Interactions among polyphagous anthocorid bugs used for thrips control and other beneficials in multi-species biological pest management systems.

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ABSTRACT

Interactions between anthocorid bugs (*Orius majusculus*) for control of western flower thrips (*Frankliniella occidentalis*), gall midges (*Aphidoletes aphidimyza*) for control of cotton aphids (*Aphis gossypii*), and predatory mites (*Phytoseiulus persimilis*) for control of spider mites (*Tetranychus urticae*) on pot gerbera (*Gerbera jamesonii*) were investigated in climate controlled glasshouse cabinets. The experiments suggested that by introducing anthocorids in a ratio to thrips of 1:150 or less, the thrips populations were reduced to less than 1 per leaf within 4-6 weeks. Not only thrips but also aphids were controlled on a constant low level after anthocorid establishment and throughout the culture period. The efficacy of the anthocorids for thrips control was not hampered by the presence of neither spidermites, predatory mites, aphids, nor gall midges. Contrary, the experiments suggest that the anthocorids benefit from these alternative prey species in situations with scarcity of thrips. However, control of spidermites and aphids by predatory mites and gall midges, respectively, was influenced by the presence of anthocorids. Due to the predation on the other beneficials, presence of anthocorids delayed their control of spidermites and aphids. The pests consequently achieved higher densities before arrestment of their population increase. However, already five weeks after introduction of beneficials, the number of spidermites was at the same low level in the plots with both predatory mites and anthocorids as in plots with predatory mites as the only beneficial. The aphid control effect by the gall midges was totally overshadowed by the aphidophagous effect of the anthocorids in plots where both predators were introduced. Furthermore, our experiments document a predatory effect of thrips on spidermites under glasshouse conditions.

INTRODUCTION

During the past decade, biological pest control has been used as a routine measure by Danish glasshouse vegetable growers (1,2). Normally, all pests are controlled exclusively by biological agents during the entire growing season. Biological pest control has proven not only to be environmentally safe and beneficial to the working environment in the glasshouse industry but also efficient and economically superior to chemical pest control. An important factor in the successful implementation of biological pest control in vegetable crops has been that only few pest species are present in each vegetable culture. Furthermore, most growers rely on production of a single culture. However, in ornamental crops the pest complex is often larger than in vegetables because most ornamental plant species are host plants to several insect and mite pests and because ornamental growers, especially growers of pot plants, often have several ornamental species in culture and often several plant stages or even different plant species are grown side by side in the same glasshouse. These aspects, together with the very low damage thresholds, have made implementation of biological pest control in ornamentals lack behind the implementation in vegetables. By introduction of highly insecticide resistant strains of the western flower thrips *Frankliniella occidentalis* (Pergande) in 1985 (3) the interest in biological pest control among Danish ornamental growers increased and today biological pest control is implemented on approximately 20% of the glasshouse ornamental area.

The implementation of biological pest control programs in ornamental crops most often involves control of a range of pests with a series of beneficials. Thus, different beneficial species must be integrateable without severely interfering the control effect of each other. The investigations on biological pest control and the practical experiences gained from implementation of biological control in vegetable crops illustrate situations of one-pest-one-

beneficial-systems. Therefore, these results may not be transferred directly to biological pest control systems in ornamental crops where the fauna most often is much more complex. Especially in situations with introduced polyphagous beneficials, a direct predation on other introduced beneficials may occur. The objective of this investigation was to quantify the effects of interferences among introduced anthocorids and other predators in complex biological control programs implemented in ornamental crops.

MATERIALS AND METHODS

The experiments were conducted in 24 glasshouse cabinets of 1m³ with fully controlled climate. In each cabinet, 18 four-week old Gerbera (*Gerbera jamesonii* cv. Hummingbird) plants were placed. Before placement in the cabinets, the plants were dipped in insecticidal soap (Silva 50; 2%) to remove all present insects and mites. Furthermore, Etiadizol (AAterra 35; 75 g/m³ soil) was watered into the pot soil as a prophylactic treatment against root pathogens. During the experiments supplementary light (250 W/m²) was given for 16 hours daily. Temperature and air humidity was held constant at 20 °C and 60% R.H., respectively. Plants were fertilized according to ordinary growing procedures.

In the beginning of the experiments, each plant in the relevant species combination were infested with three (2♀♀ : 1♂) adult thrips (*F. occidentalis*), two adult aphids (*Aphis gossypii* Glower) and/or two mated spider mite (*Tetranychus urticae* Koch) females. Three weeks after the introduction of thrips, seven (4♀♀ : 3♂♂) adult anthocorids (*Orius majusculus* [Reuter]) and/or two mated predatory mites (*Phytoseiulus persimilis* Athias-Henriot) (*P. persimilis : T. urtucae* ≈ 1:3500) were introduced per relevant cabinet. Adult gall midges (*Aphidoletes aphidimyza* Rondani), that all were less than 24 hours old but had had ample opportunity to mate, were released into the relevant cabinets three times: First introduction one week after the aphid introduction (2♀♀ : 7♂♂ per cabinet), second time (10♀♀ : 10 ♂♂ per cabinet) nine weeks later, and the third time (5♀♀ : 4♂♂ per cabinet) eleven weeks after the aphid introduction. The species combinations were for each experiment replicated with two to five cabinets for the untreated controls and three to five cabinets for systems with two or more introduced species. The number of replicate cabinets necessary were estimated on basis of the variation in earlier experiments using the same experimental setup.

Flowers were removed on the but stage to avoid aggregation of pests and beneficials in the flowers, thus, obscuring the population developments on leaves. The developments in pest and beneficial populations were monitored by sampling one leaf per plant (i.e., 18 leaves per cabinet) weekly and counting these for insects and mites under microscope in the laboratory.

RESULTS

The results of the two experiments are shown as population development of the insect and mite species in the various species combinations and illustrated as mean number of individuals per leaf per species combination.

The populations of the thrips in the untreated controls never exceeded seven thrips per leaf and after some initial fluctuations a rather stable population density with an average of four thrips per leaf occurred (figs. 1 & 2). In cabinets where also aphids and anthocorids or aphids, gall midges and anthocorids (fig. 1) or spider mites, predatory mites and anthocorids (fig. 2) were introduced, the thrips populations decreased four weeks after introductions of beneficials and stayed at a low mean level of 0.3 thrips per leaf until the end of the experiments. In the cabinets of the first experiment (fig. 1) where only anthocorids were introduced beside the thrips, the thrips population fluctuated some after the introduction of the beneficials but tended to decrease to the same low level as other treated cabinets towards the end of the experiment. In the second experiment the thrips populations did not differ among treated cabinets regardless the anthocorids had access to alternative food sources or not. Therefore, the results are pooled for untreated and treated cabinets, respectively (fig. 2).

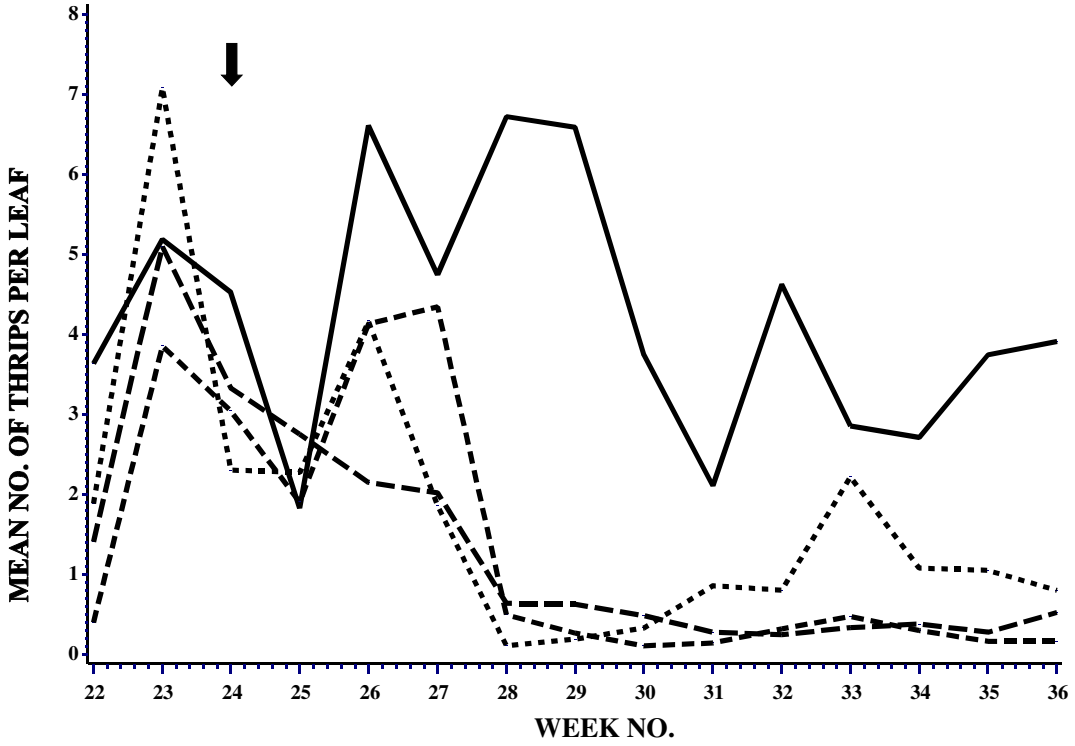

Fig. 1. *Development of thrips (*F. occidentalis*) in the first experiment, average number of thrips per leaf during the experimental period. (———) thrips control; (- - - - -) thrips treated with anthocorid bugs (*O. majusculus*); (---------) thrips in cabinets with aphids (*A. gossypii*) and anthocorid bugs; (– – – –) thrips with aphids, gall midges and anthocorids. Arrow indicate introduction of anthocorids.*

The populations of the aphids in the untreated control cabinets (fig. 3) showed a exponential increase rate from introduction throughout the experiment. The apparent drop in population density at the end of the experiment is an artifact because only subsamples of leaves were taken at aphid levels of approximately 900 per leaf. In the cabinets where both aphids and gall midges were introduced, an exponential aphid growth rate was also seen but was here delayed three weeks compared to the untreated controls. At average aphid populations of 200 per leaf in the gall midge treated cabinets, two additional introductions of beneficials were made. The increase rate of the aphid populations decreased after the second gall midge introduction and after the third introduction the number of aphids decreased. The aphid populations were kept at a constant low level during the entire experimental period in all cabinets where anthocorids had been introduced. The difference between the development in aphid populations treated with anthocorids, only, and both anthocorids and gall midges was not significant (fig. 3).

The population development of gall midges in the first experiment is shown in fig. 4. In the cabinets where they were the only predator species present the populations showed an increase after the first introduction to a mean number of 0.2 larva per leaf one week after the introduction of the adults. However, already two weeks after the introduction, the number of gall midges had decreased significantly. Four to five weeks after the first larval peek a second smaller increase in the number of gall midge larvae occurred peeking at 0.002 larvae per leaf. Following the second and third introduction of gall midges, the number of gall midge larvae increased to one per leaf one to two weeks after the introductions, respectively. However, the number soon decreased and two weeks later was down to 0.03 larvae per leaf. In the cabinets where thrips and anthocorids were introduced as well, the number of gall midge larvae following introductions was significantly lower than in the cabinets with aphids and gall midges, only. In the cabinets with the introduced anthocorids the gall midge larval number peeked at just 0.3 per leaf after the third introduction and the second gall midge peek was not seen in these cabinets.

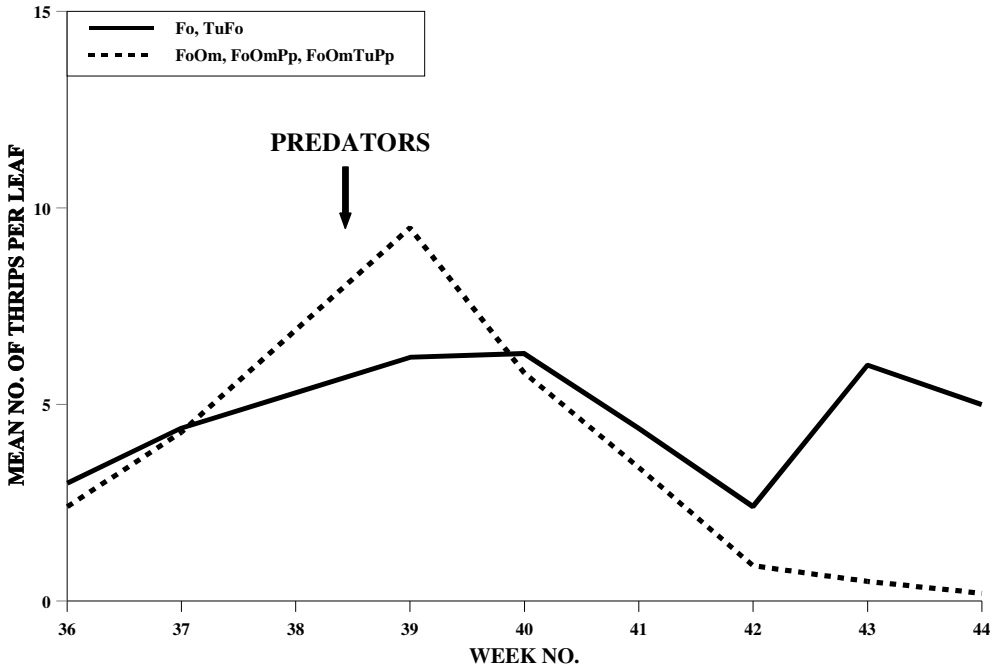

Fig. 2. *Development of thrips populations in the second experiment with different combinations of thrips, spidermites, predatory mites and anthocorids.* Fo*: cabinets with thrips;* FoTu*: cabinets with thrips and spidermites;* FoOm*: cabinets with thrips and pirate bugs;* FoOmPp*: cabinets with thrips, anthocorids and predatory mites;* FoOmTuPp*: cabinets with all four species.*

Already one week after the introduction of the anthocorids, an increase in numbers on leaves was seen in all species combinations (fig. 5). Three weeks after the introduction the numbers peeked at 0.3 anthocorid per leaf. In the cabinets where thrips were the only prey available, the number of anthocorids became very low in week 31. However, the number increased again two weeks later with a second peek in week 34. In cabinets where plants were infested with both thrips and aphids the first peek of the anthocorids was prolonged over two to three weeks and after a decrease stayed at a low level to the end of the experiment. In the cabinets with thrips, aphids and gall midges, the anthocorid populations stayed at a relative high level after the initial peek and had a very high second peek in weeks 34 to 35.

The populations of spidermites in the untreated controls in the second experiment developed exponentially from infestation (week 32) and during the following ten weeks. During the last two weeks of the experiment, the spider mite populations decreased due to accidental infestation with predatory mites (fig. 6). The rapid control effect by the predatory mites on spider mites was demonstrated in the cabinets where *P. persimilis* were introduced. The exponential growth rate of the spider mites was stopped already one week after predator introduction at a rate of 1:3500 to the spider mites and during the following period of five to six weeks the spider mite population was controlled successfully to near extinction. *P. persimilis* control of spider mites was affected by the presence of anthocorids, because in these cabinets the increase rate of the spidermites was not slowed until week 40 (fig. 6). Not until week 42 did the number of spider mites decrease. The spider mite population developed significantly different when thrips were present in the cabinets. The initial increase rates of the spider mites were much slower that when thrips were absent and in cabinets where the species complex consisted of spider mites, predatory mites, thrips, and anthocorids, spider mite populations were kept at low levels during the entire experimental period ending with complete control.

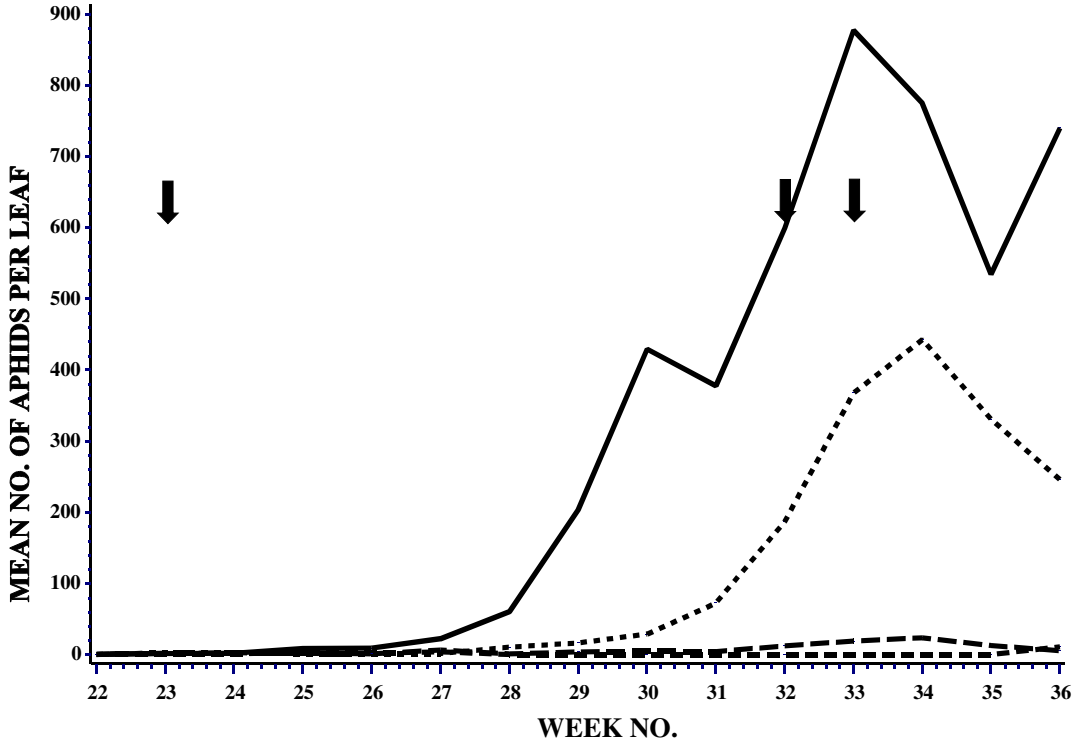

Fig. 3. *Development of cotton aphids (*A. gossypii*), average number of aphids per leaf during the experimental period. (———) aphid control; (- - - - -) aphids treated with gall midges (*A. aphidimyza*); (----------) aphids in cabinets with thrips (*F. occidentalis*) and anthocorid bugs (*O. majusculus*); (– – – –) aphids with gall midges, thrips and anthocorids. Arrows indicate introductions of gall midges.*

DISCUSSION

The initial fluctuations in the thrips populations in the first experiment with aphids are probably effects of discrete generations because the infestations were based on single introductions of adults, only. In both experiments the untreated thrips populations stayed at a rather stable level of four to five thrips per leaf after the initial fluctuations. This is a rather low level suggesting that non-flowering Gerbera is a suboptimal host plant for *F. occidentalis*. In the cabinets where anthocorids were introduced, the thrips populations decreased two to three weeks after introduction of beneficials. The thrips control in the cabinets where only thrips and anthocorids were present was so effective that the number of thrips became extremely low for more than a week in the experimental period (fig. 1). This low thrips population level caused shortage of food for the anthocorids which then decreased in numbers (fig. 5) and stopped egg laying (4). The resulting very small anthocorid population in week 31-32 led to an increase of thrips populations in this period (fig.1). However, the anthocorids were able to react numerically on the increase of thrips resulting in a successful thrips control towards the end of the experiment.

In the cabinets where not only thrips and anthocorids were introduced but also aphids or aphids and gall midges, the populations of thrips were controlled successfully to a level of less than half a thrips per leaf from four weeks after the introduction of anthocorids to the end of the experiment (fig.1). The reason for the fact that the thrips were kept at a constant low level is probably that the anthocorid populations benefited from aphids and gall midges as alternative food sources in periods of scarcity of thrips and, thus, were able to maintain a relatively dense population during the experiment (fig. 5). In the second experiment (fig. 2) no difference in thrips control occurred regardless availability of alternative prey because the anthocorids did not over-exploit the thrips prey in this experiment. Cloutier & Johnson (5) observed a poorer thrips control if spidermites or predatory mites were available as alternative food sources. This difference in results may be due to the fact that Cloutier & Johnson (5) conducted the experiments on detached leaves in the laboratory. Such a two-dimensional setup is a much more simple system than the very complex three-dimensional system in the present experiments. In a complex system the opportunity for natural behaviour for both pests and beneficials is much better and the resemblance to glasshouse conditions will therefore probably be better, too.

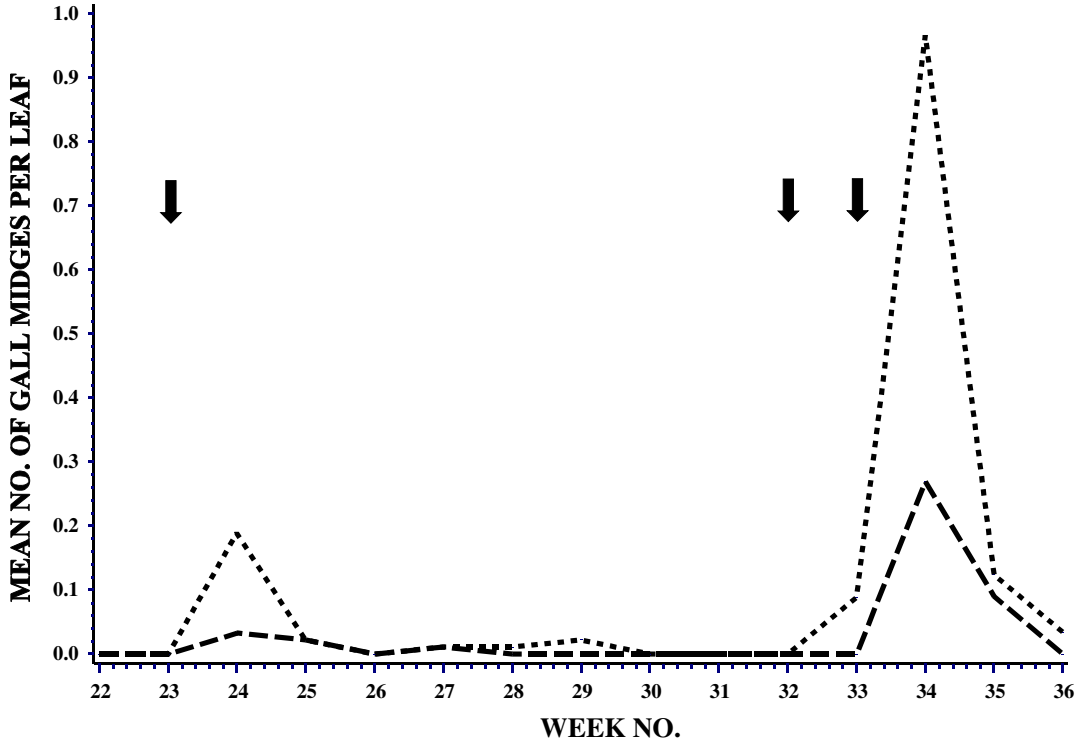

Fig. 4. *Development of gall midges (*A. aphidimyza*), average number of gall midges per leaf during the experimental period. (- - - - -) gall midges with aphids (*A. gossypii*); (— — —) gall midges in cabinets with aphids, thrips (*F. occidentalis*) and anthocorids (*O. majusculus*). Arrows indicate introductions of gall midges.*

The results of the present experiments suggest that *O. majusculus* is an effective thrips control agent on non-flowering Gerbera. Earlier experiments have suggested that the thrips control effect of the anthocorids is increased on flowering Gerbera crops compared to vegetative Gerbera crops. This is probably due to the fact that both the thrips and anthocorids have preference for the flowers, why the searching efficiency of the anthocorids is better on a flowering crop (6).

Even though the aphid population development was delayed three weeks in cabinets with gall midges compared to the untreated control cabinets, the results suggest that biological control of *A. gosypii* using few introductions of adult gall midges was unsuccessful. The major reasons for this probably was that the adult lifespan of the gall midges is approximately one week and the total generation time is 3.5 weeks of which the larval time (i.e., the control time) is one to two weeks (7). As a consequence of this, relative long periods occured where the aphids were able to develop without any control pressure. In a practical situation, this problem will not be present because gall midges are recommended introduced several times in the pupal stage. Thus, a synchronization of generations will not occur if such a introduction scheme is used. However, as the main purpose of the present experiments was to quantify interactions among several species of beneficials, well-defined introductions of beneficials were more important than avoidance of discrete generations.

Comparing the development of the aphid populations in cabinets with and without anthocorids it is obvious that *O. majusculus* is not only aphidophagous but an efficient aphid control agent on Gerbera. However, Fischer et al. (8) reported that *O. majusculus* was unable to control *A. gossypii* on glasshouse cucumbers. The difference in our results

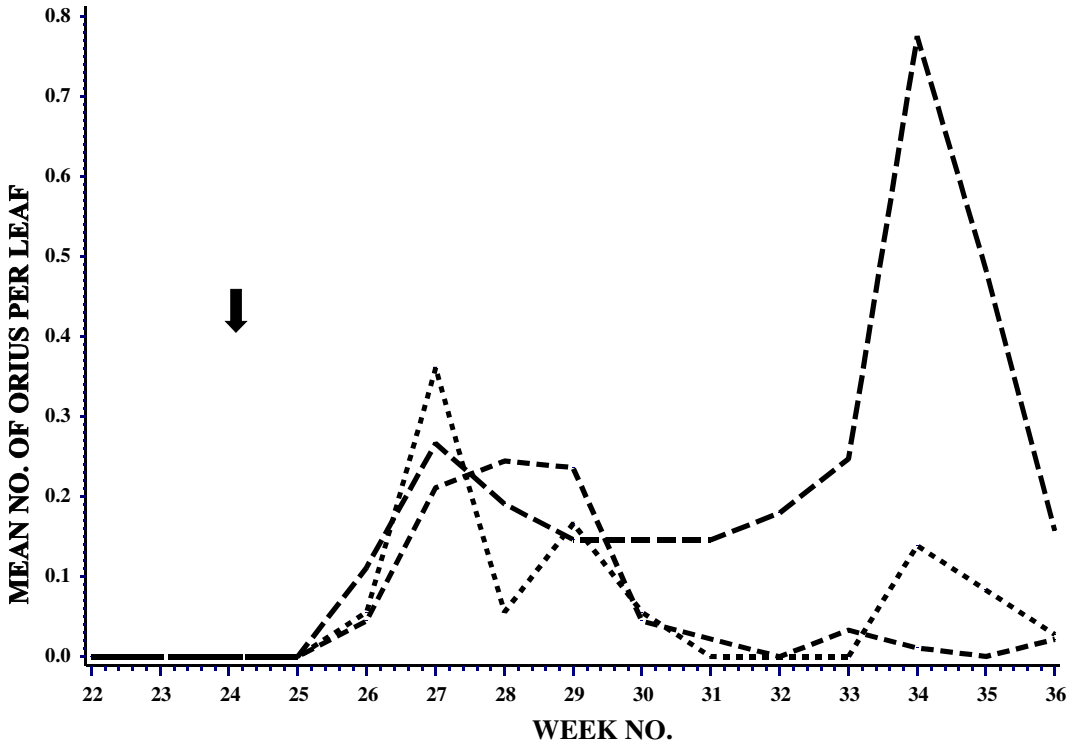

Fig. 5. *Development of anthocorid bugs (*Orius majusculus*), average number of anthocorids per leaf during the experimental period. (- - - -) anthocorids with thrips (*Frankliniella occidentalis*); (-------) anthocorids in cabinets with thrips and aphids (*Aphis gossypii*); (– – – –) anthocorids with thrips, aphids and gall midges. Arrow indicate introduction of anthocorids.*

may be because cucumbers are better host plants to *A. gossypii* than Gerbera, thus, the increase rate of the aphids may be higher than the predation rate of the anthocorids on cucumbers. Furthermore, our results suggest that the anthocorids predated the gall midges and even reacted numerically on the increase in gall midge populations (figs. 4 & 5). Thus, the effect of predation on gall midges did not influence the control effect on the aphids. Furthermore, laboratory studies suggest that the predatory effect on aphids and gall midges is not influenced of thrips presence on the same plants (Brødsgaard & Enkegaard unpubl. data).

The results of the second experiment suggest that *P. persimilis* is a very effective spider mite control agent on Gerbera with a fast control result even at very low introduction rates (1:3500) (fig. 6). The control effect was delayed in cabinets with both predatory mites and anthocorids compared to cabinets with *P. persimilis,* only. This is in accordance with previously published laboratory experiments (5, 9) that suggest that *Orius* spp. predate *P. persimilis*. The spider mite control was much more successful in cabinets where thrips were present, too. This was probably due to the facts that *F. occidentalis* is predatory on spider mite eggs, thus, reducing early spider mite population buildup (10) and that *O. majusculus* have preference towards thrips compared to mites reducing predation on predatory mites in cabinets where thrips also are available.

CONCLUSION

These experiments suggest that thrips control using a highly polyphagous anthocorid predator such as *O. majusculus* do interfere with other biological control systems and may generate different outcome of the other systems than what could be expected from previous experiences with single pest-beneficial systems. However, the interference is temporary and the end-result from multi species systems will not differ from single species systems. On the other hand, our experiments suggest that thrips control using *O. majusculus* as the control agent will benefit from presens of alternative food sources in situations of scarcity of thrips giving a more reliable thrips control. Furthermore, our experiments demonstrate the aphidophagous effect of *O. majusculus* on Gerbera.

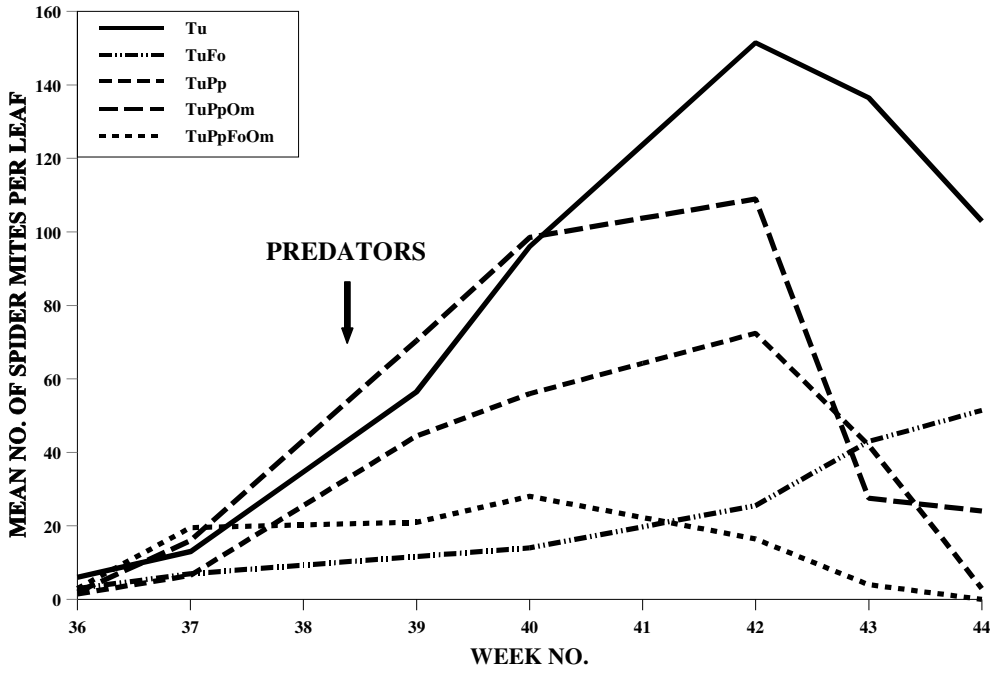

Fig. 6. *Development of spider mite populations in the second experiment with different combinations of spider mites, thrips, predatory mites and pirate bugs.* Tu*: cabinets with spider mites;* TuFo*: cabinets with spider mites and thrips;* TuPp*: cabinets with spider mites and predatory mites;* TuPpOm*: cabinets with spider mites, predatory mites and pirate bugs;* TuPpFoOm*: cabinets with all four species.*

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