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# Conservation biological control of codling moth, *Cydia pomonella*

**Lene Sigsgaard**
*Department of Plant and Environmental Sciences, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg C, Denmark*
*E-mail: les[a]plan.ku.dk*



**Abstract:** Ecological infrastructures in apple orchards may reduce pest infestation by improving conditions for natural enemies. The present study assessed the density of overwintering codling moth *Cydia pomonella* L. (Lepidoptera, Tortricidae), level of parasitism, infestation by entomopathogenic fungi and other mortality factors in five organic orchards with flower strips and five organic orchards without flower strips. In orchards with flower or grassy strips, predation on sentinel prey was assessed in different distances from the strips. No clear difference was found between infestation levels in organic orchards with and without flower strips. Within orchards with flower strips mortality of codling moth larvae collected near flower strips was higher than for larvae collected further away from strips. Likewise mortality of sentinel eggs was higher in trees near the flower strip than further way. Lack of difference between orchards with and without flower strips could be a result of high variability between orchards. Within orchards with flower strips, there was increased predation activity and increased mortality of codling moth larvae from near flower strips that could be predator induced.

**Key words**: flower strip, natural enemies, sentinel prey, predation

## Introduction

Pests and diseases cause quality and yield reductions in organic apples and consequently Danish production of apples is small and unstable. At the same time there is a large potential for organic apple production in Denmark, as consumers have become increasingly interested in organic foods. Prevention of pests and diseases is essential if yield is to be stabilized or increased. A central part of prevention is to enhance natural enemies of pests so they can contribute to control, negating the need for direct control. As a part of the project Fruitgrowth we assess the role of flower strips for natural control of the codling moth in organic apple orchards.

Ecological infrastructures are the places in and around the orchard where beneficial insects such as predators and wild bees can find food and habitat and this way be protected and augmented for the benefit of the farm. Examples are hedgerows, flower strips, patches of wild vegetation, extensive grass areas, banks, wood piles and waterholes. IOBC, the International Organization for Biological Control in its guidelines on IPM, recommends at least 5% of the entire farm surface (excluding forests) must be identified and managed as ecological infrastructures with no input of pesticides or fertilizers, in order to enhance botanical and faunistic biodiversity and to enhance a supportive conservation biological control of key pests by antagonists (IOBC-WPRS, 2012). Planting flower strips can increase plant diversity and thereby the associated herbivores that act as alternative prey for natural enemies. Pollen and nectar is also provided that is utilized by predators, parasitoids and wild bees. Flower strips also provide habitat and overwintering sites for the natural enemies. A prolonged flowering period is attractive and flowers should be good sources of nectar and pollen for beneficials, while their value for insect pests should preferably be less. Also the agronomic aspects of the strips should be considered. For example the seed mix should not contain plant species that can potentially be problematic weeds.

While it is well documented that flower strips will augment natural enemies, there are fewer results showing an effect on pests. This may be because most studies are only 1-3 years long and to increase natural enemy abundance sufficiently for them to have a noticeable effect may take longer. Thus a Canadian study found that after establishing flower strips in an orchard the number of natural enemies gradually increased and the damages gradually reduced over a 5 year period (Bostanian, 2004). A Swiss study documented that sown weed strips reduced the aphid *Dysaphis plantaginea* during the year of sowing and the year after sowing. One reason was that there were more spiders in strips and adult aphids were trapped in their webs (Wyss, 1995). In Denmark there are already some organic orchards with flower strips, but their role for natural enemies and pest regulation is unknown. The present study assessed codling moth and natural enemies in the orchards with and without flower strips and as a function of distance from flower strip to contribute to a better understanding of the role of flower strips and how they may best be arranged in an orchard.

## Material and methods

The study was conducted from 2011-13 in ten organic orchards on the island of Zealand, Denmark. Five orchards had the typical grassy strips and the other five orchards had sown flower strips. Flower strips had been established when the trees were planted (3-8 years before the start of the experiment), replacing every 6$^{th}$ row of trees (3 orchards) or placed along the side of the orchard (2 orchards). Over time flower strips change, and grass and weeds can become more dominating. Therefore, flower strips were rejuvenated using the same seed mixture in all five orchards in spring 2011 thereby also ensuring the same mixture was present in all orchards. An experimental apple planting with a similar flower strip to one side was established in 2010/11 at the Pometum of University of Copenhagen, and was included in studies. To assess the possible effect of flower strips on codling moth and its natural enemies we collected overwintering codling moth using corrugated cardboard bands in all ten orchards, with 30 bands distributed evenly in three rows in orchards without flower strips and 40 bands in orchards with flower strips, half placed in rows next to the flower strip and the rest in the third row from the flower strip. Larvae were reared in the laboratory to assess emergence of adults, parasitoids and other mortality factors. Dead larvae were incubated to determine infection by entomopathogenic fungi.

Arthropods were collected from apple trees and flower strips/ grassy strips in the orchards with flower strips in 2012. We sampled tree rows adjacent to flower strips and the third rows from the flower strips using beating. Flower and grass strips were sampled with sweep net. Sampling from apple trees was repeated in 2013. In 2012 sentinel prey of *Ephestia kuehniella* was set out in orchards with flower strips in trees adjacent to flower strips, the second and the third rows from flower strips to assess egg predation and parasitism. In 2013 codling moth eggs were used as sentinel prey. Data are under analysis. Predation of sentinel prey presented in this proceeding was analyzed using ANOVA with place, date and distance to flower strip as fixed variables.

## Results

In 2011 codling moth infestation was relatively high, and over 1200 larvae were collected from corrugated cardboard bands. 2012 was cold and wet, and codling moth infestation was a fifth of the preceding year.

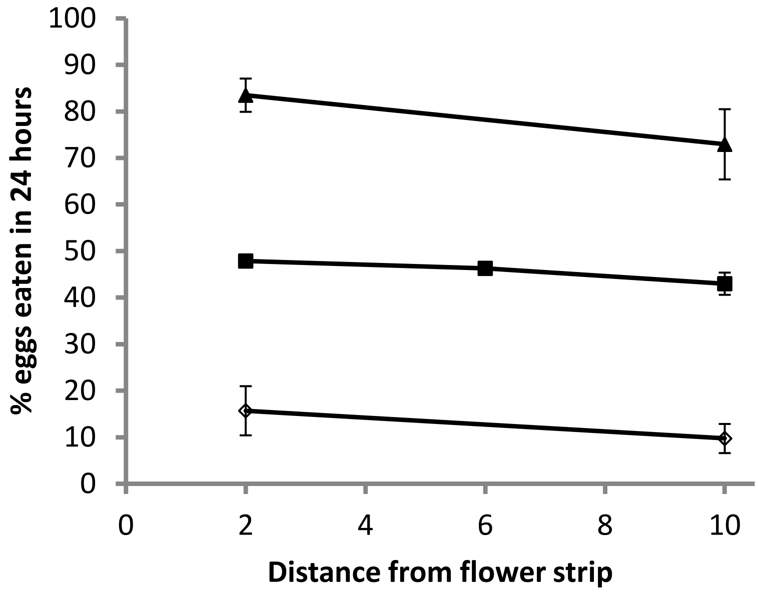


Figure 1. Percentage of sentinel eggs removed (± SE) in 24 h from egg cards in the orchard Strandegaard, Faxe, Zealand, Denmark in 2012, late May (◊), late June (■) and late July (▲) from egg cards placed in trees in the first row from flower strip (ca 2 m away), in the second row from flower strip (ca 6 m away, only assessed on late June) and in the third row from the flower strip (ca 10 m away). Predation was lowest in May, increasing in June to be highest in July. Highest predation was consistently found near the flower strip.

In both years, 20-30% larvae were parasitized. In 2011 the Ichneumonid *Trichomma enecator* was dominant. Preliminary analysis showed no significant difference in codling moth infestation or parasitism between orchards with and without flower strips. No infestation with entomopathogenic fungi was detected on incubated dead larvae.

Mortality from unknown causes was about one third of larvae in both 2011/12 and 2012/13. In 2011 there was a trend of lower infestation by codling moths in trees near flower strips. Both in 2011 and 2012 mortality of collected larvae was 10% higher for larvae collected in the trees near the flower strip (1$^{st}$ row, 2 m away) than in trees further removed (2$^{nd}$ row, 6 m and third row, 10 m). Predation on egg cards with sentinel eggs was significantly higher near the flower strip than on trees further removed (in spring on average 30% in first row from strip, 10% in third row from strip). There was a significant effect of date × orchard ($P = 0.001$) and the effect of distance was significant ($P = 0.006$). Predation was higher in mid-summer and highest by the end of summer, but the level of predation remained highest near the flower strip. Figure 1 shows results from one representative orchard in 2012. Similar results were obtained in 2013, with codling moth eggs as sentinel prey.

## Discussion

High variability between orchards and the fact that only ten orchards were sampled may be the cause that no clear differences in codling moth infestation or parasitism could be found between orchards with flower or grassy strips. Landscape data from orchards remain to be analyzed and may contribute to our understanding of this. A recent French study was unable to detect differences in codling moth infestation between farms though the farms sampled had practices that varied from conventional to organic, but found some effect of landscape factors (Monteiro *et al*., 2013). However, we found a clear effect of proximity to flower strips, in the orchards with flower strips. It is assumed that the higher codling moth mortality near flower strips can be attributed to higher activity of beneficials causing predator induced mortality. Higher predation on sentinel prey in trees near flower strips corroborates the assumption that predator activity was causing higher codling moth larva mortality from trees near flower strips.

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