---|---|---|---|---|---|
| | N | One Section | More Than One | N | One Section | More Than One |
| 1 | 113 | 0.0b | 0.0b | 105 | 0.0d | 0.0d |
| 2 (♂ side facing out) | 58 | 0.0b | 0.0b | 68 | 0.0d | 0.0d |
| 2 (♀ side facing out) | 40 | 0.0b | 0.0b | 118 | 0.0d | 0.0d |
| 3 | 93 | 0.0b | 0.0b | 94 | 0.0d | 0.0d |
| 4 (♂ side facing out) | 87 | 0.0b | 0.0b | 107 | 0.0d | 0.0d |
| 4 (♀ side facing out) | 110 | 0.0b | 0.0b | 132 | 2.3 (± 1.3)cd | 0.0d |
| 5 | 74 | 0.0b | 0.0b | 101 | 0.0d | 0.0d |
| 6 | 103 | 0.0b | 0.0b | 130 | 1.5 (± 1.1)cd | 0.8 (± 0.8)d |
| 7 | 116 | 0.0b | 0.0b | 110 | 7.3 (± 2.5)bc | 0.9 (± 0.9)d |
| 8 | 122 | 0.0b | 0.0b | 124 | 3.2 (± 1.6)cd | 0.0d |
| 9 | 114 | 0.0b | 0.0b | 93 | 11.8 (± 3.4)b | 10.8 (± 3.2)c |
| 10 | 117 | 4.3 (± 1.9)a | 1.7 (± 1.2)a | 117 | 45.3 (± 4.6)a | 24.8 (± 4.0)b |
| 11 | 107 | 5.6 (± 2.2)a | 0.0b | 131 | 44.3 (± 4.4)a | 38.2 (± 4.3)a |

**Table 3. Continued.**

| | B. Tabaci | | | F. Occidentalis | | |
|---|---|---|---|---|---|---|
| Screen* | N | One Section | More Than One | N | One Section | More Than One |
| 1 | 128 | 0.0f | 0.0e | 108 | 5.6 (± 2.2)e | 5.6 (± 2.2)e |
| 2 (♂ side facing out) | 112 | 0.0f | 0.0e | 107 | 14.0 (± 3.4)e | 8.4 (± 2.7)e |
| 2 (♀ side facing out) | 114 | 9.7 (± 2.3)e | 5.5 (± 2.2)de | 129 | 60.5 (± 4.3)b | 41.1 (± 4.3)cd |
| 3 | 104 | 0.0f | 0.0e | 110 | 60.0 (± 4.7)b | 41.8 (± 4.7)bc |
| 4 (♂ side facing out) | 112 | 0.0f | 0.0e | 119 | 10.1 (± 2.8)e | 9.2 (± 2.7)e |
| 4 (♀ side facing out) | 108 | 3.7 (± 1.8)ef | 0.0e | 114 | 83.3 (± 3.5)a | 75.4 (± 4.0)a |
| 5 | 100 | 0.0f | 0.0e | 83 | 56.6 (± 5.5)bc | 49.4 (± 5.5)bc |
| 6 | 130 | 0.0f | 0.0e | 79 | 44.3 (± 5.6)d | 29.1 (± 5.1)d |
| 7 | 115 | 32.2 (± 4.4)c | 19.1 (± 3.7)c | 61 | 44.3 (± 6.4)d | 37.7 (± 6.3)cd |
| 8 | 132 | 4.6 (± 1.8)ef | 0.0e | 146 | 47.3 (± 4.1)cd | 40.4 (± 4.1)cd |
| 9 | 95 | 21.1 (± 4.2)d | 8.4 (± 2.9)d | 106 | 84.0 (± 3.6)a | 80.2 (± 3.9)a |
| 10 | 98 | 54.1 (± 5.1)b | 40.8 (± 5.0)b | 123 | 57.7 (± 4.5)bc | 52.9 (± 4.5)b |
| 11 | 126 | 65.9 (± 4.2)a | 47.6 (± 4.5)a | 101 | 58.4 (± 4.9)bc | 46.9 (± 5.0)bc |

* Screen numbers refer to descriptions from Table 2 and are arranged by increasing hole size.
Means followed by the same letter in a column are not significantly different ($p = .05$, chi-square analysis and least significance difference test).

(530.0 µm) was not significantly different from the percentage penetrating the brass weave (#8) (537.5 µm). There were no differences in penetration of brass screen (#8) and any of the screens with smaller holes (#1-7). There were no differences in the percentage penetration (7.3%) of the 530 µm polyethylene weave (#7) and the brass weave (#9) with 640 µm holes (11.8%). This suggests, at least for this species, there is an interaction between hole size and barrier composition. As with *L. trifolii,* the holes had to be approximately 1.5 times the size of the thorax for *A. gossypii* to penetrate.

*Bemisia tabaci* demonstrated similar ability to penetrate the screens (Table 3). There was a significantly higher penetration of the 530 µm polyethylene weave (#7) than the 537.5 µm brass weave (#8). This species also showed a slight tendency to penetrate through holes on the female side of the polyethylene sheets (#2,4), but they did not move through the same holes from the male side. Unlike the previous two insects, the holes had to be larger, approximately twice the thorax width, for the insect to penetrate.

*Frankliniella occidentalis* was the smallest insect tested (Table 1) and penetrated through all barriers (Table 3). Unlike the other species, this insect passed through holes only slightly larger than the width of its own thorax. As observed with *B. tabaci,* a significantly larger percentage of individuals moved through the polyethylene sheet barriers (#2,4) from the female side than from the male side. The percentage of thrips that moved through smaller holes from the female side of the sheets (#2 or #4) was either significantly greater than or not significantly different from the percentage of thrips that moved through much larger holes in the woven material (#5 - 10). This species is frequently found in tight spaces and between flower petals in closed buds (Robb 1989). It is possible that the unobstructed opening and tight sides of the holes presented by the female side stimulated movement through the barrier. The male side has a corolla of barrier material around the hole which may effectively hide the opening from small individuals.

## Discussion

Exclusion of arthropod pests by barriers from greenhouse horticulture is an alternative to remedial control of established populations with pesticides (Mears 1990). Few, if any, greenhouses are actually closed systems. Most have varying degrees of openness, including: fans for positive or negative air flow, vents both on the sides and/or top; and sidewalls that can be covered with shadecloth or left open. Our results suggest that covering the open areas of the greenhouse with screening will effectively deter certain insect pests. However, the crop's injury threshold and pest complex (i.e. the part of the plant affected by the insect) is very important when considering the size or type of screening to be used. In addition, methods of compensation for loss in air flow due to screening of the vents or fans must be considered (Robb and Parrella 1988).

Use of screening to reduce pest densities in greenhouses has worked well in applied situations (Robb and Parrella 1988). Our study was designed to test the ability of the five critical pests to pass through the barriers. Our results suggest that insect populations of each of these species may be reduced through the use of screens. However, the pest complex and cost are obvious considerations. Metal screens, are more durable and more costly. Polyethylene screens last only a short time but are easily replaced and are relatively inexpensive.

The species tested showed varying ability to pass through barriers with different hole sizes. Any barrier, when challenged by a complex of pest species, is unlikely to be absolute, rather there is a probability of excluding most, but not all, individuals. In the study reported here, unsexed individuals were used in the barrier cages and the passage of any insects through the barriers was recorded. Because males were smaller than females, they may be more likely to pass through barriers. They do not reproduce but may be capable of transmitting disease. Thus, the results indicate the most resistant barriers to any given insect species, not just the barriers that screen out the larger individuals. Decisions to use screen barriers with a particular hole size must carefully evaluate the compromises arising from the insect pest complex, the probability of exclusion, potential damage to the greenhouse crop, reduction in light or air flow, and cost of both the screen and any additional remedial control measures.

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