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Pubescence as a Factor in Codling Moth, Oviposition, and Fruit Entry in Five Apple Selections

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Abstract. **Significant differences ($P = 0.05$) in fruit infestation by codling moth larvae were found when fruit of 5 apple selections, with different levels of leaf pubescence, were evaluated. No differences in entry into fruit were found when larvae were placed on the relatively glabrous upper leaf surface. Selections having a pubescent lower leaf surface had significantly ($P < 0.05$) reduced numbers of entries. Females allowed to oviposit freely on fruit and leaves preferred to oviposit on the glabrous upper leaf surface. In all but one selection, more eggs were laid on the leaves than on the fruit. About 70% of larval entries were found in the midsection of the fruit, with 14% and 15% occurring at the calyx and stem ends, respectively. Larval entry was increased on the side of the fruit closest to the light source. Leaf pubescence seems to be a factor in 1st brood codling moth preference of apple cultivars.**

Production of commercially acceptable apple fruit in the United States is hampered by the presence of a complex of arthropod pests and diseases. The codling moth (CM) is a key pest of this complex, and the damage it causes has zero tolerance during fruit grading. Among other factors, morphology, specifically pubescence, has been reported to influence the behavior of this insect (3, 4, 6, 7). The literature also suggests different preferences for oviposition sites by CM on apple and pear (4, 7). This study quantifies leaf pubescence and investigates its effect on female oviposition and the patterns of apple fruit infestation by neonate larvae.

Five apple selections (1225-100, 673-20, 1500-100, 1569-100, and 1689-110) were chosen, based on reported (6) differences in their leaf hair densities, to give us a range of leaf pubescence. Newly hatched CM larvae were used in all tests, except Test 3 (leaf hairs), which were conducted in a growth chamber operating at 22.5° ± 1.5°C, 90% + 10% RH and 16 hr illumination with 24, 40 W cool-white fluorescent lights. Fruit bearing spurs (FS), removed from the tree 14 to 19 days after the first male CM was trapped with a pheromone baited trap (Zoecon Corp., Palo Alto, Calif.), were placed about 60 cm from the light source. All larvae were placed on a leaf of the FS 6.5 cm from a leaf axil. The twig was considered the main axis in both tests. Testing was timed to conform with the phenological events (1st cover) of apple tree development at Lafayette and emergence of the 1st brood of CM. Tests were terminated after 48 hr.

Test 1. Oxine-citrate-sugar solution (5) (hereafter called "sugar solution") has been reported to promote freshness in cut flowers (5), but its effect on apple plant parts and CM larvae is unknown. We therefore investigated its effect on our apple test system by comparing it with distilled water. FS's taken 14 days after the capture of the 1st CM male were cut to give a twig segment (2.5 cm long) bearing a single fruit (4 cm o.d.) and 3 leaves. This unit was immersed in a shell vial (21 × 70 mm) containing either the sugar solution or distilled water (Fig. 1). There were 4 treatments (water only, sugar solution only, larvae + water only, larvae + sugar solution only) which were replicated 4 times for each selection. We placed one larva on the midrib (generally the most densely pubescent area of a pubescent leaf) of the upper leaf surface of one leaf and another larva on the lower leaf surface of the opposite leaf of each replicate in each of 2 treatments, the other 2 treatments serving as controls.

A leaf disk (0.75 cm o.d.) was removed for leaf hair counts from one-half of the uninfested leaf of each spur at the beginning of the experiment and from the same location of the opposite half of the leaf at the end (2

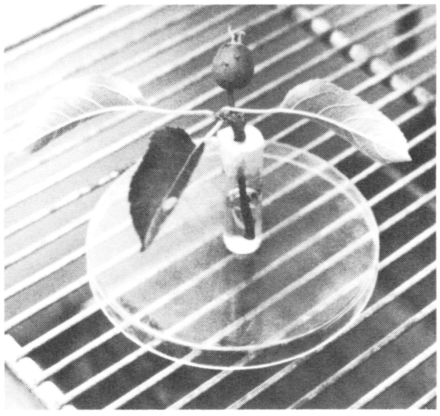

Fig. 1. A fruit spur exposed to codling moth larvae in Test 1, showing a larval entry(s) used in evaluating apple selections.

Table 1. Mean number of leaf hairs per disk[z] (Test 1) and mean number codling moth larval entries[y] per apple found when larvae were placed at the same point of the upper and lower surface of a leaf in a growth chamber study (Test 2).

Apple selection	Mean no. leaf hairs disk	Mean no. of entries/apple by CM larvae placed on	
		Upper leaf surface	Lower leaf surface[x]
673-20	12.8[w] a	1.75 a	2.38 a
1569-100	18.4 a	1.63 a	2.00 a
1225-100	19.4 a	0.63 b	1.00 b
1689-110	30.8 b	1.75 a	1.00 b
1500-100	35.9 b	1.75 a	0.63 b

[z]Leaf disks of 0.75 cm diameter were taken from opposite sides of the leaf midrib from the same location near the leaf tip.
[y]An entry was determined if fresh frass was present.
[x]Lower leaf surface more pubescent than upper leaf surface.
[w]Mean separation within a column by Duncan's multiple range test, 5% level.

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Table 2. Mean egg counts on fruit spurs bearing a single leaf and fruit from 5 apple selections exposed to 25 pairs[z] of codling moth adults for 4 days in growth chamber study.

Apple selection	Mean no. of eggs deposited				
	Leaf surface		Fruit sections[y]		
	Upper	Lower	Calyx	Middle	Stem
673-20	14.4[x] ab	14.5 b	1.1	17.1	1.6 b
1569-100	27.5 bc	6.9 ab	1.4	20.1	4.5 a
1225-100	18.9 abc	14.3 b	1.3	15.4	1.6 b
1689-110	12.6 a	1.0 a	1.6	15.8	1.4 b
1686-1	29.5 c	2.6 ab	0.4	14.8	0.3 b

[z]Twenty-five pairs of codling moth were introduced into a cage (47 × 47 × 47 cm) with 40 fruit spurs (i.e., 2 replicates per cage of 4 apples per replicate of 5 selections). Two such cages were used in this study.
[y]An apple was divided as shown in Fig. 2 for determining counts of eggs.
[x]Mean separation within columus by Duncan's multiple range test, 5% level.

days later) of the experiment. The disks were processed for counting pubescence on the lower leaf surface as described in Test 3. The counts of larval fruit entries (both successful and attempted) as indicated by fresh frass, and those of leaf hair were each analyzed using an analysis of variance (ANOVA), and Duncan's multiple range tests were used for comparing means.

Sparseness of pubescence on the upper leaf surface reported earlier (2) for some related selections was confirmed microscopically; however, the mean number of hairs/leaf disk from the lower leaf surface ranged from 12.8 to 35.9 (Table 1). Although hair density was not significantly different between selections 1689-110 and 1500-100, both were significantly (P = 0.05) more pubescent than selections 673-20, 1569-100 and 1225-100. No significant differences in larval damage (mean number of stings/apple = 0.85 and 0.95 for water and sugar solution, respectively) or apparent changes in freshness were observed between the treatments. Thus, the suitability of the test system was demonstrated.

Test 2. Pubescence in apple leaves is due to simple, nonglandular hairs (2). FS collected 19 days after the capture of the 1st CM were pruned to a single fruit and leaf per spur and placed in vials containing the sugar solution. A single larva was placed on the midrib of the upper (treatment 1) and another on the midrib of the lower (treatment 2) leaf surfaces of each apple selection for comparing differences in infestation of fruit. Selections were replicated twice in each treatment. Each fruit was divided arbitrarily into sections for determining larval entries (Fig. 2), and these counts, corresponding to their relative position, were used in an ANOVA.

Significant differences among selections (P = 0.05) was found for the numbers of larval entries and for the interaction between the location of larval placement on the leaf (upper vs. lower) and selection (P = 0.01) (Table 1). Mean number of entries for larvae placed on the upper leaf surface did not differ among selections 673-20, 1569-100, 1689-110, and 1500-100, but the number of entries was significantly reduced for selection 1225-100. The low pubescent selections, 673-20 and 1569-100, had significantly more larval entries than the other selections when larvae were placed on the lower leaf surface (Table 1). The correlation coefficient (r) between mean number of leaf hairs/disk and mean number of entries from the upper leaf surface (values ranged from 0.63–1.75) was 0.28 and from the lower leaf surface (values ranged from 0.63–2.38) was −0.85, which was below the value of 0.88 needed for significance at P = 0.05. The data from the lower leaf surface suggest that pubescence may act as a partial barrier to larvae reaching and penetrating apple fruit.

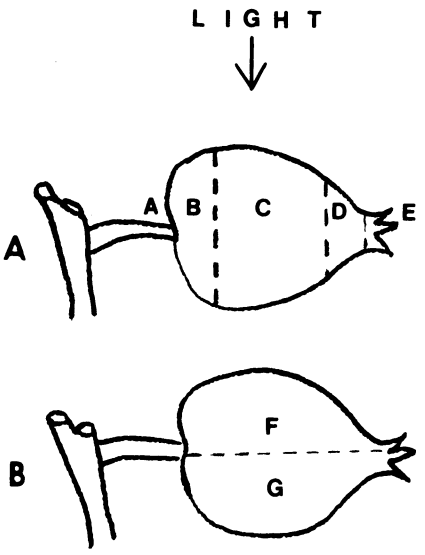

Fig. 2 The division of a fruit for recording counts of entries.
A. The fruit divided into vertical sections: A = stem end; B = area between stem end and mid-section - a distance of 1 cm from the stem; C = mid-section; D = area between mid-section and calyx - a distance of 1 cm from the calyx; and E = calyx.
B. The fruit divided along the horizontal axis: F = half closest to light source in growth chamber (upper); and G = half furthest from light source (lower).

The mid-section (section C, Fig. 2) of the fruit had 70.4% of the entries, whereas 13.8% and 14.8% of the entries were at the calyx and stem end, respectively. We also found 93% of the entries were on the upper half of the apple fruit (i.e., the surface closest to the light source), whereas only 7% of the entries were on the lower half (i.e., the surface most distant from the light source). This laboratory finding differs from the field observations of other investigators (1) and (3), perhaps due to the many uncontrollable variables encountered under field conditions. We determined only 1.7% of all entries through the fruit calyx, possibly due to differences resulting from orientation of the fruit surface to incident light. Pubescence of the calyx of young fruit (8) also may have resulted in a lower number of entries at this site.

Test 3. Determination of leaf hair length was difficult because they are long, prone, and twisted. Attempts at removing intact leaf hairs by procedures such as brushing after immersion in liquid N, desiccating with glycerin, borax, paraquat and removing hair at the cell surface with depilatory agents (Neet and Hair) before counting stubs were not effective and caused severe damage to the leaf epidermis. Leaf sections, therefore, were examined by SEM as described previously (2). The average length of 7 complete hairs identified from numerous SEM fields of the lower leaf surface (photographed at × 100), of all the selections, was 800μ.

Test 4. Due to lack of fruiting in selection 1500-100, 1686-1 was substituted. Both selections were reported (6) to have similar

Table 3. Mean number of larval entries[z] per apple from eggs laid by 25 pairs[y] of codling moth adults in a growth chamber study of spurs from 5 selections bearing a single leaf and fruit. Data were taken 7 days after adults were introduced.

Apple selection	Location of mean number of larval entries of apple[x]						
	Calyx	Calyx end	Mid-section	Stem end	Stem	Upper fruit surface	Lower fruit surface
673-20	0.1	0.6	6.1	0.8	0.6 ab[w]	4.4	3.9
1569-100	0.3	0.9	6.8	1.6	1.0 a	7.0	3.5
1225-100	0.4	0.9	10.3	2.1	0.5 ab	8.4	5.6
1689-110	0.3	1.0	5.9	1.1	0.3 b	5.0	3.5
1686-1	0.3	0.6	5.9	1.1	0.4 ab	4.6	3.4
Location mean	0.3[v]	0.8	7.0	1.3	0.5	5.6	4.0

[z]An entry was determined if fresh frass was present.
[y]Twenty-five pairs of codling moth were introduced into a cage (47 × 47 × 47 cm) with 40 fruit spurs (i.e., 2 replicates per cage, of 4 apples per replicate of 5 selections). Two such cages were used in this study.
[x]An apple was divided as shown in Fig. 2 for determining counts of larval entries.
[w]Mean separation within columus by Duncan's multiple range test, 5% level.
[v]Differences between location means 0.8 vs. 0.3, 1.3 vs. 0.5, and 5.6 vs. 4.0; significant at P = 0.01.

densities of pubescence. Two replicates (4 FS's with a single fruit per replicate) of each selection were placed in each of 2 wooden screen cages (47 × 47 × 47 cm), held in growth chambers maintained as in Test 2, and 25 mated pairs of CM per cage were released. Adults were removed after 4 days, and the number of eggs and their location on the leaf and fruit were determined. Larval entries were counted three days later and the site of entry into the fruit sections noted as designated in Fig. 2. The data were analyzed using ANOVA, and the means were separated using the Duncan's multiple range test. Student's paired *t* test was used to test significance of differences between the mean numbers of larval entries (location means) into the designated sections of the fruit. Data from the mid-section were not compared with the other sections because its surface area differed from the others.

In all selections, except 673-20 where the numbers were almost equal, more eggs were deposited on the upper leaf surface than the lower (Table 2). The lowest number of eggs was deposited on both leaf surfaces of selection 1689-110, and these were significantly different from those for the upper surface of selections 1569-100 and 1686-1 and the lower surface for 673-20 and 1225-100 (Table 2). Differences between egg numbers on the upper and lower leaf surfaces were significant ($P<.0.05$) for selections 1569-110, 1589-110, and 1686-1. When the mean number of eggs deposited on the lower leaf surface of all low pubescent selections (673-20, 1569-100, 1225-100) and those of the highly pubescent selections (1689-110, 1686-1) were calculated and compared (*t* test), the differences were significant at $P=0.01$, suggesting a distinct preference by ovipositing CM for the low pubescent surfaces. Although a significantly ($P=0.05$) greater number of eggs were found in the middle part of the fruit as compared to the calyx or stem ends, the differences in the total number of eggs deposited on the fruit among selections were not significant. In selections 673-20, 1225-100, 1686-1 and 1569-100, a higher percentage of oviposition (range 59.9% to 57.6%) occurred on the leaf than on the fruit (range 32.4% to 43.0%), whereas on selection 1689-110, the reverse was true.

Our findings in the caged pairs test agreed with those of Test 2. The number of larval entries was lowest at the calyx end of the fruit and highest in the mid-section of the fruit (Table 3). Although the differences between selections in larval entries were nonsignificant, there were more entries on the upper fruit surface than from the lower fruit surface. Differences in mean larval entries between location of entries, i.e., calyx vs. calyx end, stem vs. stem end, and upper vs. lower leaf surface, were all significant ($P=0.05$).

The overall data from Test 2 generally indicate that larvae reached the fruit from either leaf surface in spite of being placed on the most pubescent (midrib) part of the leaf. The survival of larvae on pubescent surfaces and the oviposition preference of females for glabrous surfaces suggests that leaf pubescence was probably an oviposition rather than a larval barrier.

The factors that determine resistance to CM are poorly understood and may include chemical, physical, and environmental factors. Leaf pubescence, as indicated in this study of a single stage in apple development under controlled environmental conditions, was a factor in the success of CM larvae reaching the fruit.

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Effect of Chemical Thinners on 'Delicious' Apple Trees Previously Sprayed with GA_{4+7} + BA

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Abstract. **Fruit thinning by a postbloom spray of 1-naphthyl n-methycarbamate (carbaryl) or naphthaleneacetic acid (NAA) was not increased by a previous full bloom spray of gibberellin A_{4+7} (GA_{4+7}) plus 6-benzylamino purine (BA). Chemical thinning generally increased return bloom but not fruit size. GA_{4+7} + BA consistently increased the fruit L/D ratio, showed no effect on fruit size or seed number, and these responses were not altered by the chemical thinners. Overall responses were similar for trees treated either one or 2 consecutive years with GA_{4+7} + BA and chemical thinners. Response to treatment was similar among strain of 'Delicious' and did not vary with tree age.**

'Delicious' apples produced in many areas of the United States are less elongated than those grown in the northwestern part of the country. Thus, the proprietary formulation of GA_{4+7} + BA (Promalin; Abbott Laboratories, North Chicago, IL 60064) frequently is applied in the northeastern and midwestern United States to elongate 'Delicious' fruit in order to facilitate marketing. Fruit set of 'Delicious' in these areas is frequently light (2), and the cultivar is considered easy to thin (16). It is known that GA_{4+7} + BA can thin apples (13, 14) and that effects of chemical thinners may be additive, especially when thinners belong to different classes of compounds (1, 15).

This experiment was designed to determine if a previous application of GA_{4+7} + BA on 'Delicious' trees at full bloom (FB) would enhance thinning by a postbloom application of a chemical thinner, and to determine if the fruit responses to GA_{4+7} + BA are altered by chemical thinners. All trees used in this investigation were growing at the Horticultural Research Center, Belchertown, Mass.

Trials with mature 'Richard Delicious'. Four limbs, 12–15 cm in circumference, per tree on Malling 7a rootstock were tagged, and bloom was counted prior to full bloom. Eight trees were selected in 1979 and 10 in 1980. One day after FB, 2 of the 4 limbs/trees received a dilute application of 25 ppm GA_{4+7} and BA (as the proprietary formulation Promalin; Abbott Laboratories, North Chicago, IL 60064) in 0.125% Glyodin. A dilute spray of carbaryl was applied in 1979 and 1980 at 1200 ppm 22 days after FB on

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