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Cherry in Rearing Diet Affects Development of Codling Moth (Lepidoptera: Tortricidae)

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Abstract

The development of the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) was compared on artificial diets that contained different proportions (from 0 to 50%) of fruit pulp from either 'Bing' or 'Chelan' cultivars of cherry, *Prunus avium* L. Frequency of adult emergence was inversely related to the proportion of cherry in the diet and the emergence rate was different for each cultivar. Fresh weights of adult females were not different across diet types, but fresh weights of adult males declined with increasing amount of cherry in the diet. Results suggest that cherry fruits contain chemicals that interfere with codling moth survival and development.

Introduction

Sweet cherries, *Prunus avium* L., from North America and New Zealand must be fumigated with methyl bromide before being exported to Japan to eliminate possible infestation by the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) (9, 12, 15). Yet, codling moth is not considered a pest of sweet cherries in North America (17) and no control recommendations are provided by regional agricultural specialists (2,10). Furthermore, recent research indicates that codling moth larvae develop poorly on cherry (4, 5, 15, 16).

When cherry is used as the sole food resource for codling moth larvae, survival and growth may be impeded by several factors. Because fruit pulp contains very few amino acids and other nitrogenous compounds (1), cherries may be nutritionally insufficient to support codling moth development. Also, cherry fruit chemistry may lack feeding stimulants or contain feeding deterrents that interfere with normal feeding behaviour (3, 8). Conversely, there may be compounds in the fruit that repel feeding.

Further investigation was needed to determine the relationship of cherry fruits to codling moth larval feeding. A method for establishing if cherry pulp constituents affect larval development is to perform classical dose-response experiments. Hence, the objective of this study was to compare survival and development of codling moth larvae reared from artificial diet containing different proportions of slurry made from blended cherry fruits. The experiment was designed so that the diets with the highest concentration of cherry would still be

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nutritionally adequate for normal development. If there was a direct relationship between the proportion of cherry in the diet and poor development, the absence of a feeding stimulant or presence of a feeding deterrent would be suspected.

Materials and Methods

Mature fruits of 'Bing' and 'Chelan' cherries were obtained from local growers in the Yakima Valley and Lower Columbia River Basin in central Washington state. The fruits of each cultivar were pitted, then subjected to a high speed food blender (Model 31BL42, Waring Prod. Div., Dynamics Corp. Amer., New Hartford, Connecticut USA) until a slurry-like consistency was obtained. Slurry-blends of each cherry cultivar were held in separate clear plastic 455 g (16 oz) cups with lids, then frozen until use.

The rearing diet was based on an established soy-wheat germ-starch recipe (14). This diet contained preservatives to reduce fungal growth on the substrate. The cherry cultivar slurry blends were added separately in different proportions while the rearing diet was still fluid, then stirred, poured into plastic cups (3 cm low dia, 4 cm high dia, 4 cm high), and allowed to solidify. Percentages of slurry in the final test diets were 0% (control), 5%, 12.5%, 25%, and 50%.

Newly hatched codling moth larvae were obtained from a colony reared at the USDA-ARS Yakima Agricultural Research Laboratory. Ten larvae were added to each cup, which was sealed with a plastic top. Each plastic top had a cardboard plastic strip on its inner side, which served as a pupation site. Each test diet had five cups per replicate, with a total of five replicates per diet. The cups with larvae were maintained at $\simeq$ 25°C, 40 to 50% RH, with 16L:8D photoperiod.

Adults began to emerge after a month and were collected daily. Each adult was sexed, and the date of emergence and type of diet from which it was reared were recorded. Moths were killed by freezing, then fresh weights were determined using a microbalance (model C-31; Cahn Instrument, Inc.; Cerritos, California USA); the specimens were not dried because they were used in other studies.

Data were analysed using SAS (11). PROC MEANS was used for univariate statistics. Nonparametric tests were used to determine significant differences by first arranging data by PROC RANK, then performing PROC GLM. This is the equivalent to a Wilcoxon rank sum test for two samples and the Kruskal-Wallis *k*-sample test for more than two samples. Descriptive regression models were developed using PROC GLM and differences

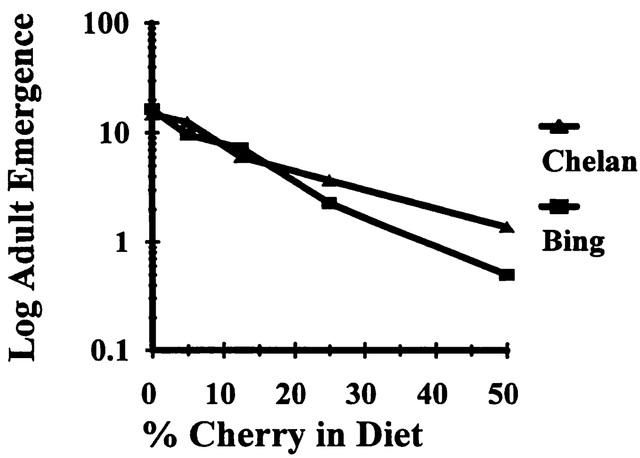

Figure 1. The relationship between frequency (number) of codling moth adult emergence and the percentage of two cherry cultivars, in rearing diet.

between slopes were determined by using Student's *t* test (18).

Results and Discussion

The number of codling moth adults emerging declined logarithmically with increasing proportion of cherry slurry in the diet (Fig. 1). Standard error for each mean emergence was <3. Calculated regression lines were: $\ln y = (2.717 \pm 0.091) - (0.069 \pm 0.004)x$, $r^2 = 0.992$ for 'Bing'; $\ln y = (2.605 \pm 0.119) - (0.047 \pm 0.005)x$, $r^2 = 0.972$ for 'Chelan,' where *x* is the percentage of cherry slurry in diet and *y* is the number of adult moths per replicate. Slopes of these lines were significantly different (t=3.806, df=8, P< 0.01). Differences in adult emergence between cultivars were not significant for each diet proportion except for 50% cherry (t=19.28, df=8, P< 0.01). Adults tended to emerge more from 'Chelan' than from 'Bing' diets. No significant differences were found in the sex of emerged adults between cherry cultivars by diet proportion, except for males at 5% cherry diet.

The amount of time required for insects to develop into adults tended to increase with percentage of cherry slurry in diet (Fig. 2). However, the amount of time to adult emergence was not significantly different among the diets for each of the cultivars ('Bing': F=1.65, df=4,20, P>0.05; 'Chelan': F

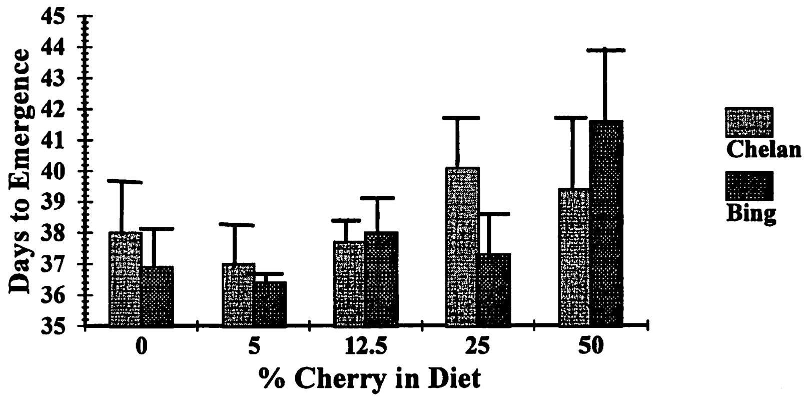

Figure 2. Average days (± SE) to codling moth adult emergence and the percentage of two cherry cultivars in rearing diet.

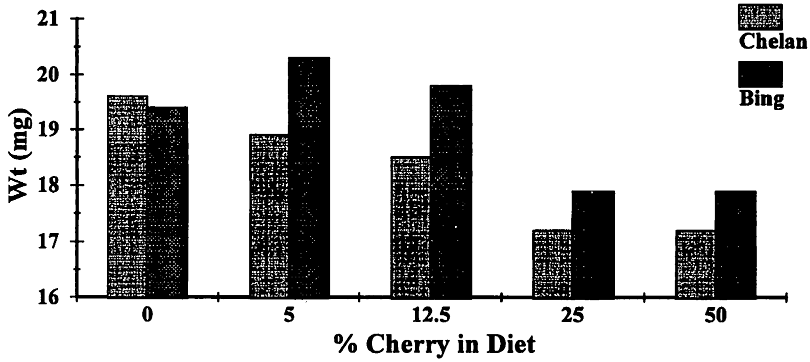

Figure 3. Average adult fresh weights of male codling moth at various percentages of two cherry cultivars in rearing diet; SE < 1.7 for all values.

=0.60, df=4,20, P> 0.05). Linear regressions of emergence time with percentage of cherry in diet were weak ('Bing': r^2=0.623; 'Chelan': r^2=0.550). The longest recorded time period for adult emergence was 57 days for 'Bing' from each of the diets except the 50% cherry diet (48 days) and was 68 days for 'Chelan' from 25% cherry diet.

Average adult weights of males and females (Fig. 3, 4) were significantly different among the diet types for each cherry cultivar (males, 'Bing': F =3.50, df=4,157, P< 0.01; males, 'Chelan': F=6.02, df=4,170, P< 0.01; females, 'Bing': F=4.63, df=4,143, P< 0.01; females, 'Chelan': F =3.863, df=4,158, P< 0.01). For each cherry cultivar, average female weights were not significantly different between the control diet and each of the cherry diets except for 50% cherry diet ('Bing': t=11.55, df=60, P< 0.01; 'Chelan': t=14.615, df=73, P< 0.01). Weights of males generally declined with increasing percentage of cherry in diet (Fig. 3). Calculated linear regressions of male weights were consistent with the proportion of cherry in diets: y = (20.745±0.320) - (0.096±0.011)x, r^2 = 0.974 for 'Bing'; y = (19.343±0.133) - (0.080±0.005)x, r^2=0.993 for 'Chelan'. The slopes of these regressions were not significantly different (t =1.357, df=3, P> 0.05).

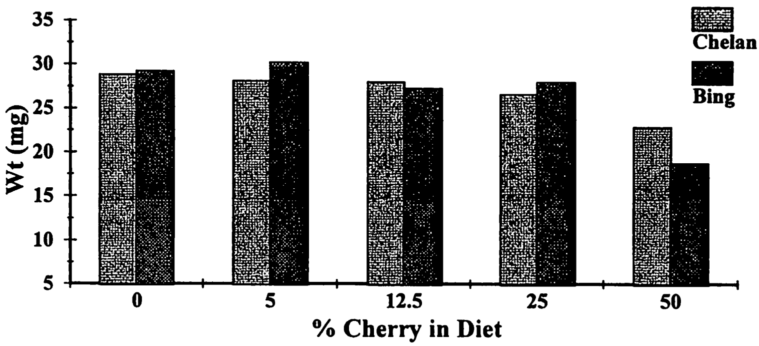

Figure 4. Average adult fresh weights of female codling moth at various percentages of two cherry cultivars, in rearing diet; SE < 1.3 for all values.

If cherries were good hosts for codling moth, there should have been no difference in adult emergence across the diets with differing proportions of cherry slurry. Yet, the amount of cherry in diet affected adult emergence. Adult emergence also differed between on the two cherry cultivars used in the diet. This impact was so consistent that the numbers of adults emerging from diets with varying proportions of cherry could be accurately described by regression models. Projecting out using these models, diets with > 70% 'Chelan' and > 50% 'Bing' would result in an emergence rate of <1% of the initial population (first instars). Earlier studies comparing codling moth development of larvae reared from 'Bing' and 'Chelan' cherries also indicated better survival in the latter cultivar. Furthermore, although females from different cherry diet percentages showed no differences in weight, except for 50% cherry, males certainly did and these were similar for both cultivars. Thus, we hypothesize that males may be more sensitive than females to diet constituents.

The processes that reduced codling moth development in cherries is not known. It has been difficult to rear these insects in the laboratory on cherry fruit alone. The consistent weights of females across diets with different proportions of cherry suggest that lack of nutrition is not the primary cause for poor adult emergence. Rather, the negative relationship between adult emergence and cherry content suggests that cherries may contain a feeding deterrent. As the amount of this material increases in the diet, fewer larvae continue to feed. Laboratory studies have demonstrated that fruit chemicals, such as α-farnesene, affect the behavior of codling moth larvae. Larvae actively orient to the source of apple odors (7) and larvae are attracted to apples that produce α-farnesene (6). Sutherland et al. (13) showed that the amount of α-farnesene varied with apple cultivars. Thus, a similar relationship may occur in cherry, but with a feeding deterrent which varies with cherry cultivar. Further studies are needed to determine if cherry fruits contain such a chemical or chemicals that repress codling moth larval feeding.

Another hypothesis for decreased emergence with increased cherry in diet would be the presence of toxic compounds in fresh cherry fruits. If such chemicals occur, perhaps they could be manipulated for insect control. The equivalent fresh weights of female moths across the diets except for 50% cherry, however, suggest no toxic effects regardless of the proportion of cherry in the diet.

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