A Farmer's Toolbox for Integrated Pest Management

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Case study IPM in Chrysanthemum with the focus on thrips control in the Netherlands

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Abstract

In this case study, three individual projects that focussed on the use of natural enemies in the integrated control of thrips in greenhouse grown Chrysanthemum were investigated.

Use of natural enemies in Chrysanthemum is not very straight forward. Though predatory mites and pirate bugs can establish themselves in Chrysanthemum, their effectiveness as a biological control agent of thrips is dependent on the timing of their introduction in the crop, the additional food available and conditions in the greenhouse. Nevertheless, there is great potential for developing a successful system for use of predatory mites and pirate bugs in the control of thrips in this crop. Further research is required to optimize conditions under which these natural enemies will best establish themselves, and to determine under practical conditions if their use can be combined with other biological control agents and potential chemical control methods that prove necessary to control severe infestations or infections of other pest or diseases.

1. Introduction

Integrated Pest Management in the Netherlands was first developed in the 1980s and 1990s as a part of the wider concept of Integrated Farming. The potential proved to be very high in comparative farming systems studies proving that agrochemical inputs could be strongly reduced, however, its success strongly depended on the support of stakeholders in the agricultural community.[1]

Especially in protected cultivations, the use of IPM has developed rapidly over the years. The protected cultivation of vegetables and ornamentals are an important sector in Dutch agriculture (approx. 1000 hectares of protected horticulture[2]). As in high-value ornamental crops, a near-zero tolerance for pest damage prevails, this sector is highly dependent on pest control methods. In this case study, Chrysanthemum was chosen as a key representative crop of the practical use of IPM in the Netherlands. It is a crop that is sensitive to a variety of pests and is grown on a wide scale in the Netherlands (approx. 400 ha in greenhouses in 2018-2020[2]). Chrysanthemum is sensitive to various nematodes, fungal diseases and especially to insects. Leaf aphids, leaf miners, caterpillars and spider mites are abundant in greenhouse grown Chrysanthemum and difficult to control. However, the most important bottleneck in the protected cultivation of Chrysanthemum is thrips.

Larvae and adult thrips feed on the epidermal cells of leaves, buds and flowers, giving them a silvery appearance (on leaves) or causing malformation and discoloration (on buds and flowers). The thrips species native to Europe (e.g., *Thrips tabaci*) cause only very minor problems on ornamentals. However, the introduced American species *Frankliniella occidentalis* is now one of the most serious pests of ornamentals in Europe. Next to the direct damage to the crop, the Western Flower Thrips (*Frankliniella occidentalis*) is a vector of various plant viruses.[3]

In line with the basic principles of IPM, the following tactics are available to control Western Flower Thrips (WFT)[4]:

- Monitoring (visual scouting, use of traps, prediction models);
- Mechanical and physical control (sanitary practices, screening greenhouse openings);
- Biological control (use of natural enemies);
- Behavioral control (use of semiochemicals); and
- Chemical control.

The use of biological control by use of natural enemies such as predatory mites and predatory bugs such as phytoseiid mites (*Amblyseius* spp., *Transeius montdorensis*) and pirate bugs (*Orius* spp.) are highlighted in this case study.

Certain phytoseiid mites can consume large numbers of prey such as spider mites and thrips. Some may feed on pollen, fungal spores and plant exudates, and some can feed, develop and reproduce on these plant materials. They have a high reproductive rate, a rapid developmental rate comparable to their prey, a female-biased sex ratio equivalent to their prey allowing them to respond numerically to increased prey density and can easily be mass-reared.[5]

Pirate bugs, *Orius* spp., are omnivorous bugs of which both immature stages and adults feed on smaller insects, larvae and eggs, of for instance spider mites, thrips, aphids, whiteflies, but will also feed on pollen and vascular saps of plants.[6] They may have several generations per growing season.

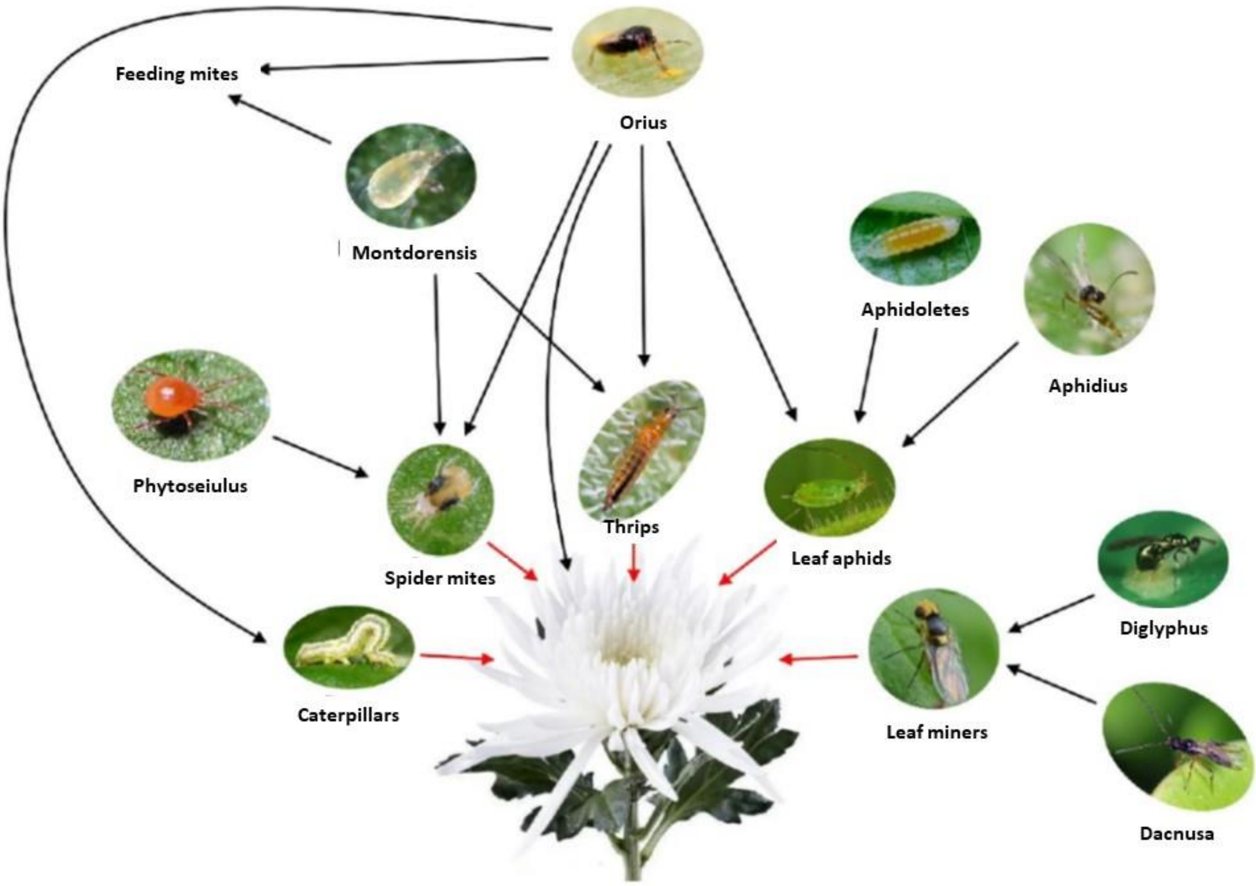

Figure 1: Interactions between different pests and biological control agents in Chrysanthemum[7]

2. Research theme

Biological control of thrips is practised by many growers in greenhouse cultivation. However, from practical experience it is known that Chrysanthemum is a very difficult crop in which to let natural enemies establish, due to its relatively short cultivation time and the short day regime under which it is grown. In order to make effective use of natural enemies in the control of thrips in Chrysanthemum, conditions must be adapted so that a robust population of natural enemies can form.

In this case study, a desk research investigation, completed by interviews, was made of national projects carried out since 2010 focussing on the use of natural enemies in the integrated control of thrips in greenhouse grown Chrysanthemum. The following research questions are posed:

- Which natural enemies are able to establish themselves in Chrysanthemum?
- What conditions must be kept so that these enemies can build a successful population and control thrips?
- Can these conditions be implemented in the practical cultivation of Chrysanthemum and what are the drawbacks?

3. Methodology

The subject for the case study was chosen based on the in-depth interviews carried out with different stakeholders. Various parties indicated that though IPM is already broadly implemented in greenhouse cultivations in the Netherlands, the control of thrips in Chrysanthemum is still a challenge.

Various national projects have been conducted over the years focussing on the use of natural enemies in Chrysanthemum. In this case study, desk research was performed in which reports of national projects conducted since 2010 were evaluated on relevance, reliability, potential impact and implementation in practical use.
Based on this, three projects were selected in which the effect of different conditions on the establishment and population growth of natural enemies in Chrysanthemum were investigated. Details of these projects are listed under Chapter 4 of this report.
In Chapter 5 of this report, the findings of the three projects are bundled and conclusions are drawn based on the research questions posed in Chapter 3.

A limitation to this case study was found to be the fragmentation of the research conducted. Many different stakeholders and researchers are involved, with different interests, leading to a lack of a centred approach to the research subject and a lack of in-depth investigation with a scientifically sound approach.

4. Activities and results

Summaries of three projects are presented below in which the effect of different conditions on the establishment and population growth of natural enemies in greenhouse grown Chrysanthemum in the Netherlands were tested.

I. Building blocks for thrips control in Chrysanthemum (Wageningen UR)[8]

4. 1 Objectives

In order for broad implementation of integrated pest management in the protected cultivation of Chrysanthemum to succeed, it is important to know which natural enemies can best be

used in Chrysanthemum and what the requirements for those organisms are to establish themselves in the crop.
A research project was started in 2012 to develop building blocks for the integrated pest management of thrips in Chrysanthemum. The research focussed on:

- Effectiveness of predatory mites in control of thrips in Chrysanthemum;
- Establishment and feeding of pirate bug *Orius;*
- Soil top layers for stimulation of predatory mites.

Many growers already use predatory mites, however, in Chrysanthemum not all predatory mites are able to establish themselves. In this project it was tested which predatory mites could establish themselves without additional sources of feed.

Where predatory mites only feed on young larvae of thrips, pirate bugs feed on larvae and adults of thrips. This, combined with the fact that pirate bugs are bigger eaters than predatory mites, makes them a good candidate for biological thrips control.
In practice, pirate bugs are barely used because they have trouble establishing a population under low pest pressure conditions. In this project it was tested if offering additional feed to predatory mites of *Orius* spp can improve their establishment and population growth.

Damage to crops from thrips is mainly caused by larvae and adults that feed on flowers and foliage. Late in the larval stages, thrips stop feeding and move down the plant to pupate in soil. Adults then emerge from the soil and resume feeding. Preventing pupation in the soil could be an important step in thrips control. Research has shown that the soil predatory mite *Macrocheles robustulus* is able to predate on thrips pupae. However, also in this case, predatory mites need sufficient food to develop a successful population. In this project, the effect of using top layers that stimulate soil predatory mite growth are tested.

4.2 Governance and functioning of the initiative

The research was carried out by Wageningen University & Research, business unit Greenhouse horticulture, funded by the Productschap Tuinbouw in cooperation with the private companies Bioline, Syngenta and Koppert. The Productschap Tuinbouw is a cooperation of all branches of Dutch horticulture (growers, auctions, retailers, etc). It is funded by standard levies for each party of the cooperation.

4.3 Results (and successes)

Effectiveness of predatory mites in control of thrips
For the following seven species of predatory mites it was tested if they could establish themselves without additional sources of food:

- *Neoseiulus cucumeris;*
- *Amblyseius swirskii;*
- *Amblyseius montdorensis;*
- *Neoseiulus barkeri;*
- *Amblyseius andersoni;*
- *Neoseiulus reductus;*
- *Amblydromalus limonicus*.

The mites were introduced in six following cultivations of Chrysanthemum.

The predatory mites *A. swirskii*, *A. limonicus* and *A. montdorensis* were found to be most abundant and to be most mobile, also spreading to plots where they had not been planted. The most effective control of thrips was found for *A. montdorensis* and *A. limonicus* (see Figure 2).

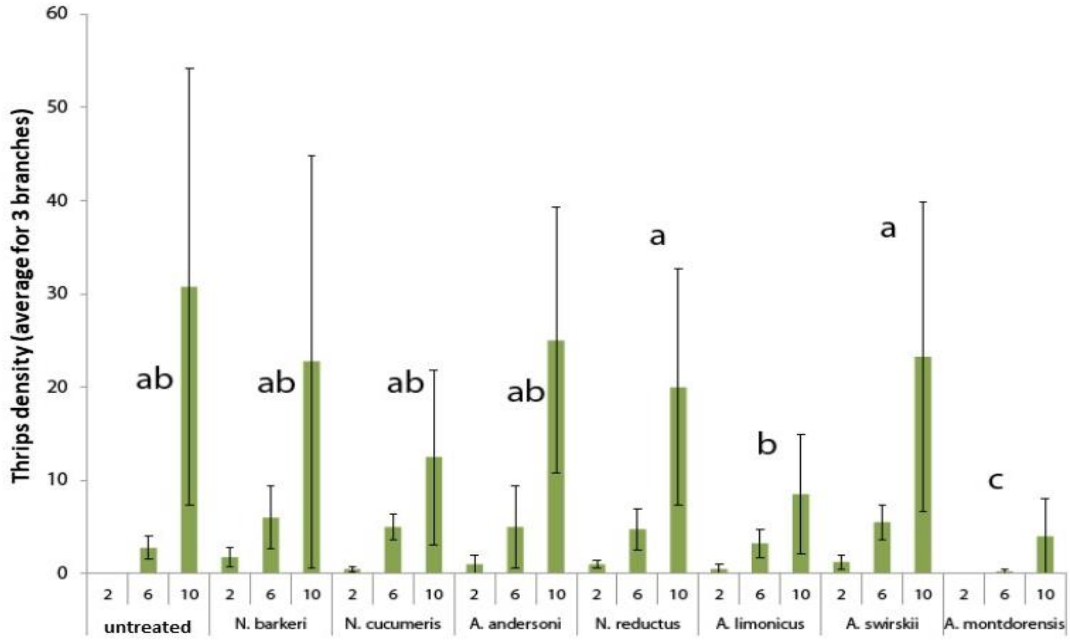

Figure 2: Density of thrips of 4 cultivations of Chrysanthemum for different species of predatory mites[8]

Establishment and feeding of pirate bug Orius

Based on a literature study and enquiry among scientists, three types of feeding were selected for the pirate bugs *Orius majusculus* and *Orius laevigatus*; alternative food source, host plants and alternative preys.

As an alternative food source feed stuffs such as pollen, moth eggs and shrimps were offered. The host plants that were tested were Alyssum and pepper. As alternative preys feeding mites were used.

It was found that feeding with moth eggs of Ephestia kuehniella offered the best results in both tested Orion spp (see Figure 3).

Shrimps of *Artemia* offered disappointing results in a practical situation, though good results were observed on a laboratory scale. It is expected that the pirate bugs need a higher moisture content in their food in order to absorb it. Successful use of Artemia as an additional food stuff for *Orius* therefore requires the food to be fed as a high moisture substance, instead of the dry strewing that was used in this practical test.

Using pollen and host plants led to differing results between the two tested *Orius* spp. While the *O. laevigatus* population was able to increase when fed with pollen and availability of host plants, *O. majusculus* had only a low population increase.

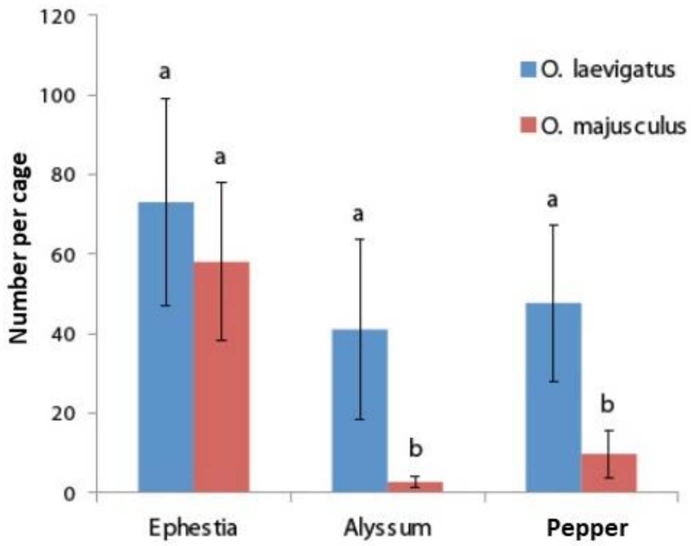

Figure 3 Population of O. laevigatus and O. majusculus on Chrysanthemum when offered Ephestia as feed or the host plants Alyssum or Pepper[8]

When using alternative preys (mites), it was found that the effect differed with different species of feeding mites. Further research will be necessary to test the effect of different feeding mites on population growth of *Orius* spp.
Overall it was found that it is possible to stimulate population growth of *Orius* spp. in Chrysanthemum by feeding. When sufficient food stuffs are available, the pirate bug is able to lay eggs on Chrysanthemum and thereby expected to build up a robust population.

Soil top layers for stimulation of predatory mites

In this study, the effect of different top soil layers on the population density of predatory mites was tested. No beneficial effects on introduced predatory mites or feeding mites were observed from adding soil top layers. However, a substantial increase in different other soil predators were observed such as on beetles, soil predatory mites and spiders. Further research is necessary to establish what these soil predators can contribute to integrated thrips control in Chrysanthemum.

4.4 Barriers (to implementing the project)

The project showed promising results of using extra food supplies to maintain pirate bugs of *Orius* spp. in Chrysanthemum. Further research is required to fine tune how to offer additional feed that is affordable and readily available to pirate bugs in a practical situation.

The research gave indication that adding top soil layers in Chrysanthemum can stimulate soil life. Further research would need to establish if stimulating the presence of soil predators can contribute to the integrated control of thrips in Chrysanthemum.

II. Pirate bugs (Orius spp.) in Chrysanthemum (Wageningen UR)[9]

4. 1 Objectives

Predatory mites have been successfully used in Chrysanthemum for several years, though in many cases it is found difficult to control thrips sufficiently, leading an increase in thrips in autumn, which leads to a high infestation of thrips in the next spring. Where predatory mites only feed on young larvae of thrips, pirate bugs feed on larvae and adults of thrips. This, combined with the fact that pirate bugs are bigger eaters than predatory mites, makes them a good candidate for biological thrips control.
Though pirate bugs of *Orius* spp. have been used successfully against thrips in the protected cultivation of sweet pepper for years, it was found that they have trouble establishing themselves in ornamental crops.
In this study, the best ways of establishing *Orius* spp. in Chrysanthemum was studied.

4.2 Governance and functioning of the initiative

In spring 2017, Wageningen University & Research, business unit Greenhouse horticulture, started a project to find a new way to control thrips in Chrysanthemum. The research was part of two projects; the project PPS Trips, in which alternative ways of feeding pirate bugs is investigated, and the project PPS Green Challenges in which the goal is to optimize the function of biodiversity in crop protection and realize system leaps.
The projects PPS thrips and PPS Green Challenges are cooperation's of various commercial parties and the Ministry of Economic Affairs and are funded by both these private and public parties.

4.3 Results (and successes)

By introducing pirate bugs to the crop as early as possible and by offering them a suitable type of food, they are able to form a strong population, a "standing army", that can control a beginning infestation of thrips.
Until now biological control in Chrysanthemum was started relatively late, leaving too little time for the natural enemies to build up a stable population. In this project, the pirate bugs were introduced onto plant cuttings. Since no thrips are available yet at this stage, it is vital with such an early introduction that pirate bugs are offered additional food.
In former research, as detailed in the summary of project 1, different types of feed and methods of feeding were tested. In this project, the potential of using shrimp of *Artemia* was again investigated. It was found that shrimps of *Artemia*, under the prerequisite that they are of good quality, offered the best feed for *Orius* spp.

With an early introduction in plant cuttings, and using *Artemia* as additional feed source, a promising population build up was observed. Where they started with one bug per plant cutting, at the end of the cultivation, 40 bugs per plant were found. The population of *Orius* spp. was found to be effective in the control of thrips and reached an effectiveness of around 95%. The pirate bugs were found to be more effective in the control of thrips than predatory mites, because also adult thrips are controlled.

4.4 Barriers (to implementing the project)

The early introduction of *Orius* spp. in Chrysanthemum cuttings can be hindered by the presence of pesticide residues in the cuttings. At the moment it is still difficult to obtain cuttings that contain little or no pesticide residues. However, with an increasing demand from growers, it is expected that nurseries will find alternative methods for pest control, making it possible to deliver low residue cuttings.

The quality of Artemia shrimp available on the market is often not of sufficient quality to offer a good feed for *Orius* spp. In cooperation with the University of Gent and the commercial company Biobee, ways are sought for the production of high-quality Artemia. It remains to be seen if affordable Artemia shrimp of good quality become readily available for growers.

Next to thrips, multiple other pests and diseases can affect Chrysanthemum. It needs to be tested and tried in practice if use of *Orius* spp. can be combined with other biological control agents and potential chemical control methods that prove necessary to control severe infestations or infections of other pest or diseases.

III. Effects of irrigation on *T. montdorensis* in Chrysanthemum (Proeftuin Zwaagdijk)[10]

4.1 Objectives

In practise, greenhouse grown Chrysanthemums are generally irrigated during the whole cultivation from above. This irrigation causes great differences in the level of humidity and temperature in the crop, that are likely to influence the natural enemies present in that crop.

In this study it was investigated if different methods of irrigation influence the establishment and population growth of predatory mites, feeding mites and thrips. The effect of standard irrigation from above is compared to irrigation by drip. Also different frequencies of irrigation from above are tested.

4.2 Governance and functioning of the initiative

The study was conducted by Proeftuin Zwaagdijk in 2019 and was commissioned by Glastuinbouw Nederland. Glastuinbouw Nederland is a cooperation of three regional farmers and growers' organisations as a network of entrepreneurs in protected horticulture. It is funded by standard levies for all the members of the farmers and growers' organisations.

4.3 Results (and successes)

The effect of irrigation methods was tested on the predatory mite *Transeius montdorensis*. The predatory mite was offered additional food in the form of feeding mites.
The following scenarios were tested:

- Irrigation from above at standard frequency (every 2-3 days);
- Irrigation from above at lower frequency (every > 4 days);
- Drip irrigation.

On the establishment and population growth of feeding mites, no clear effect of the frequency of irrigation given from above was observed. Yet, a significantly higher number of feeding mites were observed when drip irrigation was applied. The population maintained higher numbers until the end of the cultivation period. In Figure 4 an overview of the *Thyreophagus entomophagus* feeding mite population over time is given.

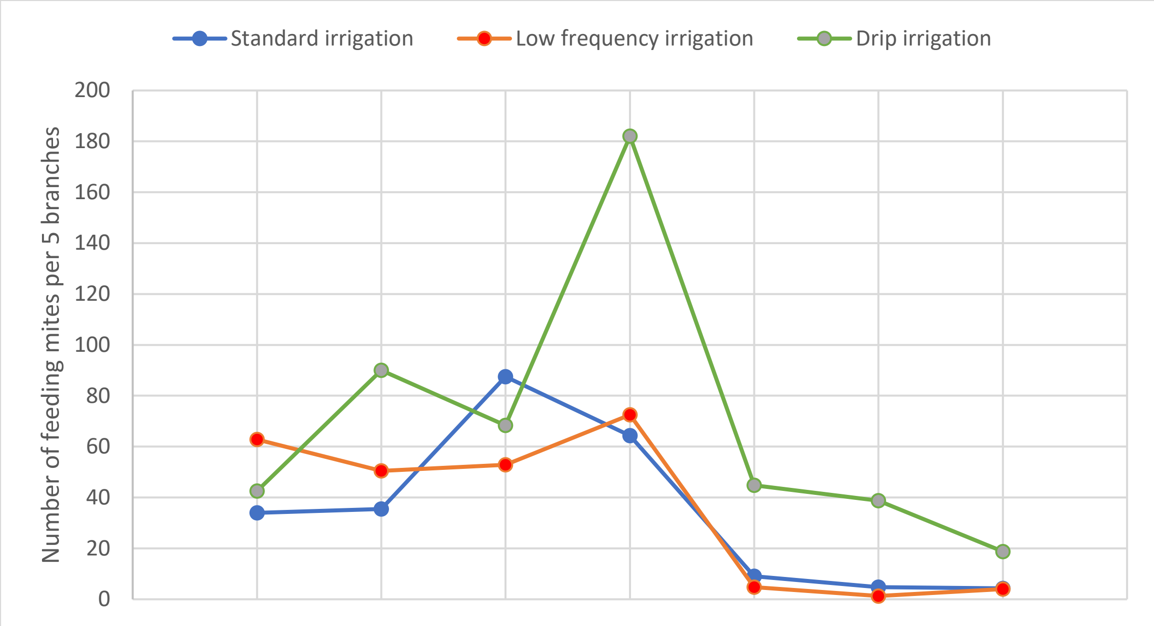

Figure 4:Establishment of feeding mites of Thyreophagus entomophagus over the cultivation period.

On the establishment and population growth of the predatory mites, no clear effect of the frequency of irrigation given from above was observed. Yet, a significantly higher number of predatory mites were observed when drip irrigation was applied. The population maintained higher numbers until the end of the cultivation period. In Figure 5 an overview of the *Transeius montdorensis* predatory mite population over time is given.

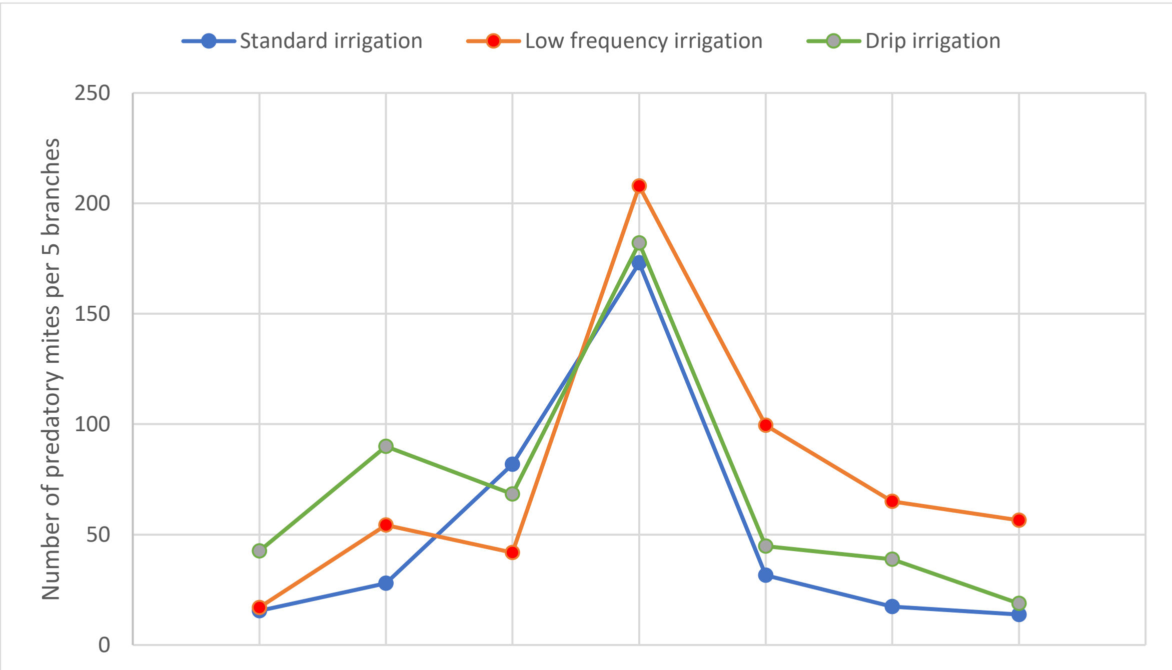

Figure 5: Establishment of predatory mites of Transeius montdorensis over the cultivation period.

The number of thrips present in the different treatment plots varied greatly. As a result of this variation, no conclusions could be drawn on the effect of the different irrigation types on the efficacy of *T. montdorensis* against thrips.

The different irrigation methods did not greatly affect the growth of the Chrysanthemum plants.

The lower frequency of irrigation from above, resulted in somewhat shorter Chrysanthemum branches. No differences between standard irrigation from above and drip irrigation were observed.

Overall, it was shown that irrigation methods can influence the establishment and population growth of predatory mites and feeding mites. Drip irrigation may offer a more stable environment for natural enemies.

4.4 Barriers (to implementing the project)

Though drip irrigation may offer a more stable environment for natural enemies as compared to standard irrigation applied from above, there are also disadvantages to using drip irrigation. The build-up of the system is much more labour intensive when a new crop is planted as each plant needs its own dripper. The system is much less flexible and can cause uneven rooting of the plant. Most importantly, the system is known to be sensitive to blockages.

5. Discussion and conclusions

Chrysanthemum is a very difficult crop in which to let natural enemies establish. In this case study, 3 individual projects were investigated that focussed on the use of natural enemies in the integrated control of thrips in greenhouse grown Chrysanthemum.

In Chrysanthemum, predatory mites and pirate bugs are used for the control of thrips. The effectiveness of these natural enemies is dependent on their ability to build up a robust population in the crop. This is dependent on the availability of food, and on favourable conditions for their growth and survival.

It was found that the predatory mites *Amblydromalus limonicus* and *Amblyseius montdorensis* were best able to establish themselves in Chrysanthemum. Where predatory mites feed only on young larvae of thrips, pirate bugs feed on larvae and adults of thrips. This, combined with the fact that pirate bugs are bigger eaters than predatory mites, makes them a good candidate for biological thrips control. It was found that the pirate bugs *Orius majusculus* and *Orius laevigatus* can establish and replicate in Chrysanthemum.

Under greenhouse conditions, thrips can exponentially increase in population size. In order for predatory mites and pirate bugs to effectively control thrips they need time to build a robust population and be able to prevent the exponential growth of the thrips population. It was found that the pirate bug was more effective when it was introduced to the crop as early as possible. When applied to plant cuttings, the pirate bug was able to establish itself successfully in Chrysanthemum and as a “standing army” it could effectively control thrips.

In order for predatory mites and pirate bugs to build up robust populations and act as a “standing army” to control thrips, it needs additional food sources to survive. Of the various food stuffs tested, the *Orius* pirate bug favoured moth eggs of *Ephestia* and shrimps of *Artemia*. Additional feeding with these food stuffs allowed them to establish themselves in the crop when no thrips or only a low number of thrips were present. Nevertheless, it was found that the food stuff should be of good quality for them to survive on it. This was especially the case for *Artemia*.

Other conditions can also influence the survival of natural enemies in the crop. In practise, greenhouse grown Chrysanthemums are often irrigated from above. This irrigation causes great differences in the level of humidity and temperature in the crop, that can influence the natural enemies present in that crop.
It was found that irrigation methods can influence the establishment and population growth of predatory mites and feeding mites. When standard irrigation applied from above was

compared to drip irrigation, it was found that with drip irrigation higher numbers of feeding mites and predatory mites were present in the crop and that they remained in the crop for longer. Drip irrigation may thus offer a more stable environment for natural enemies.

Overall, it can be concluded that use of natural enemies in Chrysanthemum is not very straight forward but that there is great potential for developing a successful system for use of predatory mites and pirate bugs in the control of thrips in this crop. Further research is required to optimize conditions under which these natural enemies will best establish themselves, and to determine under practical conditions if their use can be combined with other biological control agents and potential chemical control methods that prove necessary to control severe infestations or infections of other pest or diseases.

The knowledge that is gained from research on the conditions required for the successful establishment of natural enemies in a difficult crop such as Chrysanthemum will help to further optimize the use of natural enemies in other greenhouse cultivations.

Much knowledge is available on different aspects of IPM, but a clear overview of its practical benefit is lacking. As many different parties, with different interests, are involved in the research of various aspects of pest management, the research often limits itself to details that are of minor relevance to practical use. It is considered that a more centralized approach would greatly benefit the effectiveness of biological control methods and further implementation of IPM in the Netherlands.

Annex I - Bibliography

[1] Wijnands, F.G, Brinks, H, Schoorlemmer, H. de Bie, J. Integrated Pest Management Adoption in the Netherlands: Experiences with Pilot Farm Networks and Stakeholder Participation. Integrated Pest Management pp 513-554. (2014).
[2] CBS StatLine. Centraal Bureau voor de Statistiek. 2021.
[3] EPPO standard PP 2/13(1) Ornamental plants under protected cultivation. (1998).
[4] Mouden, S, Sarmiento, K.F, Klinkhamer, P.G.L, Leiss, K.A. Integrated pest management in western flower thrips: past, present and future. Pest Management Science 73(5): 813-822. (2017).
[5] Fathipour, Y, Maleknia, B. Chapter 11 – Mite Predators. Eco-friendly Pest Management for Food Security, p 329-366. Academic Press. (2016).
[6] Kiman, Z. B. & Yeargan, K. V. Development and reproduction of the predator Orius insidiosus (Hemiptera: Anthocoridae) reared on diets of selected plant material and arthropod prey. Annals of the Entomological Society of America. 78 (4): 464–467. (1985).
[7] Bakx, S, Halbersma, G. Gewasbescherming in de chrysantenteelt onder tripsgaas. Van Iperen. (2020).
[8] Van der Linden, A, Grosman, A, van der Staaij, M. Messelink, G. Bouwstenen voor tripsbestrijding in Chrysant. Rapport GTB-1243. Wageningen UR Glastuinbouw. 2013.
[9] Van Woerkom, M. Onderzoekers vinden doorbraak in tripsbestrijding chrysant. Vakblad onder glas. (2018).
[10] Van der Meer, M, Sanders, J. Het effect van irrigatiemethoden op de vestiging van *Transeius montdorensis* in chrysant. Proefnummer: 190295. Proeftuin Zwaagdijk. (2019).