Biological control is more than enemy and prey

Biological control cannot simply be seen as a one-on-one relationship between the predators and their prey. Natural enemies in combination with the pest organisms create a web of food within which all kinds of interactions occur that can influence the efficacy of control. This interaction creates more complexity, but at the same time offers opportunities to make a growing system more resistant to pest and diseases. A number of examples are provided here from our research at Wageningen UR Greenhouse Horticulture.

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Biological pest control is part and parcel of modern horticulture. Vegetable growers already started using natural enemies en masse back in the 1980s. In the ornamental growing sector, biological control has gradually gained in importance and has even become essential in properly controlling certain pests. One of the consequences of this development is that pest control is becoming more complex. Several species of natural enemies are deployed at the same time. An extreme example is sweet peppers or aubergine grown organically, where an entire arsenal of ten different natural enemies is sometimes used. At the same time, a shift is becoming evident in the use of chemical agents from broad spectrum to selective, so the number of pests is increasing.
While chemical agents are becoming more specific, the trend with biological methods is towards more general effectiveness. In the early years of biological pest control, people were more convinced that the best way to attack pests was with highly specific natural enemies. Over the years, however, users have started deploying more general predators that feed on several types of prey. The most successful generalists are found among the assassin bugs (*Orius*, *Macrolophus*) and the predatory mites. Generalists have the advantage of establishing more easily in crops as they can survive on a variety of foods, including pollen. The presence of generalist predators increases the resistance of crops to pests.
It is precisely with the generalists that we see all kinds of interaction between predators and pests that can make biological control more complex. Controlling one pest can no longer be seen in isolation from controlling a different pest. Together with the plant, the pests and predators form a complex web of food with all kinds of direct and indirect interactions that may have both negative and positive effects on biological control. Greater insight can lead to the eradication of the negative interactions and better utilisation of the positive ones. Using the food web model for cucumber as an example, we can illustrate some of the possible interactions, together with the main consequences for the success of biological control.

The cucumber model

Various pests can occur simultaneously on cucumbers. The western flower thrips is nearly always present. Spider mites, whitefly and cotton aphid also occur regularly. The standard weapon against thrips is a generalist predatory mite, usually *Amblyseius swirskii.* This is also effective against whitefly and spider mites, although spider mites also have to be controlled with specialised predatory mites. A veteran is the specialised spider mite predator *Phytoseiulus persimilis.* Biological control of leaf aphid can be done using predatory wasps, such as *Aphidius colemani* against cotton aphid. The aphid midge *Aphidoletes aphidimyza* is a valuable assistant here. Both are rather specialised, namely limited to leaf aphids.

Empty aphid midge eggs and red *A. swirskii*.

Whitefly can also be efficiently combated using specialised predatory wasps, such as *Encarsia formosa* and *Eretmocerus eremicus*. Figure 1 shows an overview of the interactions currently known for this food web. The examples are based on research results from Wageningen UR Greenhouse Horticulture in projects financed by the Product Board for Horticulture and the Dutch Ministry of Agriculture, Nature and Food Quality.

Direct interaction between natural enemies

It is the generalist natural enemies in particular who do not just attack the pests they are introduced to control, but also attack other natural enemies. If they are of the same species, this is referred to as cannibalism. If they are other natural enemies of the same pest, it is referred to as intraguild predation. This is not by definition negative for the control of the pest. This is well illustrated in our model system for cucumber in controlling spider mites. The generalist *A. swirskii* can feed on young stages of the spider mite specialist *P. persimilis*, so the population has more difficulty in establishing. Trials run in greenhouses, however, showed that this had hardly any effect on the efficacy of spider mite control, as A. swirskii itself can also have a considerable impact on spider mites. In addition, the web of the spider mites protects *P. persimilis*; this predatory mite can move around easily under the web, while *A. swirskii* has difficulty doing so. These two predators make a fine team together.

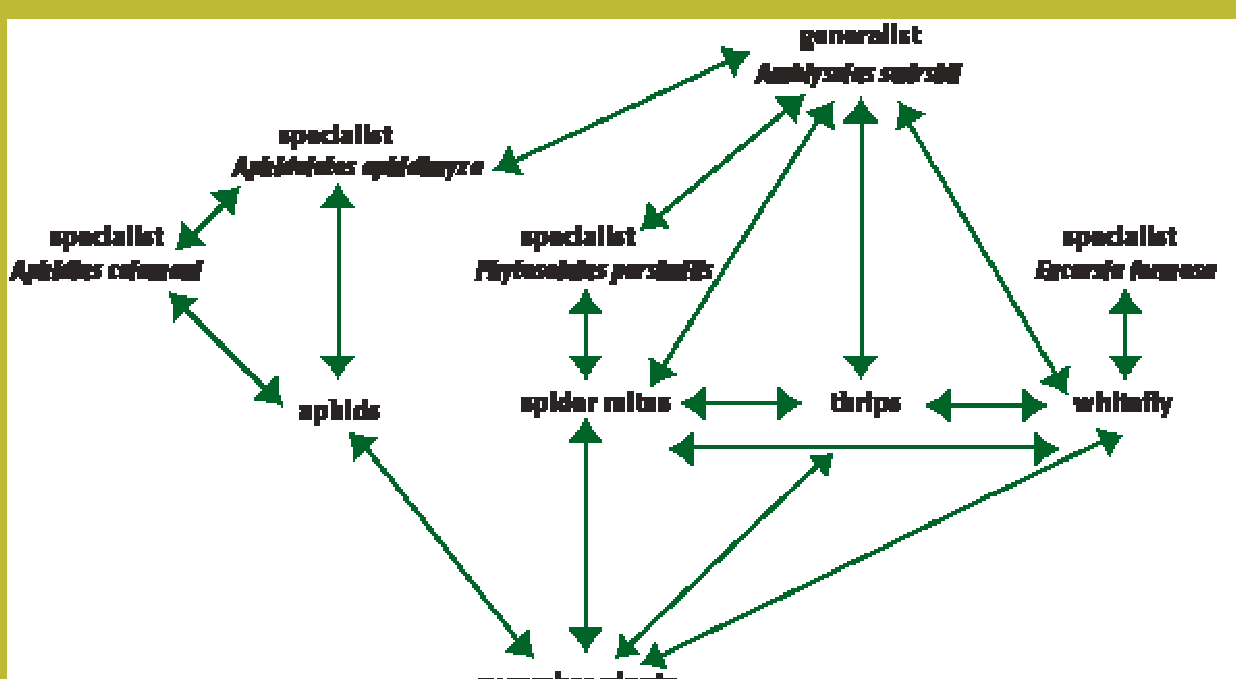
It is even better if the natural enemies are mutually complementary – for example, because they destroy pests in various stages of their development. In the case of cucumbers, *A. swirskii* (which feeds on the eggs of the white fly) is complemented well by predatory wasps that parasite on the older larval stages. This type of system is more resilient, as the one can replace the other in its absence (for example, if chemical agents have knocked out one of the predators).

With other pests, however, generalist *A. swirskii* can disturb biological control. The predatory mite has absolutely no effect on leaf aphids, but they can feed on the eggs of the leaf aphid predator *A. aphidimyza*. Trials in sweet peppers in greenhouses showed that this delayed the suppression of the aphid population to an enormous extent. Knowledge of these interactions is important in determining which biological predators are used in certain crops.

Interaction between pests with a predator in common

The cucumber model shows that pests influence each other indirectly if they have a predator in common. In this case, thrips, spider mite and whitefly have an effect on each other via their predator *A. swirskii.* Greenhouse trials have revealed that the control of spider mites and whitefly improved considerably if thrips was also present. It was striking that the predatory mites developed better on a diet of two pests. Apparently, a combination of the pests gives the predators better nutritional value. In follow-up studies we will be investigating

FIGURE 1. OVERVIEW OF POSSIBLE INTERACTIONS BETWEEN PESTS AND PREDATORS ON CUCUMBERS.



P. persimilis in a spider mite web.

A. swirskii preying on whitefly eggs.

whether the diet of the predatory mite in situations with a single pest can be supplemented using alternative food, helping to enhance its effectiveness.
In the short term too, many pests can also have negative results. For example, an excess of whitefly appeared to temporarily hamper the control of thrips because of saturation of the predatory mites. Knowledge of this will help us understand and react to the complexity of practical situations.

Interaction between pests via the crop

Pests that occur concurrently on the crops can compete for food (the plant), but they can also have a mutual influence via the plant if they feed on different parts of it. With cucumbers, the presence of larvae of the greenhouse whitefly restricts the population development of spider mites on other parts of the plant by an average of 25%. This is also called induced resistance. In our study, if the spider mite was subsequently controlled using spider mite predators, the effect was considerably better and faster on plants where spider mite development had already been inhibited by whitefly. The presence of greenhouse whitefly therefore gave an indirect advantage in the battle against spider mites. In the follow-up study, we will examine whether this plant reaction can be induced in other ways to help improve biological control of spider mites.

The next step

The examples we have mentioned for cucumbers show that pest control quickly turns into a complex food web with various mutual interactions (Figure 1).
Understanding these interactions leads to an improvement in biological control through better choices in the field or to the development of new measures based on this knowledge, such as developing alternative food for the generalists and benefiting from induced resistance. The mechanisms have a wider application and can support, for example, developments in the ornamental sector. Using natural enemies does not always simplify pest control, but it certainly offers new openings to develop resistant cultivation systems. ■