Pheromones for Insect Control in Orchards and Vineyards
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Combination of pheromone and an additive for the control of codling moth, *Cydia pomonella*

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Abstract: BASF AG recently developed a modification of the codling moth mating disruption dispensers RAK 3. In addition to the pheromone used in dispenser RAK 3, RAK 3R contains citral as an additional additive filled in a separate chamber in the dispenser, designed to enhance mating disruption. Semi-field and laboratory experiments were conducted to study the effectiveness of citral. Mating rates in cages with different moth densities placed in an apple orchard treated either with RAK 3R, RAK 3 or untreated were not significantly different. In small cages in the RAK 3 treatment, were mating differences significant. However, mating at low moth densities per cage were significantly lower in the treatments (RAK 3R, RAK 3) compared to the control. Experiments in a windtunnel revealed a significantly reduced attractivity of the pheromone if combined with Citral. In a closed system of glasscylinders (3,3 l) mating could be prevented when Citral was present at concentrations exceeding 2000 mg/l.

Key words: mating disruption, *Cydia pomonella*, codling moth, Citral

Introduction

Mating disruption using the main pheromone component 'codlemone', against codling moth has been used in apple production for several years. However, this control method does not always work reliable enough and is more expensive than insecticide applications (Waldner 1997, Cardé & Minks 1995). Different non-pheromonal compounds have been investigated for their effectiveness on mating disruption (Hathaway *et al.* 1979, Witzgall *et al.* 1997). In windtunnel experiments with *Lobesia botrana* Den. & Schiff. the monoterpene Citral - a secondary plant component - showed an impact on pheromone perception (Meiwald 1995). Therefore the BASF AG has developed a new type of dispenser that contains pheromone plus Citral (RAK 3R) aiming the improvement of mating disruption success. First field trials were carried out with a density of 125 dispensers per hectare as recommended by BASF. In these studies semi-field and laboratory experiments were conducted to study the effectiveness of the RAK 3R-dispensers in comparison to traditional RAK 3-dispensers and of Citral alone.

Material and methods

Semi-field experiments

Different moth densities. For testing the dependence of mating disruption success on moth density, cages (2 m × 2 m × 2 m) were placed between rows of an apple orchard treated either with RAK 3R (125 dispensers/ha), RAK 3 (500 dispensers/ha) or no dispensers as control. Either 6, 20 or 50 pairs of moths were released in each cage and two days later the females investigated for successful mating by assessing spermatophores. Densities at 50 pairs of moths were repeated only twice, 20 pairs of moths four times and 6 pairs of moths five times, therefore, only the last two densities were analysed statistically.

Small cages. Small cages (30 cm high, Ø 30 cm) were placed in an apple orchard treated either with RAK 3R (125 dispensers/ha), RAK 3 (500 dispensers/ha) or no dispensers as control. One pair of one day old moths were put in each cage and two days later the females were investigated for successful mating by assessing spermatophores.

Low moth-density. To examine the control effect of the two different types of dispensers at a low moth density, one fixed female and three male moths were put into cages (2 m × 2 m × 2 m) placed between apple tree rows. RAK 3R and RAK 3 dispensers were placed outside the cages at appropriate distances according to the dispenser density per hectare. The next day females were investigated for successful mating by assessing spermatophores.

Laboratory experiments

To estimate the mode of action of Citral, experiments in a windtunnel and in glasscylinders were carried out.

Windtunnel. Windtunnel trials were made to test if Citral has an impact on pheromone attractivity for moths. Four minitraps were baited with different lures and the recaptures observed over a two days period. Each minitrap consisted of a plastic syringe with two longish pieces of filterpaper placed next to each other and soaked in the according solution. This method was taken from Meiwald (1995). A constant air flow through the syringes (100 ml/min) was guaranteed by a pump. Temperature in the windtunnel was 20-24 °C and the relative humidity about 40%. The experiment was repeated five times.

Traps were baited either with: (1) control (silicon oil), (2) pheromone, (E,E)-8,10-dodecadien-1-ol solved in silicon oil, at a dilution of 10^{-3}, (3) bait 2 plus Citral solved in silicon oil at a dilution of 10^{-1} (4) bait 2 plus Citral non-diluted

Glasscylinder. Based on the results obtained from the windtunnel experiments, the question arose whether Citral is able to prevent copulation in a closed system (glascylinders 3,3 l). One pair of one day old moths per cylinder were exposed to different concentrations of Citral solved in hexane. Two days later, females were investigated for successful mating by assessing spermatophores.

Results

Semi-field experiments

Different moth densities. No significant differences were observed between mating rates in the three plots of 20 and 6 pairs per cage (Fig.1).

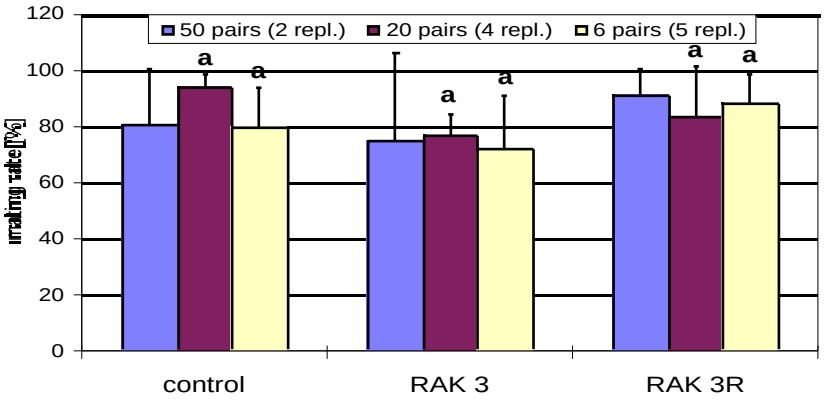

Figure 1. Mating rate in cages with different moth densities (Wilcoxon-test, p<0,05, same letters mean no significant difference within treatments)

Small cages. Only RAK 3 treatment was able to reduce mating significantly (Fig.2).

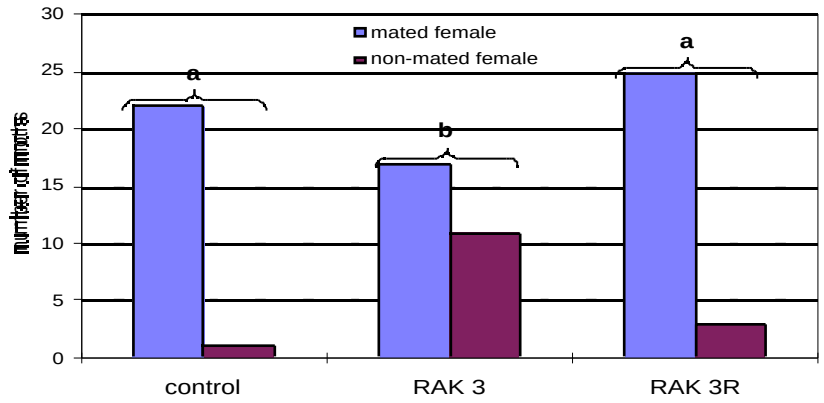

Figure 2. Mated and non-mated moths in small cages (χ2-test, Ryan, p<0,05, same letters mean no significant difference within all treatments)

Low moth density. In this experiment both dispensers RAK 3R and RAK 3 could prevent mating to a sufficient extent (Fig.3).

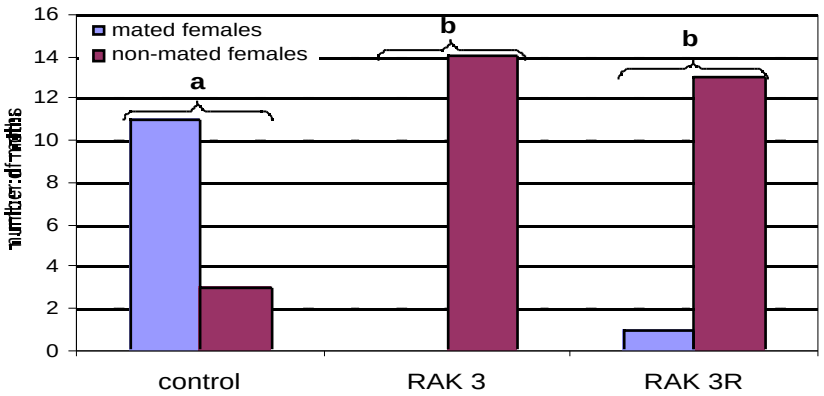

Figure 3. Number of mated and non-mated females in cages (χ2-test, Ryan, p<0,05, same letters mean no significant difference within all treatments)

Laboratory experiments

Windtunnel. The windtunnel experiments showed a significant reduced attractivity of the pheromone (Ph) if combined with Citral (C) (Fig.4).

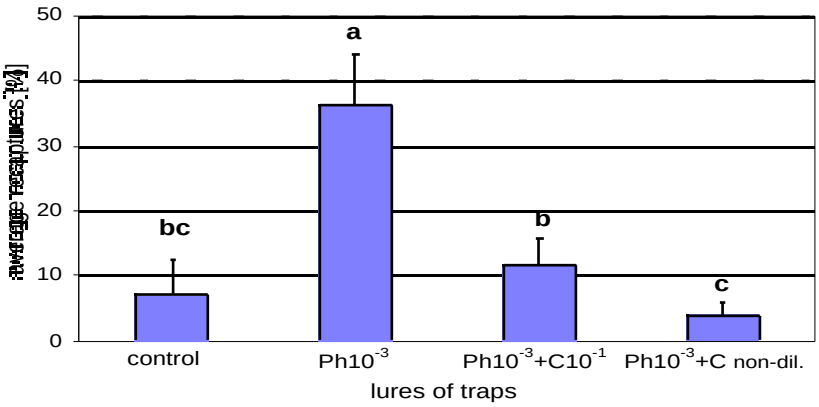

Figure 4. Recaptures of moths in a windtunnel baited with different traps (Tukey-test, $p<0,05$, same letters mean no significant difference within all treatments)

Glasscylinder. Mating is prevented if the concentration of Citral solved in hexane exceeds 2000 mg/l (Fig.5)

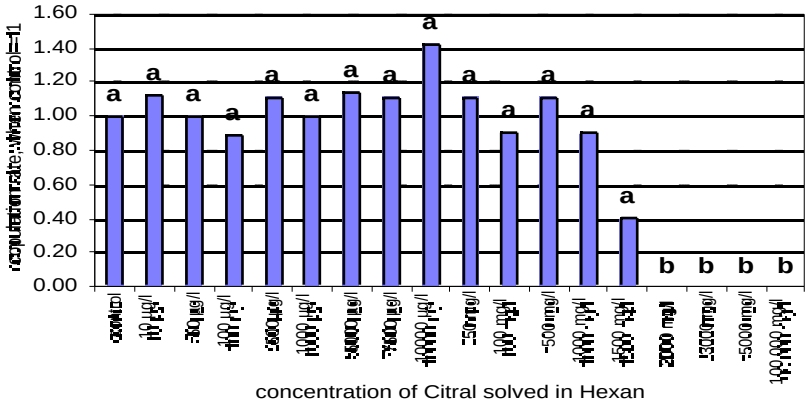

Figure 5. Copulation rate in glasscylinders with different concentrations of Citral (χ2-test, Ryan, $p<0,05$, same letters mean no significant difference within all treatments)

Discussion

In trials testing the dependence of mating disruption success on moth density there were no obvious effects of either Citral or RAK 3 treatment on mating of *C. pomonella*. However, the lowest density of six pairs of moths in a space of 8 m^2 is still high and would correspond to approximately 25000 pairs of moths per hectare. It is known that at high population densities the mating disruption technique does not work well (Cardé & Minks 1995, Neumann 1997, Casagrande & Jones 1997), because of increased chance meetings. However, matings in small cages in the RAK 3 treated area were reduced compared to RAK 3R treated area and control. A possible explanation could be the larger mesh size of the gauze of the small cages compared to the big cages and therefore better wind and pheromone transmission. At low moth densities

with one female per big cage, matings were prevented by both RAK 3R and RAK 3 dispenser types. However, the contribution of Citral towards mating disruption efficiency is still not clear. In field experiments, RAK 3R showed good results at low moth densities. At high moth densities both RAK 3R and RAK 3 failed (Kirchert *et al.* 2000).

Laboratory windtunnel experiments showed that Citral could reduce the attractivity of the pheromone significantly. Meiwald (1995) obtained similar results with *L. botrana.* Moreover Citral was able to prevent copulation in a closed system if the concentration exceeded 2000 mg/l.

Little research has been done about fumigant effects of Citral on insects. It showed some insecticidal properties against Diptera and Coleoptera by fumigant treatment (Rice & Coats 1994). According to Ryan & Byrne (1988) Citral works as a competitive inhibitor of acetylcholinesterase and, thus, has a toxic effect on the sensory nervous system in insect antennae. But the interaction of Citral and pheromone is still not clear and requires further investigation.

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