

## **Appeal: efficacy and mode of action of attract and kill for codling moth control**

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**Abstract:** Appeal is a novel attracticide product for the control of the codling moth, *Cydia pomonella*. It is a viscous formulation based on castor oil containing the pyrethroid cyfluthrin and (E,E)-8,10-dodecadienol, the main component of the codling moth sex pheromone. The attract and kill efficacy and the pheromone release rate of field aged samples of the formulation were tested. Both factors remained relatively stable over a period of up to six weeks. Field trials in Poland showed that this semiochemical based strategy can compete with conventional spray applications of insect growth regulators and is therefore a good alternative for codling moth control in integrated fruit growing.

**Key words:** Attract & kill, codling moth, *Cydia pomonella*

### **Introduction**

The codling moth *Cydia pomonella* L. (Lepidoptera: Tortricidae) is a major pest of fruit orchards worldwide (Barnes, 1991). Currently, codling moth control relies primarily on conventional spray applications, predominantly of organo-phosphates or insect growth regulators (IGR). The development of resistance against the latter group of insecticides makes it necessary to develop novel control methods compatible with the aims of integrated pest management (Croft & Riedl, 1991). In this context, the mating disruption technique has become a widespread method for controlling codling moths (Waldner, 1994) despite a number of problems associated with this strategy, such as the large size of the treated plots and the high costs of the pheromone active ingredients (Charmillot, 1990; Minks, 1997). Another semiochemical based approach is the attract and kill strategy, involving the combination of a semiochemical lure with an insecticidal effector (Howse *et al.*, 1998). The principle has already been successfully applied to the control of the codling moth (Hofer & Brassel, 1992; Charmillot *et al.*, 1996, 1997; Dickler *et al.*, 1998; Lösel *et al.*, 1998a, b, 2000). Appeal is a novel attracticide product for the control of the codling moth utilising the main component of the *C. pomonella* sex pheromone E8, E10-dodecadienol (Codlemone) as the lure to draw male moths to 100µl sized drops of a sticky formulation containing the contact insecticide cyfluthrin. The castor oil based formulation has a sticky consistency for the efficient uptake of the insecticide and was optimised for the controlled release of the attractant over a period encompassing a complete codling moth generation. Appeal is applied to branches in the upper parts of the tree crown with the aid of a hand operated pump-type dispenser.

The aim of work described in this paper was to investigate the longevity of the protective effect against male codling moths in the field. To this end field-aged samples of the formulation were tested using a simple attract and kill bioassay in the greenhouse and using analytical procedures to examine pheromone release characteristics. In addition, field trials were conducted in commercial apple orchards in Poland to assess the feasibility of the attract and kill strategy.

## Material and methods

*Laboratory and greenhouse experiments.* Drops of the formulation were applied to plastic strips (3 x 20 cm) which were attached to a wire fence surrounding a test orchard in the Agricultural Research Centre, Monheim, at the beginning of May, shortly before the start of the codling moth flight period. Four strips were removed for the purposes of bioassay and analytical testing at biweekly intervals. Bioassays to test the attract and kill efficacy were conducted with two strips in the greenhouse as described by Lösel *et al.* (2000). Ten male moths (2-3 d old) were kept in a cage (40 x 40 x 40 cm) together with one plastic strip for three days after which mortality was recorded. Each strip was tested twice. For the analytical testing, volatiles released from each of two samples of the formulation headed to 40°C in a 100 ml glass gas washing flask were collected on Tenax-filters. A stream of nitrogen gas was continuously flushed through the apparatus. After thermal desorption, samples were analysed quantitatively with GC-MS using internal standards.

*Field experiments.* Experiments were conducted in a mature orchard ( $\pm$  1 ha, 0.25 ha per treatment) in Drabovice, Poland, during the 1998 and 1999 growing seasons. The plot used for experiments in both years of the study was identical. It consisted of about 2000 trees (cv. Elstar) planted at a spacing of 2 m between trees and 4 m between rows. The product was applied to branches in the upper half of the tree crown at the end of May and six weeks thereafter. The first application was carried out immediately after the onset of male moth catches in monitoring traps. The treatments consisted of 2000, 4000 or 6000 drops/ha for each application. For comparison, one plot was treated with one spray application of Alsystin 480 SC (0.4 l/ha) and one plot remained untreated. Damage was assessed using 1000 hand-picked and 200-400 windfall fruits from selected trees in the centre of the various test plots.

## Results and discussion

*Laboratory and greenhouse experiments.* The attract and kill efficacy of the product remained relatively stable over a period of up to six weeks, causing around 90% mortality in the cage experiment, after which it dropped visibly (Figure 1). A similar trend was observed for the codlemone release rate. Although the insecticidal effect is known to decrease over a six week period the 4% insecticide dose in the fresh formulation ensures that there is sufficient reserve for the treatment period. The overall decline in efficacy measured here, is therefore most likely to be linked to a decline in the release rate of the attractant. Unlike the insecticide dose, that of the attractant cannot be increased without affecting its release rate. Lösel *et al.* (2000) showed that increases in the codlemone concentration of the formulation had a deleterious effect on its attractiveness to male codling moths. Maintaining attracticide activity of Appeal for a period of time spanning a complete codling moth generation is essential for the success

of the strategy since the attract and kill source must compete effectively throughout this period with the natural sex pheromone sources: the calling female moths in the orchard. The longevity of the treatment offers the grower a further major advantage, in that the timing of applications based on first catches in pheromone baited traps is much easier to achieve than are those for products targeting the period of oviposition or hatching of larvae.

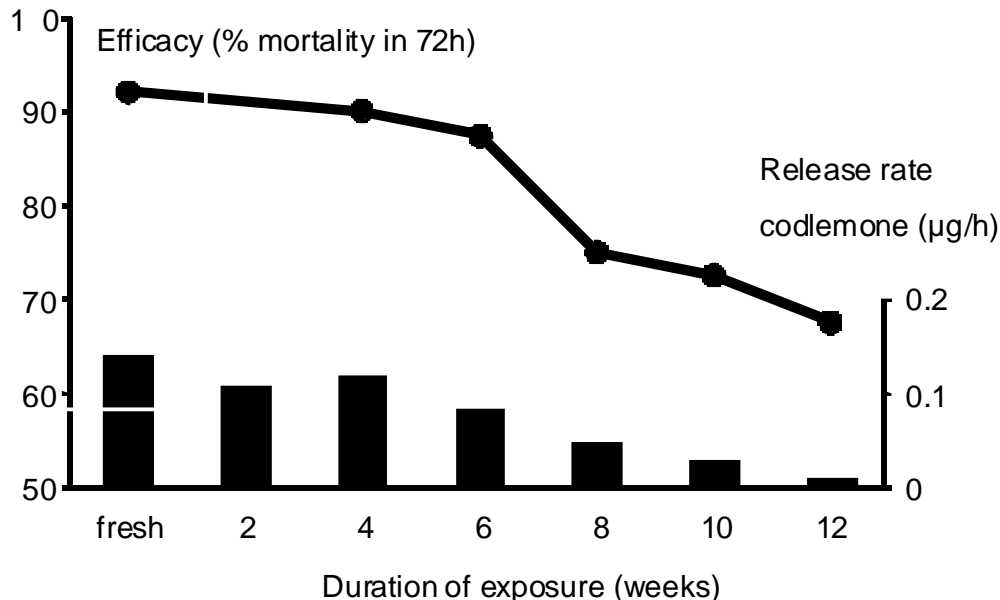


Figure 1. Efficacy of Appeal against male codling moths in a cage experiment (line;  $n = 4$ ) and codlemone release rate (bars;  $n = 2$ ) after different periods of weathering under field conditions.

*Field experiments.* Two applications of 4000-6000 drops/ha gave a level of control comparable to that achieved with the Alsystin treatment, demonstrating that this semiochemical based strategy can compete with conventional spray applications of IGR products which are currently the main stay of codling moth control for integrated fruit growers. The results with Appeal in the Drabovice field trial confirm early field data with the prototype of Appeal (Dickler et al., 1998; Lösel et al., 1998a, b) and broadly agree also with findings in studies employing other attract and kill products for codling moth control (Hofer & Brassel, 1992; Charmillot et al., 1996, 1997).

The stochastic principles underlying all sex pheromone based trapping and attracticide strategies dictate that the success of the treatment depends upon the chances of the target organisms, here the male moths, encountering an attract and kill point source are considerably greater than are their chances of encountering a mate. The greater the density of the attract and kill sources, the greater theoretically should be the success of the treatment, i.e. the smaller the number of successful matings. The albeit limited data from field experiments in the current study bear this out, with the level of damage decreasing with increasing drop density in the range tested (Figure 2) and agree with results of earlier work (Dickler *et al.*, 1998). From a practical point of view however increasing the number of manually applied attract and

kill sources affects the economic viability of the approach because of increases in labour and material costs incurred. An optimisation of drop density based on reliable data regarding the population density of female moths in the orchard would therefore be needed to predict which treatment density would be required at a particular site.

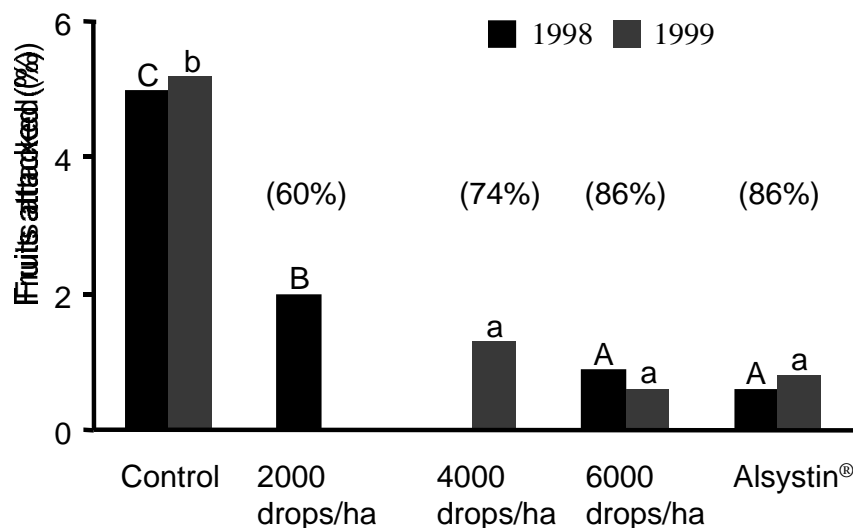


Figure 2. Efficacy of Appeal applied at different densities compared with a standard insecticide in an apple orchard near Dabrowice, Poland, in two seasons. Abbott values are given in parentheses. Different letters (upper case - 1998; lower case - 1999) indicate significant differences ( $P < 0.05$ ; Duncan's  $t$ -test).

## Conclusions

Attract and kill is a highly efficacious method of controlling codling moths in integrated fruit growing. The specificity of the sex-pheromone employed ensures that only the target species is affected, avoiding deleterious effects on beneficial and other non-target organisms often associated with broadcast spray-applications of conventional insecticides.

This study demonstrates that not only the longevity of the product but also its spatial distribution significantly affect the efficacy of the strategy. The stable pheromone release characteristics displayed by Appeal ensure that when 4000 or more sources per ha are applied, male moths are effectively controlled for a period of up to six weeks. According to the length of the codling moth's flight activity two or more applications of Appeal give season long protection.

## References

- Barnes, M.M. 1991: Codling moth occurrence, host race formation, and damage. In: World Crop Pests, Vol. 5. Tortricid Pests: Their Biology, Natural Enemies and Control, eds. Van der Geest, L.P.S. & Evenhuis, H.H., Elsevier Press, Amsterdam: 313-328.

- Charmillot, P.J. 1990: Mating disruption technique to control codling moth in western Switzerland. In: Behavior-Modifying Chemicals for Insect Management, eds. Ridgeway, R.M., Silverstein, R.M. & Inscoe, M.N., Marcel Dekker, New York: 165-182.
- Charmillot, P.J., Pasquier, D., Scalco, A. & Hofer, D. 1996: Essais de lutte contre le carpocapse *Cydia pomonella* L. par un procédé attracticide. Mitt. Schw. Ent. Ges. 69: 431-439.
- Charmillot, P.J., Pasquier, D., Scalco, A. & Hofer, D. 1997: Lutte contre le carpocapse *Cydia pomonella* L. par un procédé attracticide. Rev. Suisse Vitic. Arboric. Hortic. 29: 111-117.
- Croft, B.A. & Riedl, H.W. 1991: Chemical control and resistance to pesticides of the codling moth. In: World Crop Pests, Vol. 5. Tortricid Pests: Their Biology, Natural Enemies and Control, eds. Van der Geest, L.P.S. & Evenhuis, H.H., Elsevier Press, Amsterdam: 371-387.
- Dickler, E., Wirth, J., Bäumer, S., Lösel, P.M. & Elbert, A. 1998: Experience with two consecutive years of attract and kill in two commercial orchards in the Baden-Württemberg region of Germany in the 1995-96 growing seasons. Abstract, Proceedings of the VIth European Congress of Entomology, Ceske Budejovice (August 23-29, 1998): 641.
- Hofer, D. & Brassel, J. 1992: "Attract and Kill" to control *Cydia pomonella* and *Pectinophora gossypiella*. IOBC/WPRS Bull. 15: 36-39.
- Howse, P., Stevens, I. & Jones, O. 1998: Insect Pheromones and their Use in Pest Management. Chapman & Hall, London.
- Lösel, P.M., Ebbinghaus, D., Elbert, A. & Scherkenbeck J. 1998a: Laboratory and field studies for the development of an attract and kill strategy to control the codling moth in apple orchards. Abstract, Proceedings of the VIth European Congress of Entomology, Ceske Budejovice (August 23-29, 1998): 640.
- Lösel, P.M., Potting, R.J., Thwaite, G.W., Elbert, A., Nicoll, D. & Scherkenbeck, J. 1998b: Field studies on factors affecting the efficacy and mode of action of the attract and kill strategy for the control of the codling moth. Abstract, Proceedings of the VIth European Congress of Entomology, Ceske Budejovice (August 23-29, 1998): 647.
- Lösel, P.M., Penners, G., Potting, R.P.J., Ebbinghaus, D., Elbert, A. & Scherkenbeck, J. 2000: Laboratory and field experiments towards the development of an attract and kill strategy for the control of codling moth *Cydia pomonella*. Ent. Exp. Appl.: in press.
- Minks, A.K. 1997: Mating disruption of the codling moth. In: Insect Pheromone Research, eds. Cardé, R.T. & Minks, A.K., Chapman & Hall, London: 372-376.
- Waldner, W. 1994: Verwirrung 1995 - Unsere Empfehlung. Obstbau Weinbau 31: 288-299.