Graduate Student CERES Grant Final Report

1. Project Title: *Control of plum curculio and codling moth using strip cultivation in organic apples*

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3. Major Professor: Dr. Matthew Grieshop, Assistant Professor, Michigan State University, Dept of Entomology

4. Accomplishments:

To meet the project objectives I completed a set of field experiments and a set of lab experiments, investigating the effectiveness of strip cultivation as a management tool for Codling Moth (*Cydia pomonella* L.) and Plum Curculio (*Conotrachelus nenuphar* Herbst). Field experiments were used to assess the effectiveness of the WonderWeeder® —a commonly-used orchard cultivator— in achieving burial and/or physical damage of resting/pupating stages. Lab experiments were used to assess survival of the insects at different depths of burial.

Two field experiments were performed: one each with plum curculio and codling moth. For the plum curculio field experiment, thinning apples ordered from the USDA Research Center in Yakima, WA were infested in the laboratory with plum curculio larvae. This was achieved by exposing 60 mesh bags of 50 thinning apples each to 2 male and 4 female plum curculio adults. Adult weevils were acquired from the plum curculio colony maintained by Pete Nelson and Dr. Mark Whalon at the Michigan State University Pesticide Alternatives Laboratory, and separated by sex. After exposure to the breeding weevils, samples of 5 apples were taken from each bag and assessed for successful infestation. The 50 bags with the greatest number of larvae found in their apples were used for the field experiments - all apples sampled from these contained at least one weevil larva. Each of the 10 "Control" experimental units, which consisted of 50 fruit each, contained one apple from each of the above 50, while each "Cultivation" experimental unit (also 10), which consisted of 150 fruit, consisted of 3 fruit from each.

Two adjacent rows were selected at random in a mature orchard in Flushing, MI. Bags containing the Control apples were dumped across ten roughly 5 x 2 foot areas adjacent and parallel to tree row, evenly spaced - 50ft. apart - in the rows. Bags containing Cultivation apples were dumped identically in the adjacent row. The apples in the Cultivation row were then gone over using a custom built ground-driven Lilliston-style cultivator by the orchard owner. We then attempted to recover all the apples, recording percent of apples that were buried, estimating the range of burial depths we observed as we were digging them up, and rating each individual apple according to how badly damaged it was. The damage scale we used was 0-3: 0-undamaged, 1-surface damage, 2-deep gash and exposed apple flesh, 3-apple cut entirely apart by blades of tiller. After apples were collected, they were placed in a mesh bag and left in the orchard to assess difference in adult emergence from damaged apples.

For the codling moth field experiments, similar methods were employed. Pupae were ordered from the USDA Research Laboratory in Yakima, WA. Rather than infesting dropped/thinning apples, we instead wrapped the pupae in bright label tape in order to: simulate the leaf litter that is their preferred environment when pupating on the ground, make the pupae easier to locate, and attach a small metal nut to each without damaging the pupa, to facilitate the use of a metal detector to locate buried pupae. We performed the experiments in the same orchard used for the plum curculio cultivation experiment, and in the same way (previous paragraph). We used a metal detector to locate the buried pupae and sample size was 8 per treatment rather than 10. Percent burial and approximate depth range were recorded. After being collected, pupae were returned to the lab and unwrapped, the number of physically damaged pupae was recorded, and they were placed in rearing chambers in the same proportions of buried and exposed pupae as they were found in the field, to assess survival and emergence as adults.

Results from the field experiments showed the following: a Lilliston-style cultivator buried roughly 61±1% of dropped apples to an estimated depth of 1-5 cm, and roughly 83±3% of diapausing codling moth larvae on the orchard floor to a similar depth. As for assessing survival and emergence from field experiments, mistakes with field/lab rearing apparatus were made with both insects, so no data of this kind was obtained.

Since no data about successful emergence was acquired from field experiments, lab experiments were done to find out the burial tolerances of the two insects in question. We cut PVC tubing (4" inner diameter) and glued shear fabric to one end. These stood on end formed chambers in which to test emergence of both insect species from different depths of burial. Burial depths used for plum curculio were 0 (surface), 2.5cm, 7.5cm, 15cm, and 45cm (Figs 1-3). Burial depths used for codling moth were 0 (surface), 1cm, 2.5cm, 7.5cm, and 22cm. We cut each chamber to leave 7.5 cm of space above the soil media surface and below the buried insects. We made five chambers for each depth level for each insect.

Rearing protocol for plum curculio was the same as for the field experiments. I acquired codling moth eggs from the codling moth colony at the MSU Trevor Nichols Research Center. I dipped these eggs for one minute in diluted bleach to sterilize any potential diseases present on the chorion surface, and then left the eggs out in a sealed bag in the lab until they hatched. When they hatched, I made codling moth diet out of Pinto beans, yeast, agar, and a few other ingredients, and filled two batches of 150 two-oz. deli cups each half full with the diet and let it dry for half an hour. I added a single larva to each cup in the first batch (all of them moving and therefore known to be alive) and three larvae to each cup in the second batch (most of which were not moving and it was unknown whether they were still alive, hence adding extra larvae to ensure at least one living larva per cup).

Burial chamber experiments were performed as follows: first we added enough of the soil media to fill the bottoms of the tubes up to 7.5cm. Then we added the insects in their rearing media - we dropped five infested apples in each plum curculio tube, and we dropped eight diet "globs" in each codling moth tube (Fig. 1). We filled the gaps between the apples or diet globs with soil media, then we added soil media over top until we reached the proscribed depth for that tube (Fig. 2). We wetted the media to field capacity, and then attached a sheet of shear fabric to the top with a rubber band to keep any adults from emerging uncounted (Fig. 3). The chambers were then checked periodically by carefully removing the rubber band and fabric on top, and counting the insects inside. Any adults, larvae, and pupae above the soil surface were counted. The plum curculio experiment was run once with sand only. The codling moth experiment was run twice - once in sand and once in potting soil.

Results from lab experiments clearly showed the following: codling moth adults were unable to emerge from as little as 1 cm depth of burial in either sand or potting soil. Non-diapausing codling moth larvae, on the other hand, were able to dig out of up to 2.5 cm of soil, though their survival was reduced when buried compared to those on the surface (Fig 5). Plum curculio larvae that were buried in the apples on which they were feeding were able to emerge as adults from 15cm of soil depth, but not 45cm (Fig. 5). Percent emergence of plum curculio actually increase in buried apples as compared to apples on the soil surface (Fig 5).

5. Conclusions

My results suggest that it may be possible to reduce codling moth populations by cultivating at times of the year when they are resting in the soil. In an orchard with smooth-barked trees that are regularly cleaned of vining plants, codling moth have been shown to diapause, and then pupate, in the soil. This may be another tool for managing codling moth in organic orchards. As many growers are already using strip cultivation as a weed management strategy, simply changing the timing of these cultivation events might have the added benefit of impacting moth populations. This study was only the first step in finding out whether this could be used as an effective management strategy: further field experiments would have to be done to confirm. In any case, in order to have an impact cultivation would have to occur at one of three times: a) before first flight of the moths, b) between the two adult generations just before the second flight, and/or c) in the late summer / fall after both adult generations have become inactive.

The results also suggest that burial of plum curculio infested apples - June drops, thinning apples, or mature drops - would have no negative impact on the population of the weevils and indeed, may help them along. Future research should address whether a cultivating implement that can cause a large percentage of these apples to be cut up, might expose plum curculio to additional mortality due to crushing, fungal diseases, etc.

6. Figures

Fig. 1. Custom Lilliston cultivator

Fig. 2. Codling Moth diet in burial chambers

Fig. 3. Soil is filled in over the diet.

Fig. 4. Shear fabric cover over top.

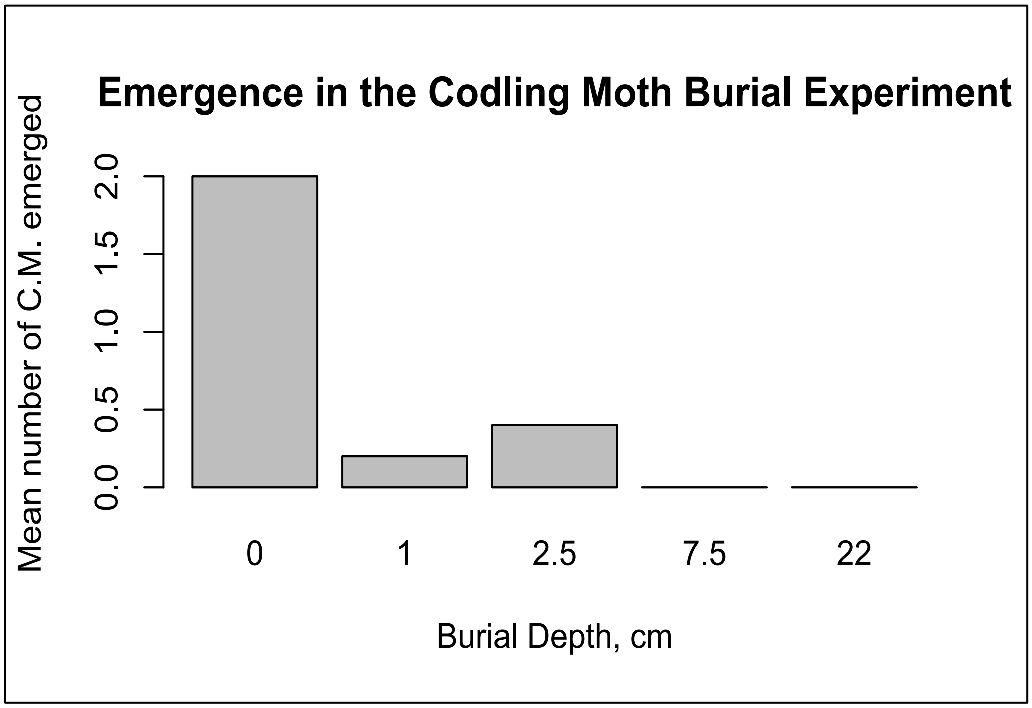

Fig. 5 - Codling moth emergence

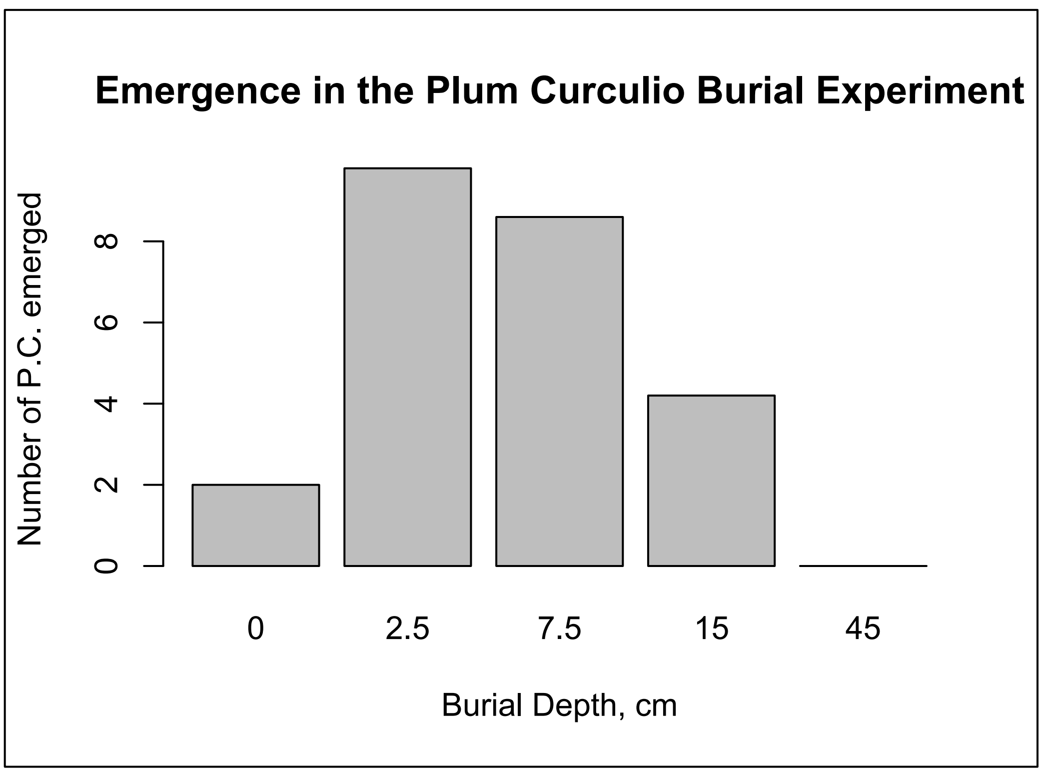

Fig. 5 - Plum curculio emergence