Alternative food sources for optimization of biological control of whiteflies.

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Introduction

The whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae) is a worldwide pest, causing yield loss and economic injury in many crop species (Gerling and Mayer, 1996; Oliveira et al, 2001). It causes damage to the crop through direct plant feeding, plant physiological disorders, *B.tabaci* transmitted viruses and by honeydew production with associated black mould development, resulting in reduced photosynthesis and a decreasing commercial value of the crop (Oliveira et al, 2001). Whiteflies have a high level of resistance to insecticides as well as insect growth regulators (Palumbo et al 2001).

A solution to this problem could be biological control of whiteflies by utilizing their natural enemies. Several properties of the system determine the success of prey elimination or suppression. The predator has to be able to use whiteflies as a food source and be able to survive and reproduce on a diet of whiteflies. Preferably the predators have a high survival and reproduction rate and a high population growth rate relative to the prey.

Predatory mites (family Phytoseiidae) are small wingless arthropods, currently used in protected and outdoor crops as biological control agents against herbivorous mites and insects pests such as thrips. Predatory mites could be also used as biological agents for whiteflies (Nomikou, 2003). They are not very voracious, but do have a high population growth rate relative to whiteflies and can feed on whiteflies. Based on their juvenile survival, developmental periods, oviposition rates and sex ratio when feeding on a diet of *B. tabaci*, 2 species of predatory mites are selected in a study by Maria Nomikou that could be suitable as biological control agents for whiteflies: *Thyphlodromips swirskii* (Athias-Henriot) and *Euseius scutalis* (Athias-Henriot).

Biological control limitations

A problem in biological control systems can be the continuity. When the prey suppression is successful, the prey density decreases. This results in low food availability for the predators and can cause the predator population to decrease as well. In turn a low predator density allows the prey population to increase again. To avoid the predator population decreasing in period in which the preys are scarce or even absent, it is possible to supply another food source for the predators.

Non-prey food sources are alternative food sources, such as pollen, honeydew, nectar, fruits and leaf tissue, that can be used as a complementary or substitute food source to the prey diet by the predator species. Non-prey food sources can serve as a supply of water and nutrients complementary to the prey diet, but sometimes also allows for reproduction when used as a single food source. Alternative food sources can allow predator populations to persist in periods with low prey density (Bakker, 1993; Van Rijn et al, 2002). However, *E. scutalis* switched to pollen feeding when both prey (crawlers) and pollen were available. The ovipostion rate of *E. scutalis* remained the same, which results in a negative influence on the biological control. For *T. swirskii* the addition of pollen did not alter the predation or the oviposition rate. Pollen supply could therefore be a suitable method for *T. swirskii* as a biological control agent to survive periods in which prey is scarce. The presence of alternative food can result in high predator-prey ratios and the predators can maintain their effectiveness as biological control agents throughout the whole crop-growing season.

Vulnerability of prey

Predatory mites can feed on all immature stages of the whiteflies, although the vulnerability of whiteflies the predation by predatory mites differs between the different developmental stages. The vulnerability decreases with the increase in stages. The eggs and crawlers of the whiteflies are the most vulnerable and the pupae the least. The predation rate does not change because of the smaller size of the younger stages, because the oviposition rate changes as well. The later stages could be less nutritious or more difficult to attack (Nomikou, 2003).

Research questions

How many predatory mites and how much pollen is needed to optimize the biological control of whiteflies in green house systems? This is not a simple question to be answered and this can be divided into several sub-questions. For example what is the minimal whitefly density for predatory mites? How and when does a predatory mite switch from whitefly feeding to pollen feeding? Does this behave like a switch on a certain threshold value of the whitefly density or is this a gradual process with an increasing percentage of pollen feeding? How nutritious is pollen for predatory mites? Does it supply all essential nutrients and how does the conversion efficiency differ from that of whiteflies? How nutritious are the different developmental stages of whiteflies for predatory mites?

I've selected one important aspect in this system for this essay: the switching of the predatory mites to an alternative food source, the choice of diet: prey or pollen. As mentioned before differences have been observed in the feeding on prey of different developmental stages. This is likely to influence the choice of diet, food uptake, growth and reproduction of the predators as well. The DEB-model could be a useful tool and could help to gain insight in the nutritional values of prey and pollen and how this will influence the food uptake of the predatory mites and the consequences for growth and reproduction. This could help to optimize biological control of *B. tabaci*.

Material and methods

In order to answer these questions I propose an experiment with predatory mites and supply of different densities of prey and pollen. The choice of diet will depend on factors like the food density (the encounter rate), the nutritional value (conversion efficiency), and the handling time of the different substrates. The choice of diet could change at a certain threshold value, on which the predatory mites stop feeding on one food source and start feeding on another. More likely however, is that this is a gradual process with intermediate stages in which the mites are feeding on more than one food source.

Food density: The pollen density depends on the density supplied by the researchers and is replenished to the original level regularly when the predators have fed on the pollen. Since the application would be in a greenhouse situation this could a realistic representation of the situation. For the prey the food density is somewhat more complex. The nutrient availability for the plants is assumed to be non-limiting, since this is supplied by the crop-growers. The plant density is determined by the number of plants, minus the amount eaten by the whiteflies. The number of plants is chosen by the crop-growers. The prey density is therefore determined by the (maximum) reproduction of whiteflies and the predation by mites and the food density.

Handling time: The feeding could be explained resembling enzyme kinetics, on the basis of a synthesizing unit (SU) working in a sequential process. The uptake system does not accept arriving food particles when it is busy processing a food particle. This will determine the maximum uptake rate of the substrates. The handling time and maximum uptake rate will differ for the different substrates. The saturation coefficient is inverse to the product of handling time and the searching rate (DEB Ch 3).

Conversion efficiency: The predatory mites are feeding on more than one substrate, and all substrates are used for the synthesis of one reserve. This process of converting food into reserve is called assimilation. Substrates and reserves are taken to be generalized compounds, i.e. mixtures of chemical compounds that do not change in chemical composition, and which can be quantified in terms of C-moles (DEB, Ch 5). The different food sources (substrates) will differ in the chemical composition and therefore the conversion efficiency of substrate into reserves will differ for the different food sources. The assimilation efficiency of food is taken to be independent of the feeding rate. This makes the assimilation rate proportional to the ingestion rate. The conversion efficiency of food into assimilated energy is written as $\{ p_{Am} \}/\{ J_{Xm} \}$, where $\{ p_{Am} \}$ is a diet-specific parameter standing for the maximum surface-area-specific assimilation rate. The assimilated energy that comes in at food density X is given by $\{ p_{Am} \} f V^{2/3}$, where $f = X/(X_K+X)$ and V the body volume (DEB Ch 3). The feeding of the predatory mites might also differ between the different life stages of the mites. Juveniles need more protein to grow and adults need energy for maintenance, but not for growth and therefore need lees proteins.

Functional response: the ingestion rate of an organism as a function of the food density, X, expressed as C-moles per surface area or volume is described by $J_X = f\ J_{Xm}$ with $f \equiv (1+X_K/X)^{-1}$ where X_K is the saturation coefficient (density at which food intake is half the maximum value) and J_{Xm} is the maximum ingestion rate.

The κ-rule: Important for the reproduction is the κ-rule for allocation: a fixed proportion (κ) of energy utilized from the reserves is spent on growth plus maintenance, the remaining portion (1-κ) on development plus reproduction (DEB, Ch 3). Maintenance stands for the collection of processes necessary to stay alive. Growth does not depend on food density directly.

Different characteristics and parameters will have to be measured. For example, the encounter rates for both whiteflies and pollen, the handling times of whiteflies and pollen, the maximum ingestion rate, saturation coefficient, the chemical composition of pollen, whiteflies and the reserve of the predatory mites, uptake rates and digestion, and the surface area uptake rate.

Discussion

In real greenhouse situations many factors will complicate the system. For instance the encounter rate depends on several factors. It is not realistic to assumed that the encounter rate is just dependent on the density. The predatory mites might be able to sensory detect whiteflies and therefore increase the encounter rate and of course the other way around, whiteflies could flee. This probably changes with the different stages of larval development. To complicate matters further, predation frequency is not only dependent on encounter rate, but also on maximum uptake, reserves and maintenance costs. Within the prey population there are differences in vulnerability, this differs between stages and less healthy individuals might also be more vulnerable to predation. In many crops whiteflies are not the only pest. In case of cucumber other pests are also suppressed with biological control agents. Consequently there is no influence of chemical control, but it could result in complex interspecies interactions. The predatory mites could also feed on other pests, which might be more nutritious or more frequently encountered. Until this pest has a low density and then could start feeding on whiteflies. Also the other biological control agents could influence the predatory mite behaviour, it could compete for the whiteflies as a food source or in other ways be a competitor. It could even feed on the predatory mites. Despite this complexities, the DEB approach could provide a framework for discussing available information, identifying information gaps and optimizing biological control.

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