Site Selection for Oviposition and Larval Feeding by the Tufted Apple Bud Moth (Lepidoptera: Tortricidae) on Apple in Pennsylvania[1]

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ABSTRACT Intensive sampling was used to characterize the size and leaf type for tufted apple bud moth, *Platynota idaeusalis* (Walker), egg mass deposition, and to determine the association and site of larval feeding on fruit and foliage in Pennsylvania apple orchards. Results suggest tufted apple bud moth prefer to oviposit on smaller leaves (<20 cm^2), and egg mass size was 0.16 cm^2 during first brood and 0.12 cm^2 during second brood. Significantly more first and second brood egg masses were oviposited on leaves within nonfruiting spurs than on either vegetative shoots or fruiting spurs. Both larval broods were found in association with leaves only rather than leaves and fruit. Fruit injury due to larval feeding during both broods occurred more on the calyx (sepals) surface area than the side or stem surface areas of the fruit. In cultivar comparisons of fruit, more surface injury was located on the site of the fruit from 'Stayman' trees than for 'Golden Delicious' trees.

KEY WORDS *Platynota idaeusalis*, tortricid, sampling, apple injury, Tufted Apple Bud Moth.

The tufted apple bud moth, *Platynota idaeusalis* (Walker), has been causing minor injury to apple fruit in south-central Pennsylvania orchards since 1918 (Frost 1923), but since 1969 it has become a more serious pest (Bode et al. 1973). Larvae overwinter in the ground cover below fruit trees (Knight and Hull 1988) and finish development the following spring. Adults begin to emerge in May and larvae feed during June and July. Third instar larvae characteristically form protective shelters by cutting the petiole of a leaf and rolling it lengthwise, by tying leaves together, or by feeding in between clusters of developing fruit. The adults from this first brood begin to emerge in late July and August, oviposit, and the second-brood larvae feed during September and October.

Recently, tufted apple bud moth research in Pennsylvania has been directed primarily to sampling and population movement (Meagher and Hull 1987, Knight and Hull 1988, Knight et al. 1990), insecticide resistance (Meagher and Hull 1986b, Knight and Hull 1989), and predicting and evaluating apple injury (Meagher and Hull 1986a, Hull and Rajotte 1988). Little work has been done describing specific aspects of tufted apple bud moth ovipositional, larval, or feeding behavior. The objectives of this study were to characterize the size and ovipositional leaf type on which tufted apple bud moth egg masses were found, and to determine the larval association and site of larval feeding on fruit and foliage. Information concerning

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the physical location of egg masses, larvae, and larval feeding injury, would be helpful in future population dispersion and predictive sampling studies.

Materials and Methods

Study Site. This study was conducted in a 0.7 ha orchard in Arendtsville, PA containing 27-yr-old apple trees planted on EM 7 rootstocks and arranged in mixed-cultivar rows. Cultivars of equal numbers included Delicious, Golden Delicious, Stayman, and Rome Beauty. Tree size was maintained by pruning to a height of ca. 3.4 m and a width of ca. 3.5 m. Distance between the rows was 10.7 m, and distance between trees was 3.7 m.

Tufted Apple Bud Moth Sampling. Sampling and orchard arrangement were the same as reported by Meagher and Hull (1987). In 1982, 10 trees each of 'Golden Delicious' and 'Stayman' from the southern section of the orchard were sampled in late July and early August for first-brood egg masses and larvae. During this period in season, most tufted apple bud moth were either late instar larvae or pupae, and second-brood egg masses were not yet deposited (Bode 1975). Sampling was completed at this time because late instar larvae or pupae were easy to locate and were the least likely to move within the tree if disturbed. This section of the orchard was left untreated with insecticides until mid-August. A standard fungicide spray schedule was applied to the entire orchard (Anonymous 1982). Eight 'Stayman' trees in the northern section were sampled during late September and early October for the second brood. This section was treated with routine applications of insecticides until late July and then left untreated except for fungicide sprays the remainder of the season.

Sampling for egg masses and larvae was labor-intensive since all leaves and fruit on the trees were examined. Sampling duration was as long as 25 man/hr. per tree, especially during second brood. Egg masses were recorded as being oviposited on a leaf within a fruiting or nonfruiting spur, or on a vegetative shoot. The number of leaves in the fruiting or nonfruiting spur was also recorded. Surface areas of the egg masses and associated leaves were measured using a LiCor® leaf area meter. Leaf areas of leaves with egg masses were classified into five groups (0-10, 10-20, 20-30, 30-40, and > 40 cm^2) for frequency analysis. Larval shelters were opened to identify the leafroller species present, and the larvae were recorded as being associated only with leaves (nonfruiting spurs or vegetative shoots) or with leaves and fruit (fruiting spurs).

Fruit Area Injury Evaluation. Fruit injury caused by tufted apple bud moth larvae was measured by looking at all dropped fruit and a random sample of 100 apples from each tree for both sections of the orchard. Injury was separated by brood and cultivar and categorized as injury to the calyx (sepal), side, or stem area of the apple. First-brood injury sampled late in the season appeared as surface-feeding scars surrounded by varying degrees of decay. Second-brood injury appeared "fresher" and the injury margins were more defined.

Statistical Analysis. All data were subjected either to analysis of variance (Proc ANOVA, REGWF test), or to Proc TTEST (SAS Institute 1982). Leaf area data associated with egg mass deposition were subjected to chi-square analysis.

Results

Tufted Apple Bud Moth Sampling. The average leaf area on which an egg mass was oviposited was 14.1 ± 1.2 (SE) and 19.2 ± 1.4 cm^2, for first brood 'Golden Delicious' and 'Stayman' trees, respectively. Chi-square analysis of the leaf area frequency distribution was significant for both cultivars ($P < 0.01$), with more than 65% of the leaves less than 20 cm^2 containing egg masses (Fig. 1). The range of leaf areas with egg masses was 0.5 to 50.7, and 1.0 to 69.0 cm^2, respectively, for 'Golden Delicious' and 'Stayman,' and the average number of leaves associated with the leaf on which oviposition occurred for nonfruiting spurs was 5.0 ± 0.3, 'Golden Delicious,' and 5.3 ± 0.3, 'Stayman.' Egg mass area on both cultivars averaged 0.16 ± 0.01 cm^2. Second-brood egg masses were slightly smaller (0.12 ± 0.01 cm^2) but were found on larger 'Stayman' leaves (23.7 ± 0.6 cm^2). The leaf area frequency distribution for leaves with egg masses again was significant ($P < 0.01$), but the distribution among classes was more even than during first brood (Fig. 1). Leaf areas with egg masses ranged from 0.5 to 71.0 cm^2, and the average number of leaves associated with the oviposited leaf on nonfruiting spurs was 3.4 ± 0.1. Significantly more first brood egg masses/tree were deposited on nonfruiting spurs than vegetative shoots or fruiting spurs (7.2 ± 1.0, 1.6 ± 0.3, 0.7 ± 0.3, respectively, $P = 0.0001$). Similarly, more second brood egg masses/tree were found on nonfruiting spurs and vegetative shoots, than fruiting spurs (53.8 ± 7.3, 36.8 ± 7.1, 2.3 ± 0.5, respectively, $P = 0.0001$). Analysis of variance suggested no cultivar by oviposition location interaction for either brood ($P > 0.05$).

Significantly more first-brood tufted apple bud moth larvae/tree were associated with leaves only (23.1 ± 5.0) than with fruit and leaves (2.3 ± 0.7, $P = 0.0001$). Analysis of variance suggested no cultivar by larval association interaction ($P > 0.05$). Second-brood larvae were also found associated more with leaves only than with the combination of fruit and leaves (125.3 ± 14.0, 22.0 ± 2.7, $P = 0.0001$).

Fruit Area Injury Evaluation. First-brood tufted apple bud moth injury occurred more on the calyx area of the apples than the side or stem areas (percentage injury: 51.5 ± 2.9, 35.7 ± 2.7, 12.8 ± 2.1, respectively, $P = 0.0001$). A similar pattern resulted for second-brood injury; the most injury was found on the calyx area, followed by the side and the stem area (percentage injury: 57.4 ± 2.3, 30.7 ± 1.9, 11.9 ± 1.3, respectively, $P = 0.0001$). Cultivar differences were found when relating injury at the different apple locations. First-brood calyx injury was higher among 'Golden Delicious' than 'Stayman' apples, but the reverse was true for stem injury. Side injury was similar with both cultivars (Fig. 2). Second-brood calyx and side injury to fruit were similar between cultivars, but again 'Stayman' apples had higher stem area injury than 'Golden Delicious' apples (Fig. 2). Comparisons were also made among the location of injuries on dropped fruit as well as fruit picked from the tree. For both the first and second brood, calyx injury was found more in picked fruit samples, while side injury was found more from dropped fruit samples (Fig. 3). Stem area injury was equal between picked and dropped fruit samples for first-brood injury, but was higher in dropped fruit samples for second brood-larvae.

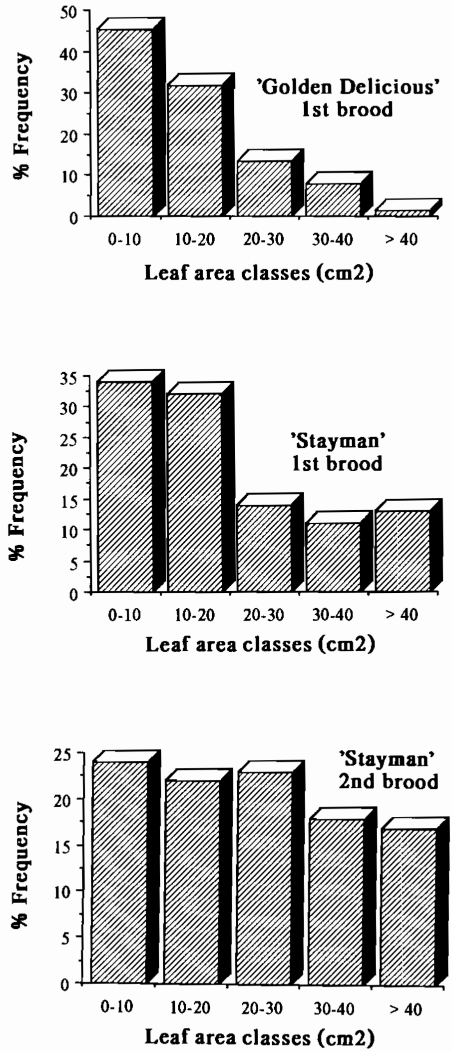

Fig. 1. Frequency of tufted apple bud moth egg masses found within different leaf area classes for first ('Golden Delicious' and 'Stayman') and second brood ('Stayman'). Chi-square analysis showed significant ($P < 0.01$) differences among classes for each cultivar/brood.

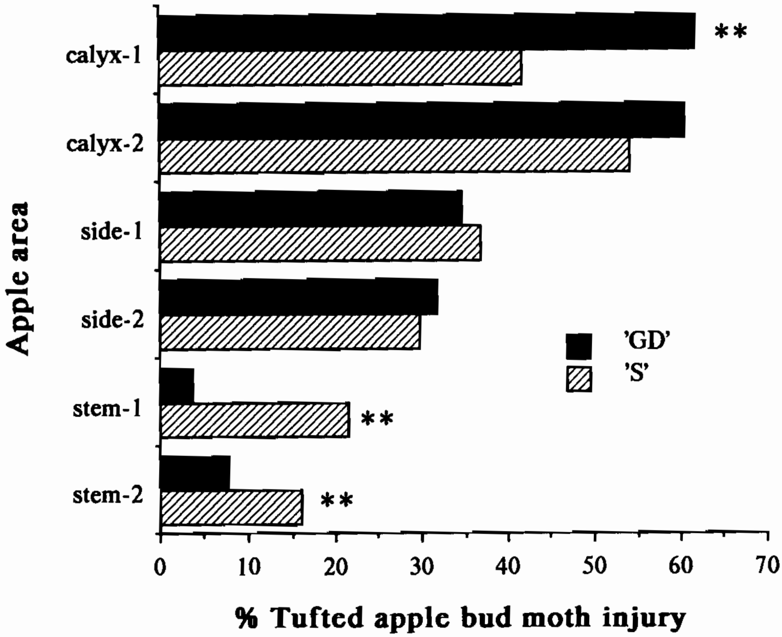

Fig. 2. Cultivar comparisons ('GD,' 'Golden Delicious'; 'S,' 'Stayman') of % tufted apple bud moth injury on different surface areas of the fruit during first- and second-brood larval feeding. Comparisons were made within apple surface areas and broods (** $P < 0.01$, * $P < 0.05$, Proc ANOVA [SAS Institute 1982]).

Discussion

The egg mass sampling data suggest tufted apple bud moth prefer to oviposit on smaller leaves (< 20 cm^2), although it is not known what the leaf area distribution is on standard apple trees. It is possible that smaller leaves predominated on these trees and that our results reflected a random distribution of oviposition in regard to leaf area. The proximity of fruit to foliage does not appear to stimulate oviposition, since most eggs were deposited on groups of leaves or single terminal shoot leaves, not on leaves associated with fruiting spurs. The ovipositional behavior of tufted apple bud moth is dissimilar to that of an internal fruit feeder such as the codling moth, *Cydia pomonella* (L.), which lay eggs near fruit (Wood 1965, Jackson 1979).

Some of the larger egg masses found during first brood may have been a result of confusing obliquebanded leafroller, *Choristoneura rosaceana* (Harris) egg masses

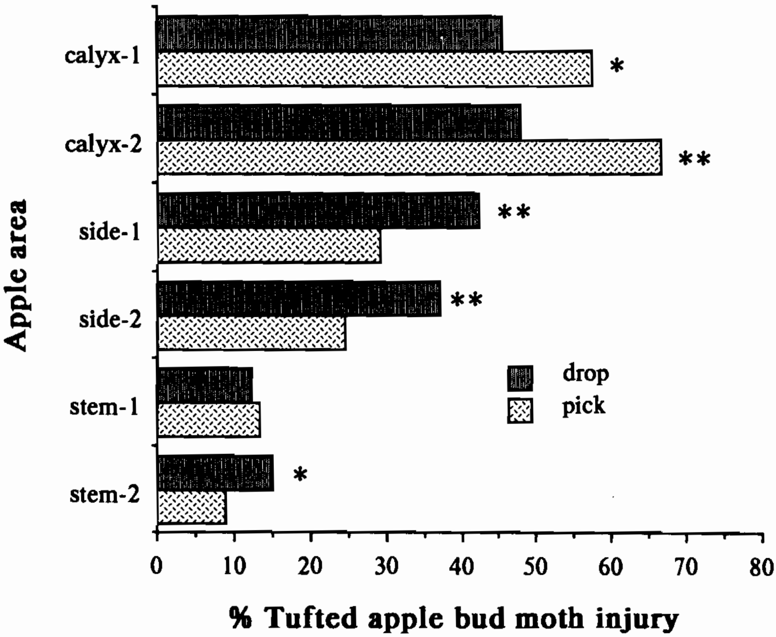

Fig. 3. Fruit sample comparisons (picked or dropped) of % tufted apple bud moth injury on different surface areas of the fruit during first- and second-brood larval feeding. Comparisons were made within apple surface areas and broods (**$P < 0.01$, *$P < 0.05$, Proc ANOVA [SAS Institute 1982]).

with tufted apple bud moth egg masses. *Choristoneura rosaceana* egg masses are also oviposited on the upper surface of the leaves and are the same color and shape as those of tufted apple bud moth (Chapman and Lienk 1971). Although egg masses were not identified to species, 23.5% of the first-brood larvae sampled were either *C. rosaceana* or were unidentified (Meagher and Hull 1987). Thus it can be estimated that < 25% of the first-brood egg masses were not tufted apple bud moth. Only 0.9% of the second-brood larvae were not tufted apple bud moth.

Although studies have not been attempted to determine the attractiveness of apple fruit to tufted apple bud moth larvae, studies have been completed comparing the surface areas of leaves and fruit. In 8-yr-old 'McIntosh' trees, the surface area of the leaf canopy was found to be much larger than that of the fruit, 88% compared to 5.2%, (Forshey et al. 1983), and Ferre (1980) found the canopy of 'Golden Delicious' trees 90% complete in June. Thus the leaf surface area changed only fractionally between the brood samples. Although factors such as tree size, cultivar, pruning, and cultivation practices may change the leaf to fruit surface ratio, it seems reasonable that an individual larva has a higher probability to disperse to a leaf than to a fruit. This surface area difference between leaves and fruit in an apple tree accounts for the difference in leaf and fruit association of the larvae. Fruit size dramatically increased between the time intervals of the sampling periods, and the ratio of leaf to fruit association of the larvae differed between broods (first brood, 10:1; second brood 5.7:1). Although fruit surface area contributes marginally to the overall tree surface area, the difference between broods in larval association may be explained by this increase in fruit surface area.

It was surprising to discover most tufted apple bud moth injury located at the calyx area of the fruit. During sampling it appeared that most injury would be at the side since leaves were webbed to fruit and injury was quite evident. Possibly some larvae were moving out of their leaf or leaf and fruit shelters nocturnally to feed on these calyx areas, since the larvae were not seen travelling during daylight. This may be one explanation as to the variation involved in the prediction of tufted apple bud moth fruit injury from larval sampling (Meagher and Hull 1986a), and may have an effect when attempting to understand the storageability of processing apples (Hull and Rajotte 1988). Also, results suggested higher stem area feeding with dropped fruit during the second brood. Future research may try to establish a relationship between stem area injury and dropped fruit, and thus add another component to tufted apple bud moth injury.

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