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Control of codling moth by attract and kill

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Abstract: The codling moth is controlled using mating disruption on about 10% (1200 ha) of the apple growing area in Trentino. The widespread adoption of this control method has been facilitated by the financial support of the growers associations. Financial support reduced the per ha cost to growers of using mating disruption, but the technique must still be applied to relatively large, contiguous areas, and this has been a barrier to wider adoption. Another semiochemical based approach is the attract and kill strategy, involving the combination of a semichemical lure with an insecticide. The principle has been successfully used to control codling moth, although some critical parameters affecting its efficacy are still to be investigated. In this paper we report on experiments designed to know some of the limits of the method. In particular we determined: longevity of the lure (more than a month) and of the insecticide efficacy (3-5 weeks depending on the insecticide added), the influence of the infestation sources close (less than 80 m) to the orchard and the satisfactory field efficacy using a low number of droplets (less than 2000/ha) in the colder fruit growing areas where the codling moth is less abundant

Key words: sex pheromone, attract and kill, release rate, C*ydia pomonella,* Tortricidae, Lepidoptera

Introduction

The codling moth *Cydia pomonella* L., is the key pest of pome fruit in the region of Trentino, one of the major apple growing areas in Europe. An average of nearly three applications of insecticide is applied per hectare each year to menage this pest. Recently growers and crop consultants have reported an increase in damage caused by the codling moth. Currently, codling moth control relies primarily on conventional spray application, predominantly of insect growth regulators (IGR) or organophosphorus (OP) insecticides. IGR's are frequently applied in spring to control overwintering leafroller larvae and codling moth, whereas OP's are applied in summer to control the second generation of the codling moth. The increasing public awareness and changes in social attitude towards exposure to pesticides together with the development of resistance against the insecticides used for the codling moth control (Ioriatti *et al*., 2000; Ioriatti and Bouvier, 2000) makes it necessary to introduce al-

ternative strategies and develop novel control methods compatible with the aims of integrated pest management. The introduction of codling moth mating disruption (Ioriatti *et al*., 1997) has resulted in about 10% (1200 ha) of the regional apple growing area using this selective method, concentrated where the pest pressure is higher. The widespread adoption of this control method has been facilitated by the financial support of the growers associations. This fact contributed to reduce only one of the problems related with the MD application, the cost of the pheromone active ingredients, but the large size of the treated plot required by the method is still a restriction for a further development in the marginal fruit-growing area.

Another semiochemical based approach is the attract and kill strategy, involving the combination of semichemical lure with an insecticidal effector. Compared with spray applications, an attracticide, as well as mating disruption, may be better accepted by consumers because its application to parts of the plant that are not harvested avoids insecticide residues on harvested crop. Ten years have elapsed since Angst and Hofer (1990) presented the first attempt of codling moth control with this novel strategy. The principle is already successfully applied to the control of codling moth (Charmillot *et al*., 1996, 1997; Kirsch, 1997; Trematerra *et al*., 1999; Ebbinghaus *et al*., 2000), and other pests (Hofer and Brassel; 1992, Suckling and Brockerhoff, 1999), although some critical parameters affecting its efficacy are still to be investigated. In this article we report on experiments designed to know some of this critical parameters.

Materials and methods

Attracticide formulation. The attract and kill technique developed by Ciba-Geigy (now Syngenta) ha been registered in Italy this year under the name of Sirene CM®. It is formulated as a viscous paste containing 0.16% codlemone (E,E)-8,10-dodecadien-1-ol to attract males and 6% permethrin (or cypermethrine), a fast-acting pyrethroid insecticide, to kill them. Using hand applicators developed specifically for the purpose, the material is applied as 50 mg droplets as high as possible on the branches or scaffold limbs of the tree. Males contacting a drop die within some hours, with a resulting decrease in mating, egg fertility and infested fruits.

Release rate of codlemone from the droplets. The release rate of codlemone from droplets was determined in two ways: (1) 50 droplets were applied to a glass sheet (10x15 cm); six glass sheets were prepared and exposed in an orchard under a shelter. At two week intervals a glass sheet was brought into the laboratory and washed with redistilled hexane, which was analysed by gas chromatography (GC-MS) and the remaining pheromone determined; (2) three glass sheets (2.5x7.5 cm) each bearing ten droplets were exposed in the field. The emission rate was evaluated at the time of exposure (Day 1), and 15, 30 and 45 days thereafter, suspending each glass sheet in stopped glass flask for 17 hours. After this time, the glass sheets were

removed and the 3 flakes were washed with a redistilled hexane, which was analysed by GC-MS (Baker *et al*., 1980).

Attractiveness of the droplets. Twelve droplet (Sirene CM®) baited traps were placed in an apple orchard during the second generation of codling moth. In six of them the lure have been weekly renewed, while in the others it remains unchanged for the period of the trial. Catches were checked, moths removed, and traps rotated twice a week.

Longevity of insecticide efficacy. Groups of 10 droplets were applied on different twigs at the beginning of June. The efficacy of the insecticides (cypermethrin and permethrin) present in the two attract & kill formulations was evaluated immediately after application, one day later and then at weekly intervals, bringing the twigs in the laboratory. Moths emerged in the laboratory from the overwintering generation, were laid on the droplet for 5 sec. using tweezers. Mortality was checked after 24 and 48 hours and corrected according to a no-treated control (Abbott, 1925).

Management of infestation sources. In order to determine the influence of a source of infestation, overwintering larvae have been released just outside a plot treated with A&K. Even though the first moths were caught on 23 May the experimental plot was treated with lufenuron (Match® 100g/hl) on 7 May when, according to the degree day sum, the first eggs were laid. After confirming that none of the fruit were injured by codling moth, instead of repeating the chemical treatment, Sirene CM® was applied on 7 June. Fruit damage was monitored randomly sampling 1000 fruits/block at weekly intervals during the summer and chemicals treatments sprayed when the threshold of 2% of fruit damage was passed. The efficacy of the control strategy was evaluated dividing the plot in four blocks 30 m wide located at increasing distance from the infestation source and by checking the fruit damage at the end of the two generations.

Field trials. Field trials were conducted in two small orchards (tab.1) with different level of codling moth populations to determine the efficacy of the control method when a low density of drops (less than 2000 drops/ha per application) were used. The attracticide droplets applied in all the treated orchard averaged 57 mg (determined after deployment by weighing the remaining material). The first application took place immediately after the first capture of male moths in pheromone-baited traps; a second and a third application of droplets was made at five week intervals. Standard pheromone traps (carpotrap® – Isagro) were installed in each plot and checked once a week. The efficacy was evaluated by assessing the fruit damage on samples of 1000 apples, randomly chosen, at different time and location in the plots. Data were compared with the surrounding conventional treated orchards. The “Toss” orchard is in part a small young orchard planted with the cultivars "hapke" and the rest with "G. delicious" 15 years old and three meter high. It has been treated on 10 and 22 May with flufenoxuron (Cascade®) at the rate of 60g/hl for the leafrollers control.

Table. Attract and kill field trials against codling moth (*Cydia pomonella*) in Trentino.

Year	Orchard	Surface (ha)	Applications		Sirene CM		Damage at harvest (%)	Curatives treatments
			N°	Date	Drops/appl./ha	(g/ha)		
1999	Toss	0.6	3	15.6- 15.7- 17.8	1173	134	0.1	-
1999	Bleggio	0.75	3	10.6- 14.7 18.8	1550	265	1.4	-
2000	Bleggio	0.75	3	22.5 29.6 9.8	2000	342	1.5	1 O.P.

Bleggio is a 6 years old apple orchard, planted with "R. gala" and "G. delicious"; the tree height is 3 meter. An IGR (Lufenuron, Match®) was applied during May of each year for the leafrollers control.

The orchards were located in the upper and colder growing area where the codling moth is still pest that have to be sprayed, but because of the less favourable climatic condition, the level of population is normally low.

Results and discussion

Release rate of codlemone from the droplets. The emission of pheromone from the drop is estimated to be between 75 and 152 ng/h for the first four weeks of exposure, thereafter, emission decreased rapidly and ranged from 5 – 17 ng/h (Fig.1). The average emission of codlemone from the droplets measured in steady air (Fig.2) is 3.1 ng/h when fresh and 2.2 ng/h after 15 days of weathering under field conditions, but decrease to 0.2 ng/h after 30 days.

Attractiveness of the droplets. The 50 moths caught in the traps in the first 4 weeks were equally distributed between the traps containing droplets that were renewed and droplets that were not renewed (Fig.3).

Longevity of insecticide efficacy. The mortality of adult moths was 100% during the first three weeks of exposure for droplets containing permethrin and during the first five weeks of exposure for droplets containing cypermethrin (Fig. 4).

Management of infestation sources. The fruit damage on the untreated trees at the point of the release reached 49.6% at the end of the first generation. In the block adjacent to the point of release of codling moths, damage caused by first-generation

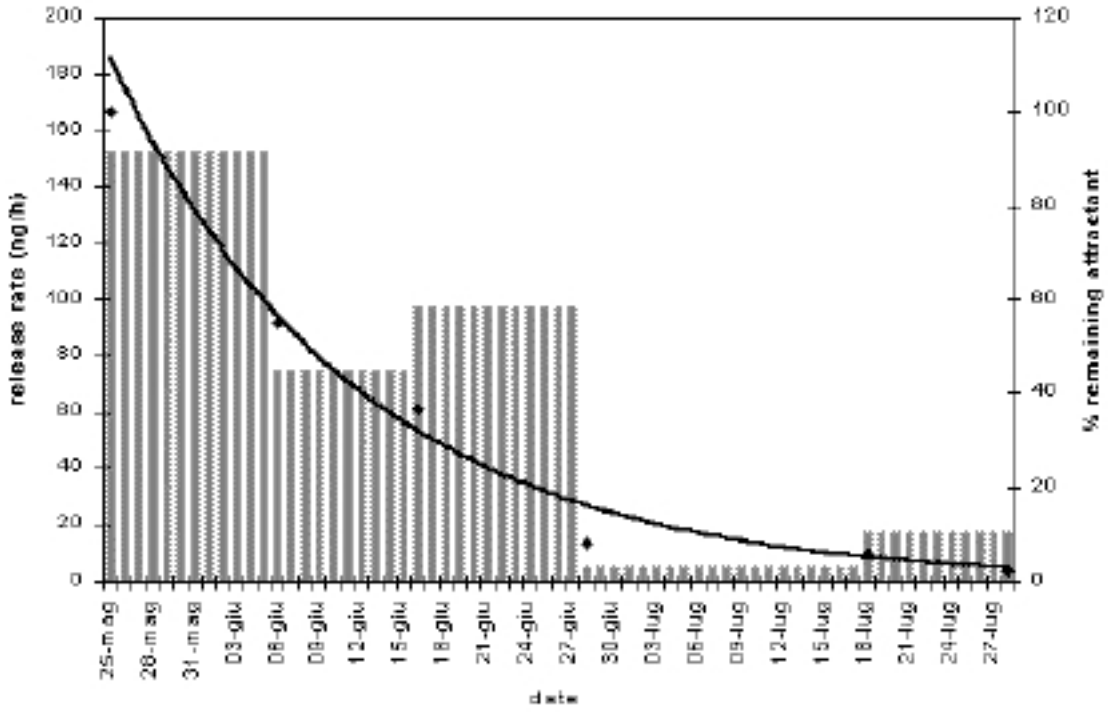

Figure 1. Release rate of codlemone (bars) from a droplet estimated according to the remaining attractant (line) determined by GC-MS.

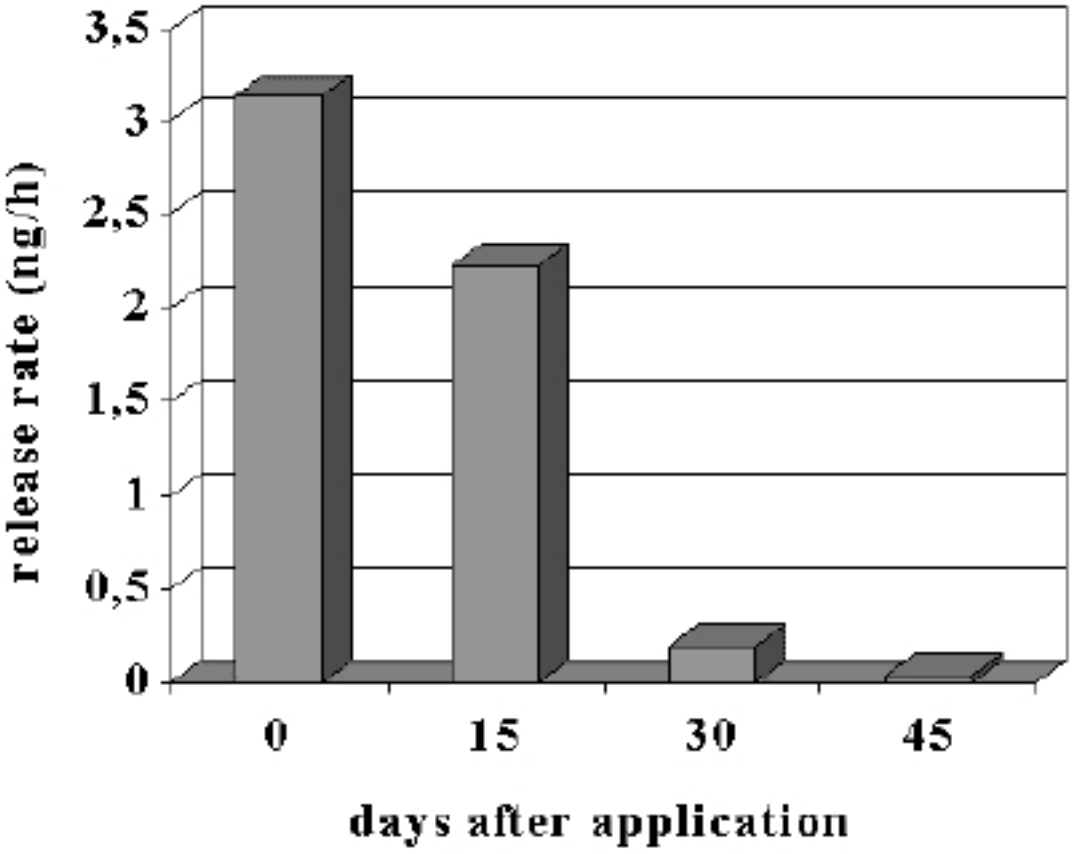

Figure 2. Release rate of codlemone from a droplet measured in steady air after different field aging periods

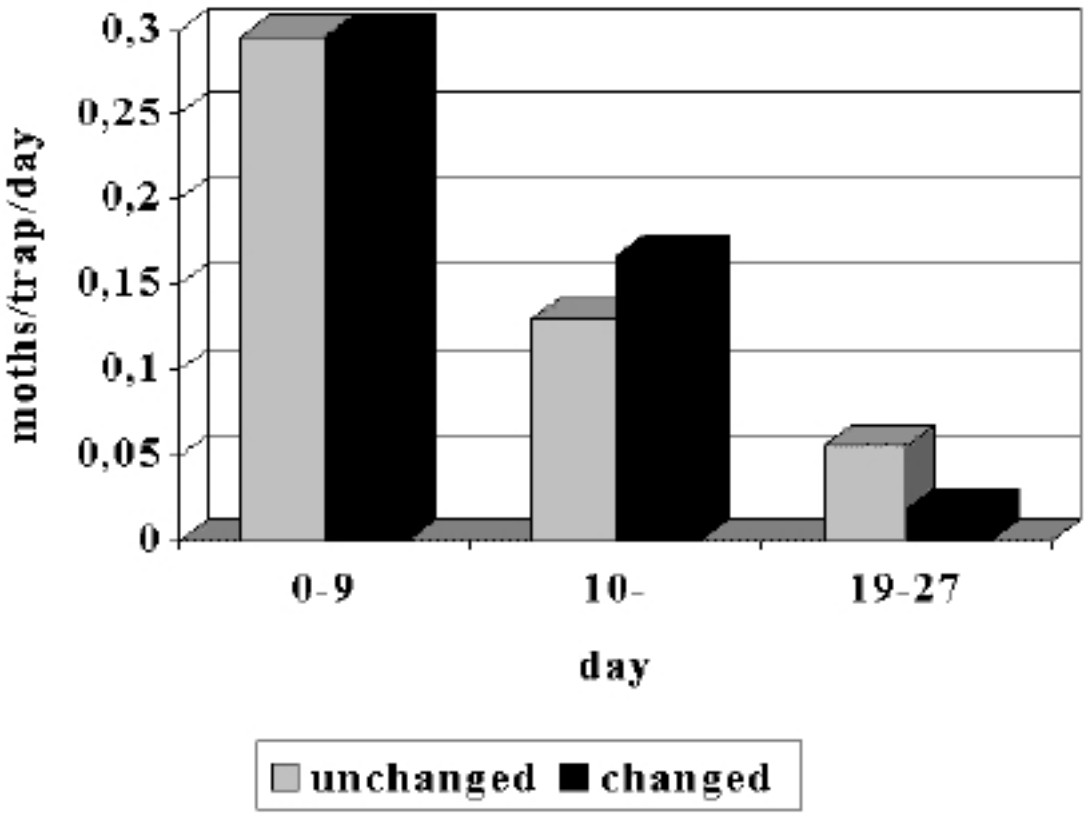

Figure 3. Averaged number of moths caught per trap and per day; gray bars = unchanged lure, black bars = renewed lure

codling moths averaged 3.5%. In the block 50-80 m from the source of infestation damage averaged 1%. There was no damage in the blocks located 80-110 and 110-140 m from the source of infestation. Because of the high level of fruit damage in the first generation, the two blocks closest to the source of infestation have been treated twice at 20 days interval with O.P. during the second generation. Damage caused by second-generation codling moths was 11.3% in the block adjacent to the source of infestation and 3% in the block located 50-80 m from the source of infestation. The damage increased again in the third block (7%), but was dramatically reduced in the fourth (0.5%).

Field trials. At Toss the pheromone traps installed in the orchard did not catch any moths and fruit damage caused by first- and second-generation codling moths was 0.1%. In the surrounding orchards treated with one to two summer insecticides, the harvest damage varied between 0 and 1%. At Bleggio; although few moths were captured in the pheromone-baited traps in both the years, a chemical treatment early in August was necessary to keep the pest under control during the second year. The average fruit damage at the harvest was 1.4% in the first year and 1.5% in the second year. During both years the years the damage was primarily located along the

south and west sides of the orchard adjacent to some untreated walnut trees and abandoned pear trees that probably served as a source of infestation that would have to be managed by the application of the droplets. In the conventionally treated orchard close to the experimental orchard, the average fruit damage registered at the harvest was 0.8% in 1999 with one summer insecticide, and 4.8% in 2000 with three summer insecticides.

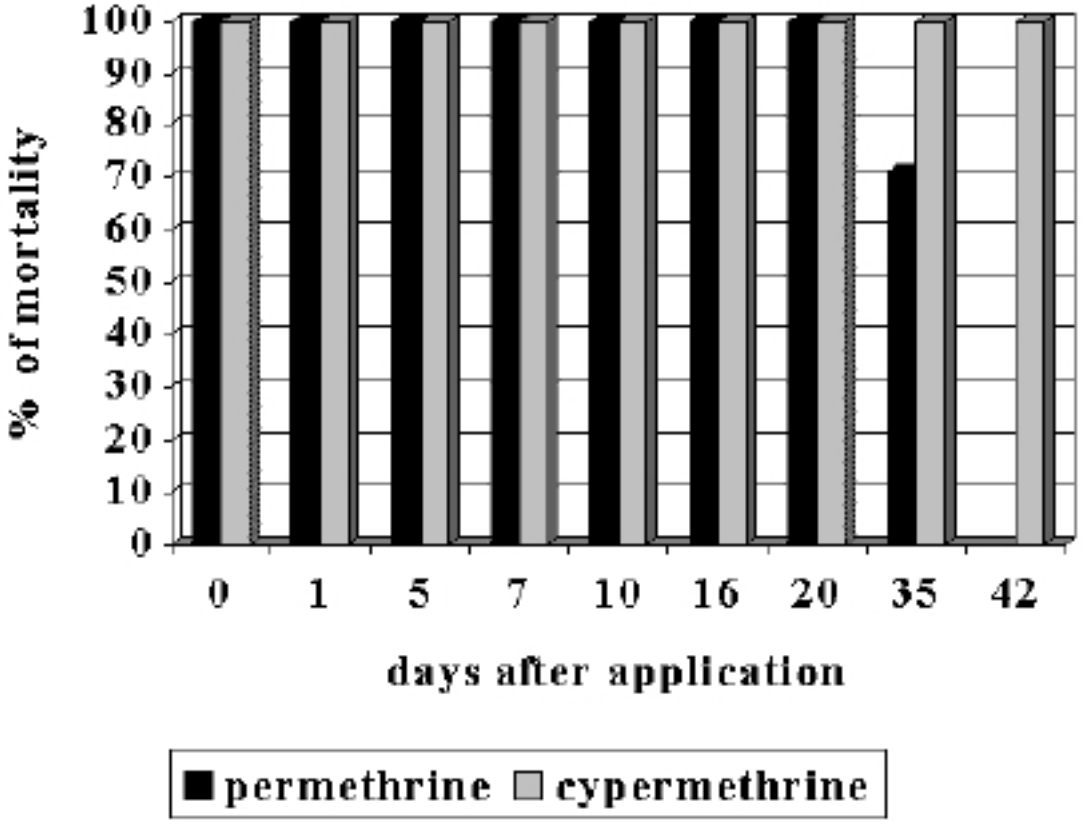

Figure 4. Longevity of the insecticide efficacy

Discussion

The use of attract and kill to control the codling moth suffers from some of the same contraints as mating disruption, including the high degree of pest selectivity, a reduction in efficacy with increasing pest density and risk of immigration of mated females. In contrast to mating disruption, the use of attract and kill removes males from the adult moth population, much lower amount of pheromone are required, and it can be applied in the small irregular and isolated orchard typical of the marginal fruit-growing areas. The results of these trials permit to better know some of the limits of the attract & kill strategy. For the formulation containing permethrin, the longevity of

the insecticide efficacy more than the attractiveness of the droplets set a time-limitfor the application. After 3 weeks the insecticide activity decrease even thought the droplets still remain attractive for the male moths. In our climatic conditions the formulation containing permethrin would require reapplication after three-four weeks of exposure whereas the formulation containing cypermethrin would require reapplication after five-six weeks of exposure. The different longevity in the insecticide activity of the two formulations has been confirmed by the study carried out on *Lobesia botrana* D&S (Angeli, unpublished data)

In our field experiment, we observed damage in a treated orchard up to 80 m from a source of codling moth infestation. These results suggest that sources or infestation adjacent to a Sirene CM®-treated orchard will also have to be treated with this product to avoid the immigration of mated females.

The efficacy of the control method came from two different mechanisms: mating disruption due to point source competition and attracticide (Charmillot et al., 1996; Suckling and Brockerhoff, 1999). The efficacy of both this mechanisms is reduced when the attraction of the drop is less than that of the moth. Our results demonstrate that the attractiveness of the droplets remain unchanged during a month.

Concerning the number of drop/ha, as the males are likely to be attracted to the droplets as to females, the attracticide is likely to work best with low pest population density so that the success of the treatment is likely to depend ultimately on the density of calling female moths per tree. As the release rate of a Sirene CM® droplet is similar to what is estimated released by a calling female (Bäckman, 1997), the greater the number of attract and kill droplets the smaller would be the chance of males finding a female prior to contact with an insecticide sources, there has to be a trade-off between gains in reliability and increased labour and material costs incurred (Lösel *et al*., 2000). Our results seem to indicate that a reduced number of drop/ha (1500-2000drops/appl.) could still be effective in the higher elevation and colder fruit growing areas where the codling moth is less abundant.

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