Ladybirds for biological control of *Adelges cooleyi*, in gas exchange experiments with Douglas-fir (Coleoptera: Coccinellidae; Homoptera: Adelgidae)

L. G. Moraal & E. G. Steingröver

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Abstract: Infestations of the Douglas-fir woolly aphid, *Adelges cooleyi* Gillette disturbed experiments in which the photosynthesis, respiration and transpiration of Douglas-fir (*Pseudotsuga menziesii* Franco) needles were being measured in branch chambers. A biological control method has been developed to prevent infestations by the aphids. Before starting the experiments, ladybirds are used to prey on the aphids. This enables the use of insecticides, and hence any possible undesirable side-effects on the assimilating tissues, to be avoided.

"De Dorschkamp", Research Institute for Forestry and Urban Ecology, P.O. Box 23, 6700 AA Wageningen, The Netherlands.

Introduction

In the ACIFORN project (ACidification In the FORests in the Netherlands), the effects of air pollution on tree growth and tree vitality are being assessed in a series of experiments (Evers et al., 1991). In this project, Douglas-fir (*Pseudotsuga menziesii* Franco) has been chosen as model species. In order to study the quality of individual needle classes, the water vapour and carbon dioxide exchange of separate needle classes was measured in branch chambers (fig. 1). Branchlets up to 12 cm long can be enclosed in the branch chambers. The branch chambers are electronically linked to a field laboratory, where the data are collated. This enables photosynthesis, respiration and transpiration to be monitored round the clock (Steingröver & van der Beek, 1991).

Moderate and heavy infestations of the Douglas-fir woolly aphid, *Adelges cooleyi* Gillette (Homoptera: Adelgidae) occurred in the trees and most branchlets were infested with these aphids. (For the life-cycle and other bionomics of this aphid see Carter, 1971). The visible damage done to the foliage consisted of chlorotic bands and twisted or curled needles. In addition, non-visible damage may result from nutrient depletion, toxic secretions, hormonal effects or simply from the physical destruction of cellular tissues (Miles, 1989). It therefore seems very likely that *Adelges* infestations affect the needles' gas exchange and directly interfere with the carbon dioxide exchange of the needles via their respiration (Llewellyn, 1988). But even more important, the physical presence of the aphid bodies may influence photosynthetic activity because the insect prevents light reaching the surface of the needles (Walstad et al., 1973). The honeydew excreted by the aphids also poses a problem.

Control of the aphids was therefore deemed to be necessary. We decided against insecticides applying, because this might cause phytotoxical effects or interfere with the needles' physiological behaviour. Therefore we developed a biological control method using natural predators.

Materials and methods

Predation by coccinellids seemed a suitable control method and to test this, we collected adult beetles from an arbitrary Douglas-fir stand.

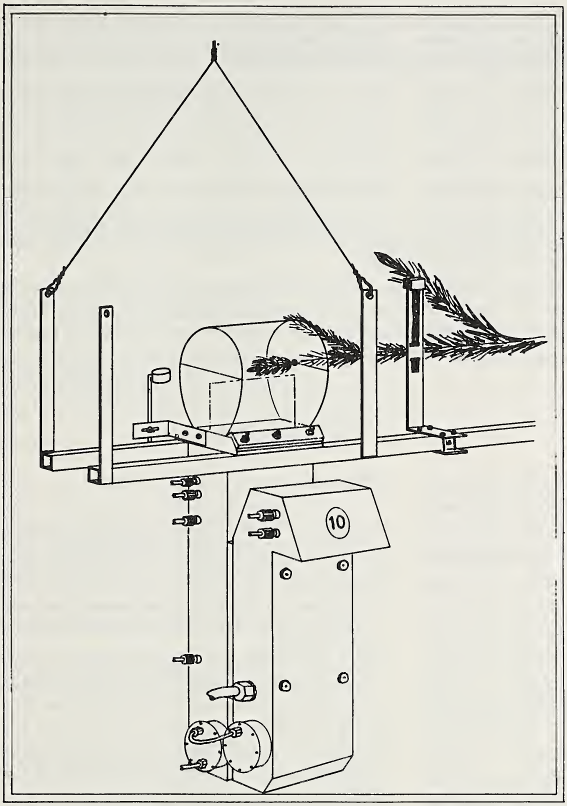

Fig. 1. Schematic representation of a branch chamber.

a. *Control of egg-laying aphids in the laboratory.*

In April 1989, *Exochomus quadripustulatus* (Linnaeus) was the most abundant coccinellid species. Ten adult beetles were transferred to a small plastic box (16 x 11 x 6 cm) containing a piece of branchlet. The beetles stayed there, at room temperature, for five days. This branchlet was heavily infested with a total of approximately 110 egg-laying aphids. Another equally infested branchlet was enclosed in another plastic box without coccinellids. Each day the predation activity of the coccinellids was observed.

b. *Control of egg-laying aphids and nymphs in the laboratory.*

In August 1989, *Coccinella distincta* Faldermann was as abundant as *E. quadripustulatus*. Therefore, both species were used separately in the same experiments as described above under a. In August, egg-laying aphids and overwintering nymphs were both present on the Douglas-fir branches.

c. *Field experiment.*

In addition to the laboratory experiments, plastic boxes, each containing 15 adults of *E. quadripustulatus* or *C. distincta*, were attached to the branches of the experimental trees. Only those branches that were not visibly damaged were selected. After 3-4 days the box of beetles was removed and the branch chamber was attached to the treated branchlet. The field experiments were carried out between April and the end of July 1989. The gas exchange of one-year-old needles was measured between April and the start of the flush (mid-May), when the current year's needles appear in Douglas-fir. After flushing a second set of branch chambers was installed to measure the gas exchange of the current year's needles. Both the one-year-old needles and the current year's needles were exposed 3-4 days to coccinellids in plastic boxes, before starting the gas exchange measurements.

Results

a. Once enclosed with the Douglas-fir branchlet, the beetles started to remove the wax-wool secretions and consumed both living aphids as well as the clutches of eggs. Within 24 hours the beetles had removed all the aphids, all the eggs and all the emerging young aphids. Only the remains of wax-wool were recovered on the bottom of the box. Within the untreated box, no mortality was observed and after two days hundreds of young newly emerged aphids covered the needles.

b. Both *E. quadripustulatus* and *C. distincta* cleaned the needles by consuming aphids and the eggs as described under a. The overwintering immobile nymphs were ignored first, but after three days of starvation the beetles started consuming the nymphs too and had predated all of them in about two days.

c. The needles were cleaned from all aphids and eggs in the same way as described under a and b. The gas exchange measurements lasted about three months. During this period no aphids were detected on the current and older needles enclosed in the branch chambers.

Discussion

Coccinellidae are intensively studied predators of aphids (Frazer, 1988) and there are several examples of using them successfully for biological control in diverse crops (van Lenteren, 1990). These predators do not capture all the aphids they encounter. Most aphids are dislodged from their feeding sites or move of their own accord if disturbed by a searching coccinellid or in response to another aphid's alarm pheromone (Frazer, 1988). The adults and overwintering nymphs of *A. cooleyi*, however, are immobile, and therefore the coccinellids can easily find and consume this aphid species.

We were thus able to avoid using insecticides or other chemical applications which might have had undesirable side-effects on the assimilating tissues. When aphids are present, we now use coccinellids as a standard procedure to clean the needles, before starting the gas exchange experiments.

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