SHORT COMMUNICATION

Date of leaf litter removal to prevent emergence of *Cameraria ohridella* in the following spring

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Introduction

The horse chestnut leafminer, *Cameraria ohridella* Deschka and Dimic (Lepidoptera, Gracillariidae), is a pest of unknown origin that was recently introduced in Europe. This leafminer has already colonised large areas of Europe, and is still spreading. *Cameraria ohridella* attacks almost exclusively the white flowering horse chestnut tree (*Aesculus hippocastanum* L., Hippocastanaceae) and can reach large population densities. Its highly visible leaf damage is caused by the feeding of larvae between the two leaf epidermis layers. At high densities, *C. ohridella* completely defoliates trees already in summer. The leaf damage is particularly spectacular in cities where horse chestnut trees are abundant and the defoliation of trees in streets, parks, and gardens in early summer raises significant public concern. The aesthetic problems and the lost filter function of defoliated trees in the city climate are considered to be the main consequence of damage. The pest is thus mostly an urban problem which is managed on the scale of cities.

The first mass appearance of *C. ohridella* was recorded in 1984 near Lake Ohrid in Macedonia (Deschka & Dimic, 1986) and since then it has spread all over Europe. The females lay 20–40 eggs on the upper epidermis of the leaves and the hatched larvae drill into the leaves (Freise, 2001). There, the larvae feed first on the sap and then on the parenchyma (Deschka & Dimic, 1986), passing through five larval stages, and pupating in the mine. Emerging adults leave their mines and reproduce. *Cameraria ohridella* produces between two to four generations per year depending on climatic conditions. In each generation a fraction of the pupae enter diapause (Freise & Heitland, 2001).

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Up to now all attempts to sustainably control the horse chestnut leafminer have failed. Chemical control is very expensive and the application of insecticides on full-grown horse chestnut trees is either difficult (Blümel & Hausdorf, 1996; Tsankov et al., 2000), ecologically questionable (Lohrer et al., 2000), or may even harm the trees (Feemers, 1997; Krehan, 1997). Therefore, a European programme was launched to develop alternative control strategies such as pheromone traps (Svatos et al., 1999), the search for biocontrol agents from the moth's place of origin, once the origin has been located (Kenis, 1997), and the conservation and augmentation of native parasitoids and predators (see http://www.cameraria.de). However, these alternative strategies are still far from practical application. Currently, the removal of leaf litter is the only advisable control method, and this is widely used by private and city gardeners all over Europe (personal observation). By removing the leaves, the pupae of *C. ohridella* hibernating in the mines are also removed and consequently the number of adults emerging in the spring is reduced (Deschka, 1993; Butin & Führer, 1994; Heitland et al., 1999). Gilbert et al. (2003) demonstrated that the removal of litter is an effective short-term control measure to reduce the impact of the moth on horse chestnut trees in the following year.

Currently, cities are advised to remove the leaves as soon as possible in autumn (personal observation), because it is feared that the overwintering pupae of *C. ohridella* will fall out of the decomposing leaves and survive the winter on the ground, even when leaves are removed later during the winter. This forces private and city gardeners to remove leaf litter immediately after the trees have shed their leaves in the autumn. However, for city gardeners this task will often be especially difficult to achieve because of constraints in time and manpower. In practice, the cleaning of parks and streets is done until deep into winter, as time and the availability of manpower allows. This increases the chance for pupae to fall out of decomposing leaves and to survive the winter on the ground. The change of this practice to

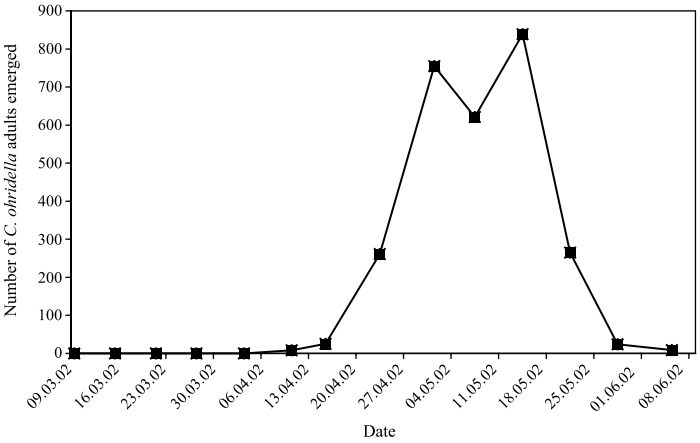

Figure 1 Total number of *C. ohridella* adults caught by the 30 photo eclectors over the emergence period in spring 2002.

meet the recommendation of early leaf removal is costly because it would require extra manpower in the autumn to cope with the increased workload. It is therefore of utmost importance to people such as city gardeners to know if early leaf removal is more effective in reducing moth densities.

In this study we tested if the date of leaf litter removal over winter is relevant to preventing the emergence of *C. ohridella* adults the following spring.

Materials and methods

Experimental set-up and procedure

The study was conducted in a completely randomised two-factorial design. The two factors were 'amount of leaf litter' (0.5 vs. 1.5 kg horse-chestnut leaf litter per m^2) and 'date of leaf removal' (at three levels: litter removed early, late, and no removal). Full combinations of the two factors resulted in six treatments which were replicated five times each. Thirty plots of 1×1 m were established in the garden of the Zoological Institute in Bern. Plots were located on a mown meadow under trees, closely resembling a park or garden-like situation in practice. Each plot was randomly assigned to one of the treatment replicates. On 20 November 2001, *C. ohridella*-infested horse chestnut leaf litter with an infestation level of about 25% damaged leaf area was collected from one site in Bern. The following day, we placed 0.5 kg or 1.5 kg of the collected leaf litter into the plots. Each plot was surrounded by a 35-cm high, metallic snail fence and protected by a fine bird net (mesh width 2 cm) to prevent the drift of leaves. Leaf litter was hand-collected and removed in a third of the plots either on 10 January (= early) or 28 February (= late) 2002. The remaining 10 plots where leaf litter was not removed (= no removal) served as controls.

Data collection and statistical analysis

After the last removal of leaves we placed a photo-eclector (= emergence trap) with a surface area of 0.21 m^2 at the centre of each plot to catch the emerging *C. ohridella*. From 9 March to 5 June 2002, eclectors were checked weekly and the number of moths trapped was recorded.

The total number of emerging *C. ohridella* adults was square root-transformed and treated as the dependent variable, whereas the amount of leaf litter and the date of removal were treated as nominal independent variables. The experiment was analysed by a two-way ANOVA. Means of the three dates of leaf removal were pair-wise compared by Bonferroni post hoc tests.

Results

Cameraria ohridella adults emerged from the leaf litter exposed from the beginning of April until June 2002 and the majority of moths were caught in the first half of May (Figure 1).

The date of leaf litter removal ($F_{2,24} = 332.00$, $P < 0.001$), the amount of leaf litter ($F_{1,24} = 14.41$, $P < 0.001$), as well as their interaction ($F_{2,24} = 18.30$, $P < 0.001$) had a highly significant impact on the total number of *C. ohridella* adults emerging. The interaction term results due to the 'no removal' treatment with two different leaf litter amounts, as in the early and late removal treatment almost no moths emerged (Figure 2). The interaction disappeared when the number of moths emerged was standardised by dividing the total number of emerging moths by the amount of leaf litter exposed ($F_{2,24} = 0.8656$, $P = 0.43$). In total 2, 2, and 2803 moths were caught in the traps of early, late, and no leaf removal (Figure 2). There was no difference in the number of moths emerging between the early and late litter removal dates (Bonferroni: $P = 1.00$) and the leaf removal treatments differed significantly from the controls (Bonferroni: $P < 0.001$). About three times the number of moths emerged from the 1.5 kg leaf litter than from the 0.5 kg amount (Figure 2).

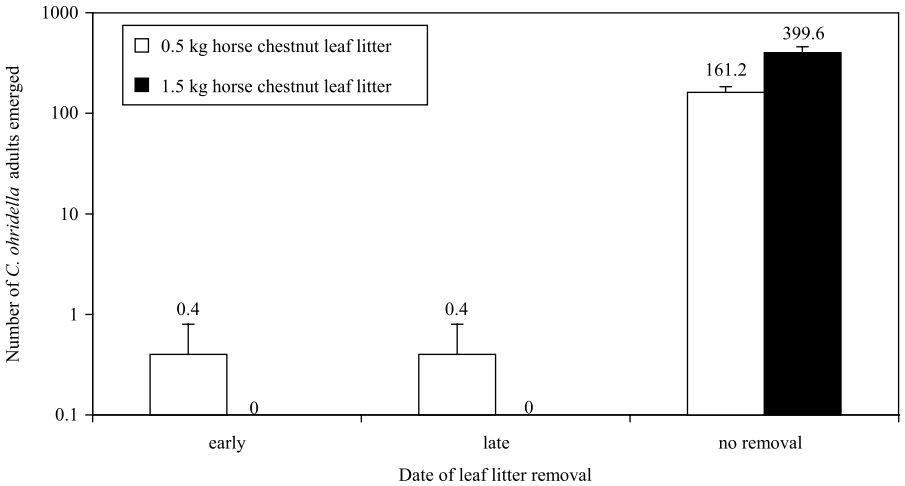

Figure 2 Impact of the date of leaf removal and the amount of removed horse chestnut leaf litter on the mean number of *C. ohridella* adults emerged in spring 2002 (y-axis in logarithmic scale). Dates of removal were 10 January (= early) and 28 February (= late) 2002. Bars = 1 SE.

Discussion

The two moths caught in the early and late removal treatment hatched in each case out of only one of the 10 plots. Therefore, it seems likely that the four moths we caught emerged from one remaining leaf part per plot which was overlooked during leaf removal. However, our experiment has shown that the date of horse chestnut leaf litter removal does not affect the number of emerging *C. ohridella* adults, as the same number of moths emerged in both the early and late leaf removal tests. Either hibernating pupae did not fall out of the decomposing leaves, or the pupae did not survive the winter outside their mines. Our findings suggest that city and private gardeners can remove the leaf litter at any convenient date before spring in order to reduce the impact of the moths on *A. hippocastanum* trees in the following growing season. Our results further stress that it is much more important that horse chestnut leaves are completely removed, and that places where leaf litter can gather and which are difficult to access are properly cleared. Even at the scale of cities, the better the leaves are removed the lower will be the leaf damage in the following year (Gilbert et al., 2003).

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