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Effect of pheromone trap position in large and small trees and in the open field on the catch of codling moth, *Cydia pomonella*, males

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Traps with the pheromone of codling moth, *Cydia pomonella* (L.), were positioned in the canopy of host and non-host plants as well as in the open field on poles placed in a distance of 10-40 m. Traps in the canopy of trees and shrubs yielded in general much more moths than traps in the open field. Another experiment was carried out in an apple orchard, in which groups of large spindle trees (3.5 m) alternated with groups of small trees (1.8 m). Traps in large trees caught much more moths than traps positioned at the same level in or near small trees.
Codling moth adults approach tree silhouettes of host and non-host plants by visual orientation. They refrain from leaving the canopy of trees. The difference in trap catch in trees and in the open field seems to be mainly due to this mode of behavior.

Keywords: codling moth, pheromone, trap position, behavior.

INTRODUCTION

For years, pheromone traps have become an accepted tool to monitor the flight of codling moth, *Cydia pomonella* (L.), males, in apple orchards. Pheromone traps are also used in the confusion technique, indicating whether the communication between the sexes is interrupted by the evaporation of pheromone or not.

The position of the traps may influence quite distinctly the catch of moths. We observed that traps positioned in the canopy of host and non-host plants attracted much more males than traps in the open field on poles and pylons (MANI & WILDBOLZ, 1977; MANI *et al.*, 1978b).

Such differences induced us to study the phenomenon more in detail. Results of such studies were presented in communications (MANI & WILDBOLZ, 1980), but never published in detail. This should be done now by comparing our data with the results of other authors.

MATERIAL AND METHODS

The traps used were horizontally suspended 1 litre (18x12 cm) cylindrical plastic boxes (MANI & WILDBOLZ, 1975), the upper half of both sides cut open, with sticky paper on the bottom. Each trap was baited with 1 mg of the synthetic pheromone E8E10-12OH on a rubber septum. All traps were placed at a height of 1.7 m.

We carried out 2 experiments:

Experiment 1: Traps in the canopy of trees and bushes and in the open field.

The experiment was realized in July/August 1978 in the Grisons and St. Gall Rhine valley. In the bottom of the valley there are often mosaiques of grassland, scattered standard trees (apple, pear, cherry, walnut, forest trees), and hedges (non-

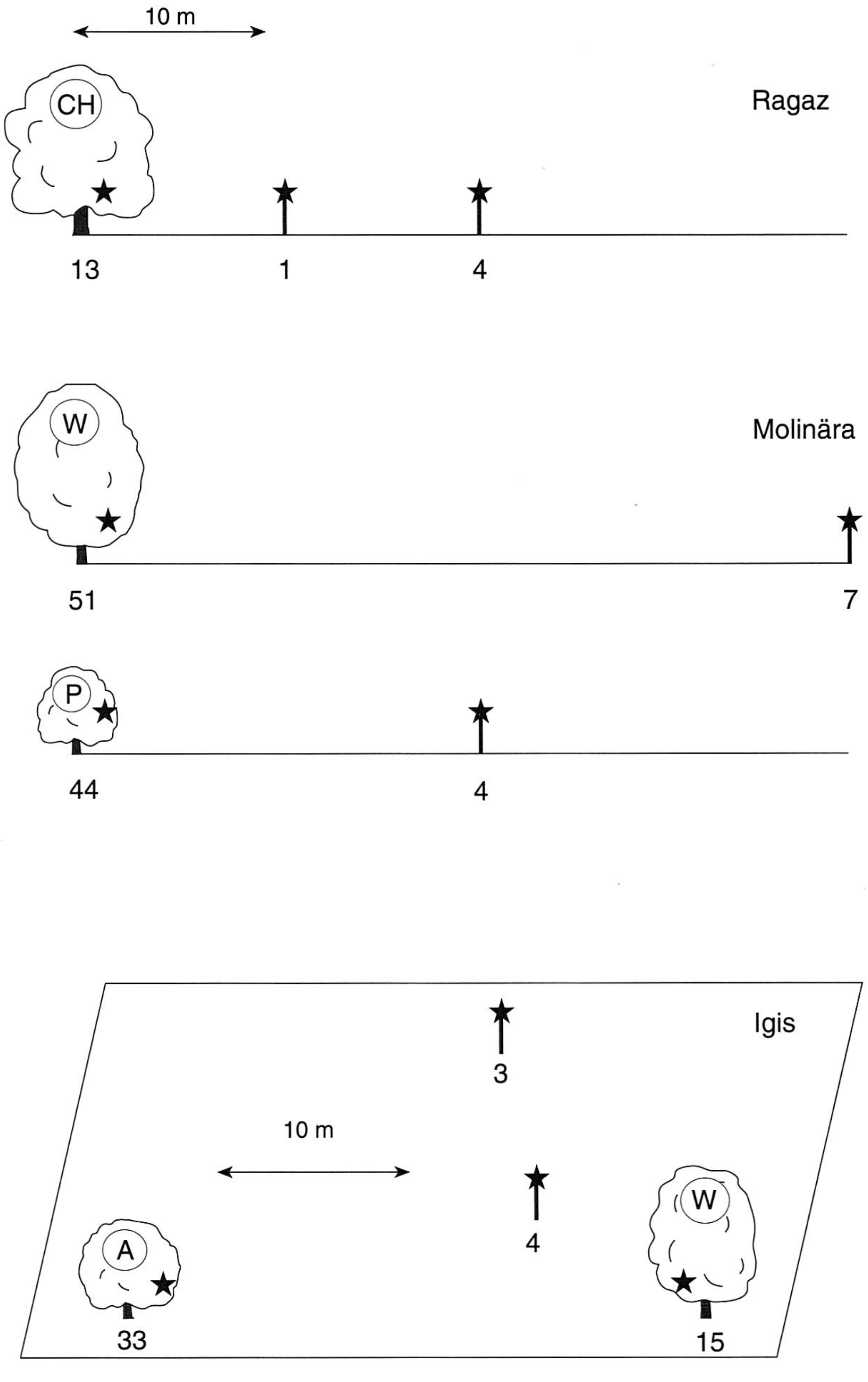
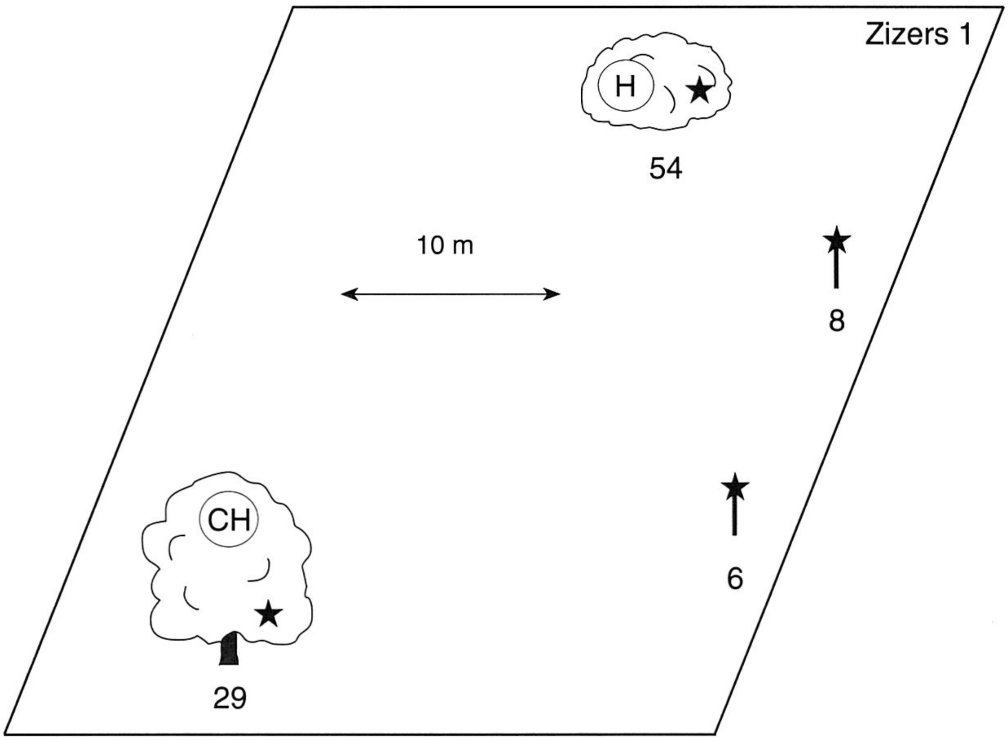
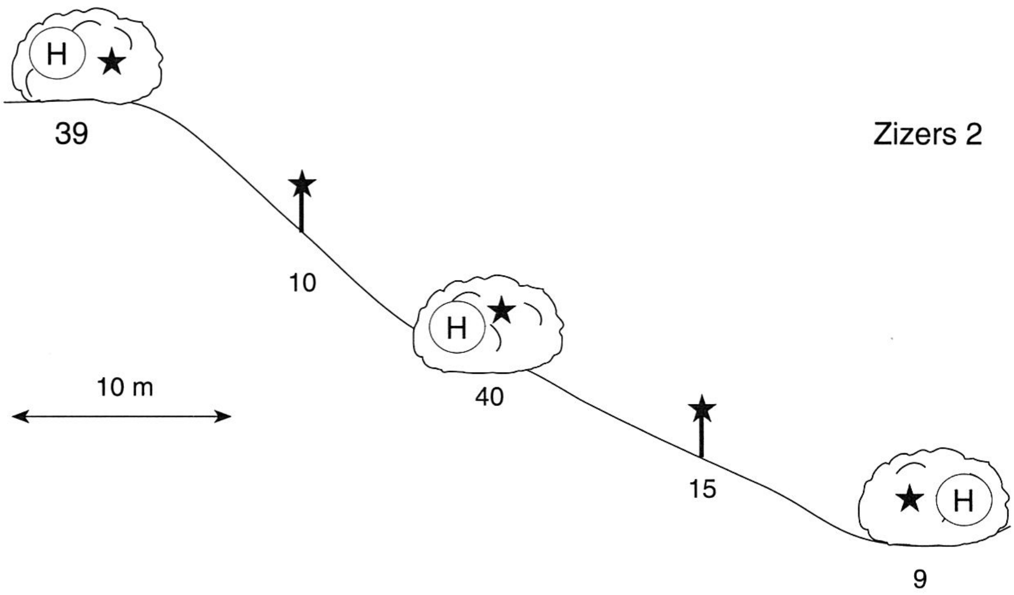


Fig. 1. Position and total catch (numbers) of pheromone traps in trees, hedges and on poles in the open field at 5 localities in the Rhine valley. Symbols: A: apple, CH: cherry, H: hedge, P: plum, W: walnut; ★ trap.


Zizers 1
H
54
10 m
8
CH
6
29


H
39
Zizers 2
10
H
40
10 m
15
H
9

host plants). At these places pesticides were rarely applied on fruit trees. Codling moth populations were quite high.

We chosed 5 localities and placed 3-5 traps in each. Traps were hung on host and non-host trees, on bushes (0.2-0.4 m inside the edge of the canopy) and, for comparison, in a distance of 10-40 m on poles in the open field (Figs 1, 2).

A special situation existed in the locality Zizers 2, where a slope with grassland, mixed with hedges, ended at the bottom of the valley. Two traps were placed in hedges on the slope, two nearby on poles in the open field. One trap was hung in a hedge below the slope in a depression (Fig. 1). Traps were cleared weekly.

Experiment 2: Traps in an apple orchard with alternating large and small trees.

The experiment was carried out in July/August 1978 in an apple orchard (T) in Wädenswil (Figs 3, 4). The 0.6 ha orchard had, due to another experiment, an unusual structure of trees: In each row, groups of large and of small trees alternated. 2 large spindle trees (height 3.5 m, tree distance 1 m, diameter of the canopy 1.0-1.5 m) alternated with 2 or 3 groups of 3 young spindle trees (height 1.8 m, tree distance 1.0 m, diameter 0.2 m). The 2 big spindle trees formed a group with 2-3 m diameter between an area of 12 and 16 m, respectively, with small and slim trees. As the large trees in one row were opposite to large trees in the next row (row distance 5 m), the impression of transverse rows of high trees was given (distance of 12 and 16 m, respectively, from the next).

We placed the traps in the 3rd row from SW (Fig. 3). Each group of large and small trees had a trap in the centre. The 8 traps in the high trees were hung on a branch inside the canopy. In the small trees 4 traps were fixed directly to the trunk of the plant and 3 traps on poles in a distance of 1.0 m from the canopy. The traps were 6 and 8 m, respectively, apart.

Fig. 2. Position of traps at the locality Zizers 1. On the left: cherry tree; in the background: hedge; on the right: 2 poles. Traps are marked with arrows.

Northeast of the trap orchard (T) was a uniform apple orchard (R) with 4 m high spindle trees (Fig. 3). To increase the moth population, we repeatedly released males in a distance of 45 m from the traps. From mid-July to the end of August we weekly released 500 males uniformly over the central row. Traps were cleared twice a week.

RESULTS

Experiment 1. Traps in the canopy of trees and bushes and in the open field

Fig. 1 shows the results: Traps in the canopy of host and non-host trees (plum, cherry, and walnut, the latter very rarely attacked in the region) and of hedges caught in most cases much more moths than traps on poles in a distance of 10-40 m. At the locality Zizers 2 the results were not so clear-cut. The traps in hedges on the slope caught 3-4 times as many moths than the neighbouring traps in the open field. The trap in the hedge in the depression, however, caught only a few moths, less than the neighbouring one in the open field. Obviously, the topography and the position of trees and hedges, giving an effect of canalisation, were important for the moths. We knew before that traps in depressions catch much less males than traps on slopes (MANI & WILDBOLZ, 1977).

Experiment 2. Traps in an apple orchard with alternating large and small trees

Fig. 3 illustrates the catches: All traps in large trees caught much more males than traps in or near small trees, positioned at the same level.

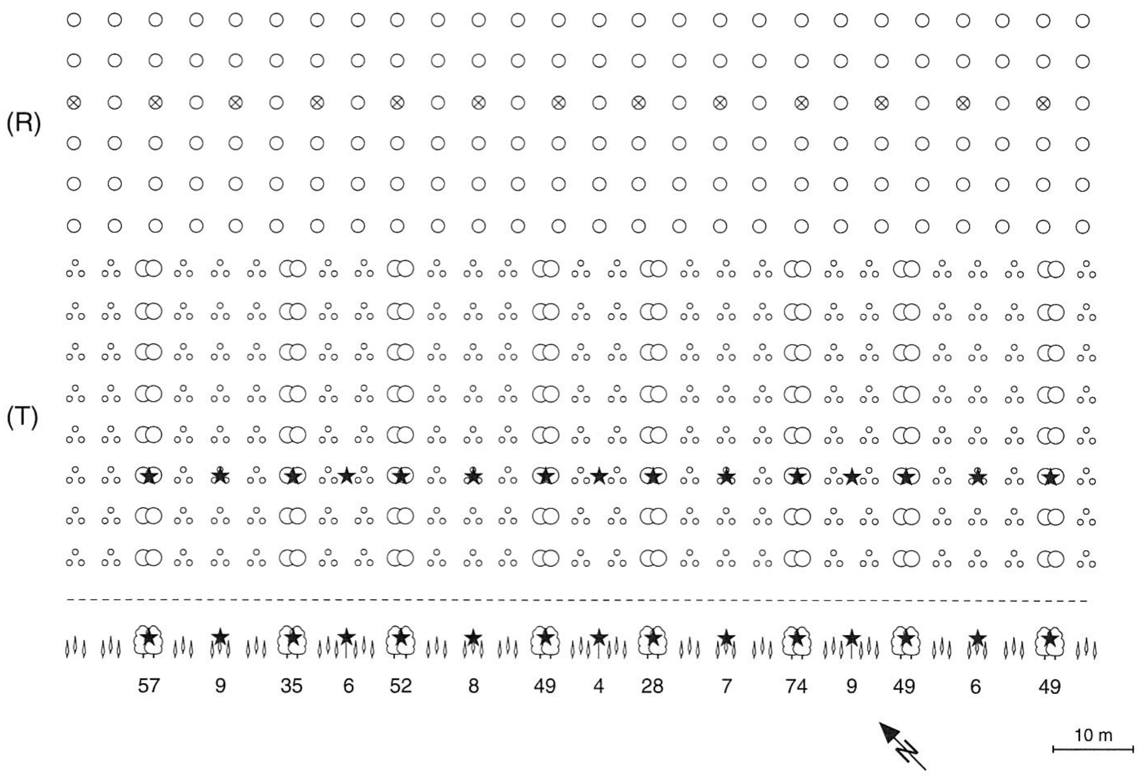


Fig. 3. Situation and results of experiment 2 at Wädenswil. Top: Map of the experimental orchard. Part (R): Release orchard with uniform spindle trees (4 m). Part (T): Trap orchard with alternating large (3.5 m) and small (1.8 m) spindle trees. ⊠ release tree; ★ trap. Bottom: Total catch per trap in high and in or near small spindle trees.

Catches were in the average:

in the 8 traps in the canopy of large trees	49.1	moths/trap
in the 4 traps in the canopy of small trees	7.5	" / "
in the 3 traps adjacent to small trees	6.3	" / "

DISCUSSION

HOWELL *et al.* (1990) studied the reaction of males to pheromone sources and trap catch in different heights within and just outside the tree canopy. The positions within the canopy were clearly favored in comparison to positions outside the canopy. This phenomenon was observed above, below, and at the side of the trees.

RIEDL *et al.* (1979) studied the trap catch within and outside the tree canopy. Inside the canopy traps caught much more moths than above and below it. Laterally, on poles halfway to the next tree, traps caught as many moths as traps within the canopy. Contrary to our experiment 1, traps on poles were positioned inside the orchard at a short distance from the next trees. A similar situation occurred in our experiment 2: Three traps were placed on poles 1 m from the small trees. They caught the same number of moths as the four traps fixed directly on small trees (Fig. 3).

MCNALLY & BARNES (1981) compared traps placed within the canopy of trees with those placed just at the edge of the canopy. The latter traps caught about twice as many moths as traps inside the trees.

There is an agreement that trap catch above and below the tree canopy sharply decreases. Laterally, the decrease is obviously less abrupt. Therefore, traps just near trees may be quite attractive.

What are the reasons for traps within and near the canopy of trees catching much more moths than traps outside the trees in the open field? Traps within the trees have certainly a different pheromone plume than traps in the open. The importance of such differences can not be judged at the moment.

On the other hand we find explanations based on the behavior of codling moth adults, which orient to tree silhouettes of host and non-host plants, to be interpreted as a visual orientation. Such behavior has directly been observed in the field (MANI *et al.*, 1974). It was also observed during releases of reared insects for the study of dispersal (MANI & WILDBOLZ, 1977) and in experiments with the "Sterile Insect Technique" (SIT) (MANI *et al.*, 1978b).

When reared codling moth adults are released, the majority of both sexes flies to the nearest trees. A few insects, however, rise sharply and leave in the direction of a gentle breeze. Such "long distance flyers" orient obviously later to silhouettes. This can be concluded from moth catches outside a SIT orchard. Traps in huge park trees and at the border of prominent forests (non-host plants) were particularly attractive (MANI & WILDBOLZ, 1977).

Codling moths have the tendency to remain within the canopy of trees. BORDEN (1931) and MANI *et al.* (1974) observed that most moths swarm in and around the trees. Only a few insects leave the trees and the orchard. HOWELL *et al.* (1990) made additional observations regarding males and pheromone sources. When such a source was placed 1 m above the canopy, many males accumulated in the top of the tree but only a few left the canopy and moved up to the source.

During the oviposition period, females obviously hesitate to leave the tree canopy and the orchard. When moths of both sexes were released centrally in an apple orchard (WILDBOLZ & BAGGIOLINI, 1959), larval attack decreased from the point of release to all sides. On the border "apple/open field" of the orchard, the attack clearly increased again. On the other side of the orchard, on the border "apple/plum" (non-host), no increase occurred.

Codling moth adults prefer the upper part of the trees. A heavier fruit attack in such parts of the trees is a consequence. Direct observation of flying insects (BORDEN, 1931, MANI *et al.*, 1974) confirms this finding. Trap catch experiments show the same: When traps are placed at different heights in the same tree, upper traps are clearly more attractive than lower ones (MANI *et al.*, 1978a; RIEDL *et al.*, 1979; CHARMILLOT, 1980; MANI & WILDBOLZ, 1980; MCNALLY & BARNES, 1981; THWAITE & MADSEN, 1983; AHMAD & AL-GARBAWI, 1986). If, however, all traps are placed at the usual height of 1.7 m, there is no competition with traps in the upper part of the tree (THWAITE & MADSEN, 1983; KHATTAK *et al.*, 1989; HOWELL *et al.*, 1990). Obviously, most moths fly to the upper part of the trees. If there are no traps there, they mill around and find the traps at lower levels.

Our experiment 2 may be explained in a similar way. Most of the approaching males oriented to the large trees. Eventually, they came in contact with the pheromone plume of the traps and got caught (trap distance 6 and 9 m, respectively). The situation was similar to the experiments with traps at different heights in the same tree. Moths had the opportunity to choose between two trap positions and preferred the large silhouettes.

Fig. 4. Position of traps in experiment 2 in large and small spindle trees at Wädenswil. Traps are marked with arrows.

If the moth population of an orchard is to be monitored, traps may be conveniently placed at 1.7 m. If, however, the effect of confusion technique is to be checked, some traps must be placed at preferred sites at the top of the trees and at the borders of the orchard (RIEDL *et al.*, 1979; MANI, 1986; MANI *et al.*, 1987; MANI & SCHWALLER, 1992).

Some other Lepidoptera obviously behave in a similar way as codling moth. LIEBHOLD & VOLNEY (1984) studied the catch of *Choristoneura occidentalis* and *Ch. retiniana* (Tortricidae) with pheromone traps. Traps in the canopy of host and non-host trees caught much more males than traps in the open at a distance of 5-6 m. The authors assume that visual orientation to trees is responsible for such results.

Coleophora laricíella (Coleophoridae) occurs during outbreaks in huge numbers. WITZGALL & PRIESNER (1984) were therefore able to observe the reaction of males to pheromone sources directly. Males flew against the wind to the sources. But flight direction was deviated by tree silhouettes of host and non-host plants, obviously due to visual orientation.

In our experiments we studied the flight of males searching females. We may distinguish different steps of behavior occurring separately or in combination: visual orientation to tree silhouettes, swarming of males within the tree, approaching flight to pheromone source. When visual orientation and approaching flight to pheromone are combined, we may call it, according to KENNEDY (1977), "odor mediated attraction to objects". However, visual orientation to tree silhouettes occurs already at distances of 50-100 m across the wind, where orientation to pheromone is not possible.

phase	orientation, behavior
♂ and ♀ in the orchard	swarming in and around trees and along tree rows, restraint to leave the canopy or very rarely: flight away with gentle breezes over long distances
young ♂ and ♀ after release	oriented flight to tree silhouettes, swarming in and around trees and along tree rows or less often: flight steeply upwards, flight with gentle breezes over long distances
♂ searching ♀	oriented flight to tree silhouettes, swarming in the tree canopy, restraint to leave the canopy, activation by pheromone, directed flight to the pheromone source
♀ before oviposition	searching flight, restraint to leave the canopy, induction of flight activity, landing and oviposition by fruit odor

Table 1: Observed steps in the flight behavior of codling moth adults.

Another phase of the flight behavior of codling moth was studied years ago: the short distance flight of females searching for the favorite place for oviposition. Females are activated and oriented by fruit odor (WILDBOLZ, 1958; WEARING *et al.*, 1973).

The flight behavior of codling moth males and females has different steps from hatching to oviposition. We know several of these steps (Tab. 1), but much remains unknown. A better knowledge is highly desirable. It is one of the prerequisites to improve the confusion technique.

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ZUSAMMENFASSUNG

Fallen mit dem Pheromon des Apfelwicklers wurden in der Krone von Wirts- und Nichtwirtspflanzen sowie in einer Distanz von 10-40 m an Pfählen im freien Feld aufgehängt. In den Baumkronen fingen die Fallen fast durchwegs ein Mehrfaches an Faltern als im Freien. Ein weiterer Versuch wurde in einer Apfelanlage angelegt, in welcher Gruppen mit grösseren Bäumen (3,5 m) mit Gruppen kleinerer Bäume (1,8 m) abwechselten. In den grossen Bäumen war der Fang an Faltern bei gleicher Fallenhöhe viel stärker als in Fallen in oder nahe bei den kleinen Bäumen.
Apfelwicklerfalter orientieren sich auf Distanz optisch nach Baumkronen von Wirts- und Nichtwirtspflanzen. Sie verlassen die Kronen nur ungern. Beide Verhaltensweisen dürften weitgehend für die Unterschiede im Falterfang verantwortlich sein.

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