# 10 years of experience with the invasive horse chestnut leafminer (*Cameraria ohridella*) in Austria

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## ABSTRACT

First mass outbreaks of the horse chestnut leafminer (*Cameraria ohridella*) on horse chestnut trees in Austria have been detected in 1993/1994. Due to its enormous reproduction potential and its ability of rapid dispersal the horse chestnut leafminer has not only spread in Austria but also in the adjacent countries within the shortest time. Since this time control measures of the horse chestnut trees were strongly required, especially for trees in parks and in public and historic areas of the cities. In the past 10 years several control strategies against this alien species have been tried or proposed in Austria at the Institute for Plant Health, especially investigations for biological control, but most with little success or applicability.

## INTRODUCTION

The horse chestnut leafmining moth (*Cameraria ohridella*), belonging to the Gracillariidae (Lepidoptera), was first observed and detected on planted horse chestnut trees (*Aesculus hippocastanum*) in the surroundings of lake Ohrid in Macedonia in 1985 (Deschka & Dimic, 1986). In Central Europe first records have been made in Upper Austria in 1989 (Puchberger, 1990). In the following years *C. ohridella* spread into the most Central and Western European countries and now it is widespread all over Europe where it causes mass infestations. Brown coloured blotches (mines) are visible on the surface of the leaves due to the feeding of the larvae inside them. Under heavy infestation the whole leaf is covered with mines, turns completely brown and finally dies off and drops down. Therefore, sometimes completely defoliated trees can be observed in August. Due to this stress the production of new green leaves and a second bloom in autumn can often be seen, too. Investigations on the photosynthetic performance, the leaf water relations and the hydraulics of mined leaves showed that the damage to the trees has less impact than what has been supposed by visual impressions (Raimondo et al. 2003). But Thalmann et al. (2003) discovered that heavily attacked horse chestnut trees produced smaller seeds which may influence severely the growth and survival of the horse chestnut trees in the natural forests in South-East Europe. Another important point is that *Aesculus hippocastanum* is in fact the main host of *C. ohridella*, but the moth is also able to develop on other *Aesculus*-species and even on other *Acer*-species (Freise 2001). So there is a possible danger of host-shift from *C. ohridella* to other tree species. Thus, no imminent danger but still heavy damage seems to be existing for horse chestnut trees in European urban areas, in contrast to horse chestnut trees of the endemic natural stands where their future is doubtful.

In consideration of these facts great efforts have been carried out in Austria and the neighbouring countries in order to find effective control measures against *C. ohridella*.

A brief survey of the conducted control measures and experiences with the horse chestnut leafmining moth in Austria is given in the present paper.

## MATERIALS AND METHODS

Different control strategies have been carried out against the horse chestnut leafmining moth during the last 10 years.

### Chemical control

In 1995 first chemical control strategies were tested with insect growth regulators at the Institute for Plant Health in Vienna (Blümel & Hausdorf, 1996). In Vienna spraying applications were carried out with 3 different insect growth regulators: "Dimilin" (Diflubenzuron), "Alsystin Bayer" (Triflumuron) and "Insegar 25 WG" (Fenoxycarb) during the period of egg laying which coincided more or less with the peak of the moth's emergence in spring. Additionally, 2 years later experiments with tree-injections have been conducted from the Institute for Plant Health in cooperation with the company BAYER and FBVA (= Federal Research and Training Centre for Forests, Natural Hazards and Landscape). This kind of control seemed to be very promising because of its systemic mode of action and because of its more easy practicable application technique compared to the great efforts of the spraying application. This method should be suitable especially for the treatment of single trees or for trees which are only reachable with difficulties, e.g. in inner courts. For this trial several trees of different sizes have been taken in an avenue of the Viennese Prater for two application dates in spring and autumn. As active substance Imidacloprid has been injected into the tree every 5 – 10 cm around the trunk.

### Cultural measures

Cultural measures play an important role in the control of the horse chestnut leafminer, especially the removal and destruction of dead leaves which contain the overwintering pupae. Several places with and without leaf removal were evaluated during different trials. Additionally, public gardeners observed the intensity and time of infestation. Laboratory experiments have been carried out to test the tolerance of overwintering pupae from *C. ohridella* on temperature and relative humidity within the scope of the EU-project CONTROCAM to get basic information for suitable composting of infested horse chestnut leaves. 1020 *Cameraria*-pupae were isolated from fallen leaves in autumn and put into plastic boxes. Warm temperatures (+24°C to +45°C) and low temperatures (0°C to –21°C) were tested with two different degrees of humidity (30% and 95% relative humidity). In spring the number of emerged and dead moths were evaluated.

### Biological control

Despite the successful control of *C. ohridella* with "Dimilin" chemical control was not regarded as a suitable solution for a sustainable control of *Cameraria* in future. Research was

needed in alternative control possibilities. Thus, only one year after the first chemical trials first investigations about natural enemies of the horse chestnut leafminer and their potential use for biological control started in Austria. In the following years several projects have been carried out about this topic at the Institute for Plant Protection: studies on the parasitoids of *C. ohridella* (Lethmayer, 1996 – 2001), a diploma thesis on parasitism of *C. ohridella* (Grabenweger, 1996 – 1998), a research project about the moth's control with natural enemies (Stolz, 1996 – 1999) and the EU-project CONTROCAM (2000 – 2004), of which Austria was one of the involved partners. The topic of this EU-project was to develop alternative, sustainable, environmental friendly measurements against *C. ohridella*. Concerning biological control the main task of the Austrian team was the qualitative and quantitative assessment of the moth's parasitoids in whole Europe and data on its predators.

**Biotechnical measures**

After identification and synthesis of the special sex pheromone of *C. ohridella* in 1999 (Svatos et al., 1999) experiments started to develop pheromone based monitoring and control methods. In Austria first trials with pheromones were carried out in the field in 2001, again within the scope of the EU-project CONTROCAM, with the aim to reduce the high infestation level. In the following years several mass-trapping methods were tested with different types of traps (sticky sheets and bottle-traps in the lower branches of the tree, glue-rings around the trunk) and different arrangement of the trees (solitary isolated trees, groups of trees and trees in a row (alleys)). The number and position of the traps and pheromones also varied from trial to trial and trees with and without leaf removal were chosen. In addition, the confusion technique was tested having used only pheromones. In the last years the company Calantis tried a new approach with attractants using plant odours as kairomones, which lure the females of *C. ohridella*.

## RESULTS

### Chemical control

Concerning the trials with the insect growth regulators best results were obtained with the WP formulations of "Alsystin Bayer" and "Dimilin": 98% - 100% of the larvae were killed depending on the number of applications. It is up to now still the control method mainly used in public urban areas. The evaluation of the tree-injections showed that only an irregular dispersion of the insecticide within the tree has been achieved, so that efficacy also was only reached in some parts of the tree. But, on these branches a duration of efficacy of more than 2 years could be observed.

### Cultural measures

In autumn the removal and destruction of infested leaves (e. g. burning or composting) has been proved to be an effective method to reduce and to postpone the first generation of the moth in the next year (spring), especially on isolated places with horse chestnut trees, such as inner courts in cities and in private gardens. In addition, observations showed that the watering and nutrient supply were also important measures to increase the tree's own defense mechanism, especially at dry periods in summer.

The laboratory experiments resulted in a percentage of pupae-mortality between 10% and 40% up to a temperature of + 36°C, but reached 100% mortality at + 39°C (for 30% RH) and at + 42°C (for 95% RH) ($p = 0,01$; $r = 0,647$). Contrary to warm temperatures the pupae showed high tolerance to the tested low temperatures. There was only a maximum of 20% dead pupae (with one exception) for 30% RH and only a maximum of 14% for 95% RH until a temperature of -18°C. Increasing mortality was indicated at – 21°C, but no significant correlation existed between the mortality of *C. ohridella*-pupae and these cold temperatures.

**Biological control**

First obtained results about the parasitoids of *C. ohridella* revealed a total of 22 species from parasitic Hymenoptera, mainly Chalcidoidea (Eulophidae) with 2 – 3 dominating species and a few individuals of Ichneumonoidea (Grabenweger & Lethmayer, 1999; Stolz, 1997). All these parasitoids are polyphagous ecto- and endoparasitoids on different leafmining insects and none were specialists. In general, the rate of parasitism was very low (about 1% – 15%, depending on the locality and the moth's generation). Experiments for rearing the parasitoids as well as the breeding of the horse chestnut leafminer itself failed. The results of the CONTROCAM-investigations confirmed that the most important enemies of *C. ohridella* were the parasitoids of the Hymenopteran Chalcidoidea and Ichneumonoidea. A total of 36 species has been achieved from all investigated sites in Europe, including the Balcan, and everywhere rather the same species composition was present. The dominating species were *Minotetrastichus frontalis*, *Pnigalio agraules* and *Pediobius saulius*. The parasitism rate was in general very low on every place (on average 6.2%). Furtheron, no significant density dependent response (the relation of host population densities and parasitism) could be observed. Interesting observations were made concerning the predators of *C. ohridella*. In the last years birds, especially tits, gained in importance having realized that the larvae and pupae were being suitable food sources. More surprising was the discovery of the southern oak bushcricket *Meconema meridionale* (Tettigoniidae, Ensifera) as an active predator of *C. ohridella* which opened the mines well directed to prey the larvae (and pupae) inside the leaves.

**Biotechnical measures**

The results of all experiments were not promising because there were no obvious differences between treated and untreated trees. Although a quite high number of moths were caught with sticky sheets and also with the glue-rings, there was still a high number of mines on the leaves respectively a high infestation of the tree. No significant reduction of the infestation level has been achieved with the confusion technique.

## DISCUSSION

During the last 10 years intensive investigations on different possibilities to control the horse chestnut leafmining moth were carried out in Austria. Although there is a successful chemical control with "Dimilin" against *C. ohridella* with only one single treatment per year, this was not regarded as the definitive solution. Other chemical methods were tested as for example the method of tree-injections.

But none of these methods were suitable for a use in practice due to problems with too little efficacy or due to registration reasons or because of the application technique itself – as in the case of the tree-injections where the injuries through the boreholes in the tree cause not only necrosis but also secondary infections. Another important point for the use of these tree-injections is the current status of authorization. Until now, such a kind of treatment is not permitted in Austria.

Beside these "chemical" problems the demand for sustainable, environmental friendly control measures increased. Although much emphasis was laid in many investigations on natural enemies and their potential use for controlling the moth, there is still no satisfying respectively practicable method for an effective biological control.

The natural parasitism rate is still very low. It seems that the native parasitoids are still not well adapted to this alien host, as it is demonstrated with the bad synchronization of the parasitoids (Grabenweger, 2004), even after such a long period of occurrence. Although there are very slight tendencies of adaptation recognizable but still no significant signs of their effective impact. The predators also still have too little influence on the high population densities of *C. ohridella*.

After disappointing results with the possibilities of natural enemies other control strategies should fulfill the expectations. Very promising seemed to be the use of attractants after the identification of the sex-pheromone of *C. ohridella*. But no conspicuous reduction of infestation could be achieved with pheromones in combination with mass-traps or as male confusion technique. The main problem were the enormous masses of *C. ohridella* which were too high for „normal" trapping methods and especially for confusion technique, even on sites with reduced *Cameraria*-population due to careful litter removal. The first results of these investigations revealed that specific control only against males did not facilitate a sufficient infestation reduction. Therefore it was high time to devise valuable means of control against males and females. This new approach is already in research and development using kairomones as attractants for the females.

The removal and destruction of infested leaves in autumn is an effective method to reduce the infestation of the (next) spring generation and to provide lower population densities, especially on places where chemical treatments are not possible. But this method cannot replace additional treatments. Besides, in forest areas and great parks where a complete removal of the leaves is not possible, this method is inefficient.

The results of the laboratory experiments demonstrated the sensitivity of overwintering *C. ohridella*-pupae to warm temperatures. Thus, in practice a minimum temperature of + 40°C is necessary within compost heaps to kill the pupae in the leaves. On the other hand, the horse chestnut leafminer shows high tolerance to low temperatures. Therefore the pupae are also able to survive periods of strong frost in winter without problems.

At the moment the use of the insect growth regulator "Dimilin" is the only possibility for chemical treatment being the only plant protection product which is registered for the control of *C. ohridella* in Austria. "Dimilin" in combination with exact leaf removal is the best strategy until now. For the exact determination of the application date in spring the use of pheromones is preferable.

To sum up, one of the most important problems of all tested control attempts against *C. ohridella* is the extremely high population density of the moth. Thus, only an integrated pest management system considering the combination of different cultural and control measurements will be promising successful control of *C. ohridella* in future. International cooperation will become much more important and necessary to find effective control measurements not only against this invasive alien species.

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## REFERENCES

Blümel S & Hausdorf H (1996). Versuche zur Bekämpfung der Roßkastanienminiermotte. *Gärtner & Florist* **10**, 4-6.

Deschka G & Dimic N (1986). *Cameraria ohridella* n. sp. aus Mazedonien, Jugoslawien (Lepidoptera, Lithocolletidae). *Acta entomologica Jugoslavica* **22** (1-2), 11-23.

Freise J (2001). Untersuchungen zur Biologie und Ökologie der Roßkastanien-Miniermotte, *Cameraria ohridella* Desch. & Dim. (Lep., Gracillariidae). *PhD Thesis*, Department of Applied Zoology, Technical University of Munich, 216 pp.

Grabenweger G (2004). Poor control of the horse chestnut leafminer, *Cameraria ohridella* (Lepidoptera: Gracillariidae), by native European parasitoids: a synchronisation problem. *European Journal of Entomology* **101**, 189-192.

Grabenweger G; Lethmayer C (1999). Occurrence and phenology of parasitic Chalcidoidea on the horse chestnut leafminer *Cameraria ohridella* Deschka & Dimic (Gracillariidae, Lepidoptera). *Journal of Applied Entomology* **123**, 257-260.

Puchberger K M (1990). *Cameraria ohridella* DESCHKA & DIMIC (Lepidoptera-Lithocolletidae) in Österreich. *Steyrer Entomologenrunde* **24**, 79-81.

Raimondo F; Ghirardelli L A; Nardini A; Salleo S (2003). Impact of the leaf miner *Cameraria ohridella* on photosynthesis, water relations and hydraulics of *Aesculus hippocastanum* leaves. *Trees* **17**, 376-382.

Stolz M (1997): Untersuchungen über Larval- und Puppenparasitoide von *Cameraria ohridella* in Hinblick auf ihre Eignung zur Laborzucht. *Forstschutz Aktuell* **21**, 31.

Svatos A; Kalinová B; Hoskovec M; Kindl J; Hrdý I (1999). Identification of a new lepidopteran sex pheromone in picogram quantities using an antennal biodetector: (8E,10Z)-tetradeca-8,10-dienal from *Cameraria ohridella*. *Tetrahedron lett*. **40** (38), 7011-7014.

Thalmann C; Freise J; Heitland W; Bacher S (2003). Effects of defoliation by horse chestnut leafminer (*Cameraria ohridella*) on reproduction in *Aesculus hippocastanum*. *Trees* **17** (5), 383-388.