# Biological control strategies for managing thrips in strawberry cropping systems

- A literature review

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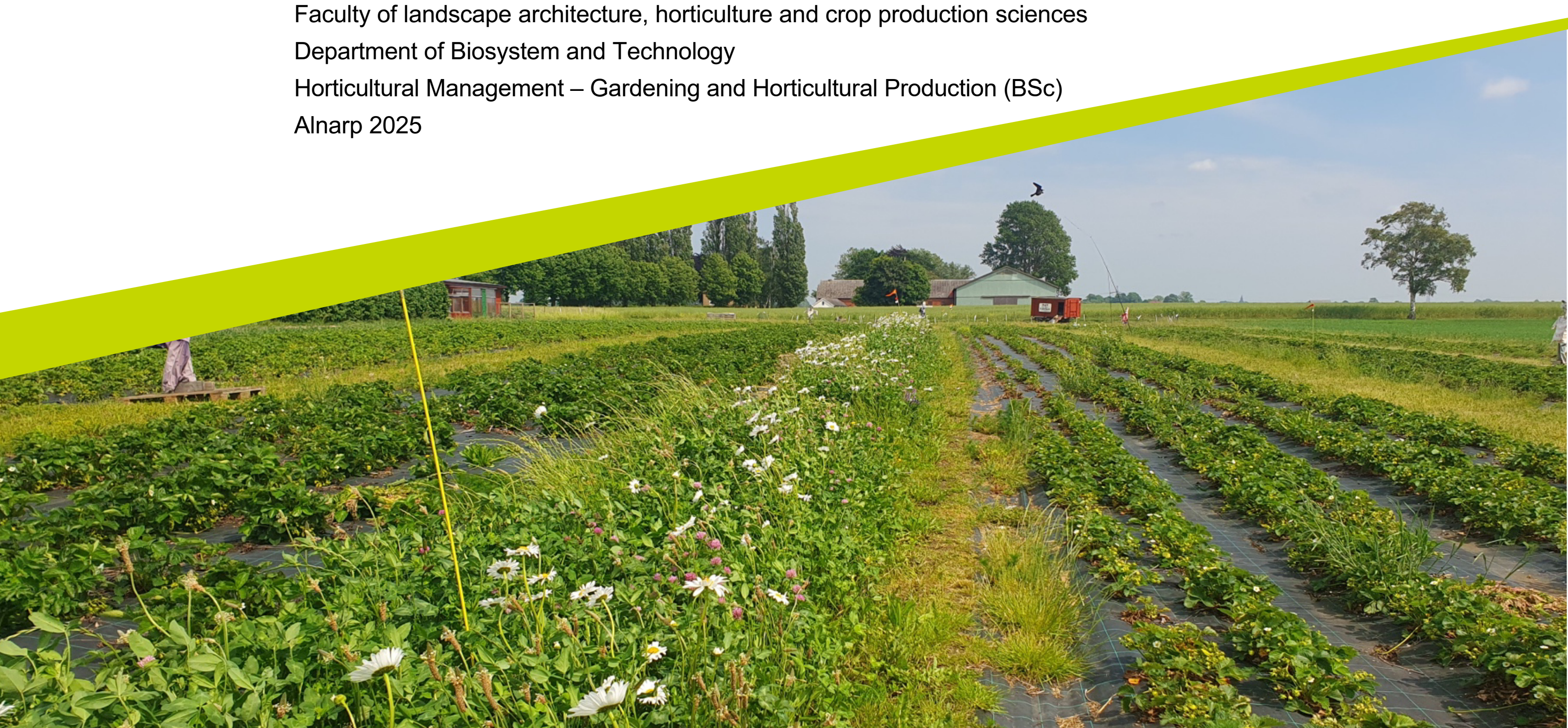

# Biological control strategies for managing thrips in strawberry cropping systems
# - A literature review

*Strategier för biologisk bekämpning av trips i odlingssystem för jordgubbar*
*- En litteraturöversikt*

Josefin Mebius

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## Sammanfattning

**Inledning**: Trips är ett av de vanligaste skadedjuren i jordgubbsodlingar världen över och orsakar allvarliga ekonomiska skador på blommor och frukter i jordgubbsodlingar. Med stigande temperaturer på grund av klimatförändringar, negativa effekter av bekämpningsmedel på ekosystem samt biologisk mångfald och ökande resistens bland tripsarter som *Frankliniella occidentalis*, finns det ett ökande behov av att hitta effektiva biologiska bekämpningsstrategier för att kontrollera tripsangrepp i jordgubbsodlingar i Sverige. Därför är syftet med denna avhandling att utforska biologiska bekämpningsstrategier för att bekämpa trips i jordgubbsodling i tunnlar, växthus och på friland. **Metod**: En strukturerad litteratursökning utfördes den 25 april 2025 på Web of Science där 11 artiklar extraherades för vidare analys av biologiska bekämpningsmetoder där resultat såsom effekt på trips i grödan, naturliga fiender, skador på grödan och avkastning jämfördes. I tillägg så inhämtades ytterligare information om biologiskt växtskydd och skadegörare i jordgubbsodling i Sverige från tre rådgivare via telefonsamtal och ett videomöte. **Resultat**: Resultaten från denna litteraturgenomgång visar att tolv olika biologiska bekämpningsmetoder reducerar trips i odlingssystem för jordgubbar på friland och i växthus genom frisättning av rovkvalster, näbbskinnbaggar (*Orius* spp.), fältrovskinnbaggar (*Nabis americoferus*) och entomopatogena svampar av arten *Beauveria bassiana*. Flera växtarter som *Cyanus segetum*, *Echium vulgare*, *Chenopodium album*, *Capsicum annuum L.*, *Lobularia maritima*, *Urtica urens*, *Lamium amplexicaule*, *Convolvulus arvensis*, *Sonchus oleraceous* och *Galega officinalis* har visat sig öka förekomsten av naturliga fiender till trips. Förekomsten av trips minskade även när prydsnadspaprika (*Capsicum annuum L.*) och strandkrassing (*Lobularia maritima*) planterades intill jordgubbsodlingar, medan prydnadspaprika ledde till en minskning av skadorna på grödorna. **Slutsats**: Resultaten från denna litteraturöversikt belyser några viktiga forskningsområden för utveckling av biologiskt växtskydd för att hantera trips i odlingssystem för jordgubbar på friland och i skyddade odlingar i Sverige. Översikten ger en sammanfattning av de mest uppdaterade vetenskapliga rönen och kan användas som vägledning för forskare, jordbrukare och rådgivare. Genom att kombinera olika biologiska kontrollstrategier finns det potential att öka kostnadsfördelarna för jordbrukare och samtidigt minska de negativa effekterna på ekosystemet och människors hälsa i odlingssystem för jordgubbar.



**Nyckelord***: Biologisk bekämpning, BCA, Thrips, Thysanoptera, Jordgubbar, Fragaria x ananassa*

## Abstract

**Introduction:** Thrips is one of the most common pests in strawberry crops worldwide that cause severe economic damage to flowers and fruits in strawberry crops. With rising temperatures due to climate change, negative impacts from pesticides on ecosystems and biodiversity, and increasing resistance among thrips species such as *Frankliniella occidentalis* there is an increasing urge to find efficient biological control strategies to control thrips infestations in strawberry crops in Sweden. Therefore, the aim of this thesis is to explore current biological control strategies to control thrips in greenhouse and open-field strawberry cropping systems. **Method:** A structured literature search was conducted on April 25th, 2025, on Web of Science where 11 articles were extracted for further analysis for biological control method with result on thrips in crop, natural enemies, crop damage and yield that was compared. In addition, information of Swedish strawberry production, pests and biological control methods was collected from advisors via phone calls and one video meeting. **Result:** The results from this literature review reveals twelve different biocontrol agents in reducing thrips in open-field and greenhouse strawberry cropping systems such as release of predatory mites, the minute pirate bug (*Orius spp.*), damsel bugs (*Nabis americoferus)* and entomopathogenic fungi *Beauveria bassiana.* Several plant species such as *Cyanus segetum, Echium vulgare*, *Chenopodium album*, *Capsicum annuum* L.*, Lobularia maritima, Urtica urens, Lamium amplexicaule, Convolvulus arvensis, Sonchus oleraceous* and *Galega officinalis* has proven to increase the presence of natural enemies for thrips. Ornamental pepper (*Capsicum annuum* L.*)* and sweet alyssum *(Lobularia maritima)* decreased the presence of thrips when planted adjacent to strawberry crops while ornamental pepper led to a reduction on crop damage. **Conclusion:** The findings from this literature review highlights some key research areas for development of biocontrol strategies for managing thrips in open-field and protected strawberry cropping systems in Sweden. The review offers a summary of the most updated scientific findings and can be used as a guidance for researchers, farmers and advisors. By combining different biological control strategies, there is potential to increase cost- benefits for farmers while reducing negative impacts on the ecosystem and human health in strawberry cropping systems.



**Keywords***: Biological control, Biocontrol agents, BCA, Thrips, Thysanoptera, Strawberries, Fragaria x ananassa*

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# 1. Introduction

In the south of Sweden, strawberries are one of the most cultivated horticultural crops (Sundgren 2014) normally grown in conventional open-field monocultures. Among them organic farms represent a minority with 96 hectares compared to 2441 hectares of conventional open-field farms in 2020 (Jordbruksverket 2023). With rising temperatures due to climate change impacts thrips are expecting to increase in the northern Europe (Parikka & Tuovinen 2014). In combination with increasing resistance against pesticides (Feit et al. 2021; Goulson 2019) among common thrips species such as *Frankliniella occidentalis* (Vervoort et al. 2017; Yuan et al. 2023), there are incentives to find efficient biological control strategies to control thrips infestations in strawberry crops in Sweden.

Agriculture has intensified since the 1950s, with new technologies and synthetic pesticides and fertilizers, to boost food production (Doehler et al. 2023; Goulson 2019). This rapid development has led to a dramatic change in landscape structure with a growing majority of arable fields consisting of monocultures to streamline the process and maximize yields (Doehler et al. 2023). In the shadow of increased yields, the intensive agricultural landscape has demonstrated negative impacts on biodiversity and ecosystem services such as biological control of pests from natural enemies (Geiger et al. 2010; Goulson 2019). A reduction in landscape heterogeneity and natural habitats disadvantages beneficial insects as natural enemies, which are an ecosystem service of major importance for pollination and natural biological control of pests (Geiger et al. 2010; Goulson 2019; Feit et al. 2021).

Thrips is one of the most common pests in strawberry crops worldwide that cause severe damage to flowers and fruits in strawberry crops (Alhmedi et al. 2024; Reitz & Funderburk, 2012). Common predators of thrips which is today used as augmentative biological control agents in greenhouse and tunnel cultivation includes the minute pirate bugs (*Orius majusculus)* and predatory mites (*Amblyseius swirskii* & *Amblyseius cucumeris)* (Mouratidis et al. 2023; Parikka & Tuovinen 2014; Pålsson[1] 2025). However, it remains a challenge to fight thrips with augmentative biological control methods in open-field systems as it's both work intensive to spread predators as mites and *Orius* spp. on larger areas by hand (Pålsson[1] 2025) and complex to implement conservation biological control methods such as flower strips to boost the presence of natural enemies while reducing pest thrips (Alhmedi et al. 2024; Gugole Ottaviano et al. 2015). According to Rännbäck [2] (2025), there are concerns among the strawberry farmers in the south of Sweden, that conservation biological control methods, such as implementation of flower strips, will attract and increase infestation of thrips and *Lygus* spp. in the strawberry crops. Simultaneously, promising results have been recorded from studies exploring the effects by planting companion plants, such as *Lobularia maritima,* on natural enemies and thrips in strawberry

[1] Joakim Pålsson, plant protection advisor, Biobasiq, phone conversation 2025-04-11
[2] Linda-Marie Rännbäck, Berry advisor, HIR Skåne, phone conversation 2025-04-16

crops (Kollet et al. 2024). It is therefore of importance to further explore the scientific foundation for alternative biological control strategies for managing thrips in strawberry cropping systems in Sweden.

# Objectives

The aim of this paper is to explore current biological control strategies to control thrips in strawberry field, tunnel and greenhouse crop production systems. This will be done through the following research questions:

1. What biological control strategies have proven efficient in reducing thrips infestations in strawberry cropping systems?
2. Which plant species can host natural enemies and thus reduce thrips infestations in strawberry cultivation?

# 2. Background

## 2.1 Biological control

The urge to improve biological control strategies as a part of integrated pest management (IPM) programs is rising around the world. To reduce the negative side effects of synthetic pesticides on ecosystems and human health, new biological control methods are being explored by innovation and new knowledge of behaviours and interactions of natural enemies to suppress pests (Mouratidis et al. 2023; Coates et al. 2021; Alhmedi et al. 2024). Since the term biological control has been developed into many sub-divisions that have been used inconsistently in scientific literature in different fields in history (Barrat et al. 2018), it may cause confusion.

In this paper, biological control is defined as; “the use of living agents (including viruses) to combat pestilential organisms (weeds, pests and pathogens), directly or indirectly, for human benefit” (Stenberg et al. 2025). The term biological control agents refer to arthropods, viruses, nematodes, bacteria or fungi (Lacey et al. 2015). Bioprotection is the umbrella term that covers both nature-based living biological control agents and nature based, non-living substances. Examples of non-living substances are extracts from plants and pheromones to repel or attract insects (Stenberg et al. 2025). Crop rotation, gene modification, manually removing bugs from the crops and noise to scare birds are all examples that are not included in the concept of biological control as these methods do not include a third part, meaning the beneficial living agent, also called natural enemies, that are targeting the pest (Stenberg et al. 2021).

In this paper, the term biocontrol will be used throughout, with the conceptual framework and definition based on a literature review by Stenberg et al. (2021) based on the following three principles:

1. Biocontrol consists of living agents including viruses and excludes all non-living organisms.
2. Biocontrol is targeting a pest, directly or indirectly.
3. Biocontrol can be classified within one of the four main categories of biocontrol.

The four main categories of biocontrol are subdivided into Natural biological control, Conservation biological control, Classical biological control and Augmentative biological control described separately below.

### 2.1.1 Natural biological control

Natural biological control is defined as nature based biological control offered from the inhabitants of our ecosystems and acts without any human actions (Stenberg et al. 2025). As Intensive farming has led to a decline of semi-natural habitats since the 1950s (Doehler et al. 2023; Goulson 2019), the need for increasing biodiversity and reducing the use of synthetic pesticides has arisen (Stoate et al. 2001; Goulson 2019). Strategies including landscape planning to increase landscape complexity and biodiversity surrounding the crops, is one way to reduce the use of synthetic pesticides and to increase the resilience of ecosystem services provided by the inhabitants (Stoate et al. 2001; Feit et al. 2021). The composition and structure of the surrounding landscape is partly an explanation of which natural enemies and pests that are colonizing strawberry crops and to what extent (Doehler et al. 2023). Natural biological control methods is not only a preventative method for open-field cultivation as there is a consensus from previous research that there is a spontaneous influx of pests and natural enemies through ventilation and openings in tunnel and greenhouse strawberry cultivation (Doehler et al. 2023). In contrast, there are still no existing protocols for how to design a landscape to promote natural biological control (Tscharntke et al. 2007; Jonsson et al. 2008).

### 3.1.2 Conservation biological control

Conservation biological control are methods enhancing the already present inhabitants in the ecosystem e.g. by planting flower or hedge trips in the borders or in between crops to offer nectar, pollen, habitats and shelter for beneficial insects as natural enemies (Eilenberg et al. 2001). Plants can act as a biocontrol mediator by various mechanisms (Stenberg et al. 2021) were different plants as sweet alyssum (*Lobularia maritima*) are currently explored to act as trap crop (also called companion plants or banker plants) in open-field, greenhouse and tunnel systems (Koller et al. 2024; Busuulwa et al. 2024). Other examples of conservation biological control methods are intercropping of flower mixes within the cultivation with the aim of attracting natural enemies of different pests which will disperse into the crop (Alhmedi et al. 2024; Gugole Ottaviano et al. 2025).

### 3.1.3 Augmentative biological control

*Augmentative control* is when biocontrol agents are added for temporary control of pests during a limited growing season (Stenberg et al. 2021). This strategy aims to increase the presence of predatory, parasitic or pathogenic natural enemies against the targeted invading pest in all kinds of cropping systems as open-field and tunnels (Stenberg et al. 2025). Examples of augmentative biological control are *Orius laevigatus* to control aphid infestation of *Macrosiphum euphorbiae* (Zuma et al. 2023), the parasitoid wasp *Encarsia formosa* against whiteflies in greenhouses (Hoddle et al., 1998), The predatory mite *Phytoseiulus persimilis* to control of two-spotted spider mites (*Tetranychus urticae*) in greenhouses (Tiftikçi et al. 2020) and the fungi *Trichoderma harzianum* to fight *Botrytis cinerea,* a common pathogen in strawberry crops causing grey mould (Yao et al. 2023).

To add predatory mites and insects such as *Amblyseius cucumeris* and *Orius majusculus* are a common examples of augmentative biological control strategies for managing pests thrips in strawberry tunnel cropping systems in Sweden (Pålsson[3] 2025).

### 3.1.4 Classical biological control

*Classical biological control* is when humans introduce non-native natural enemies to fight a pest, with the aim for the introduced species to colonize the area for a permanent control of targeted pests (Stenberg et al. 2021). There are many examples of classical biological control where exotic species have been introduced all over the world e.g. parasitoids to control the coffee berry borer (*Hypothenemus hampei,* Coleoptera: Curculionidae) in coffee growing countries or the invasive *Liriomyza spp.* leaf miners (Diptera: Agromyzidae) in vegetable crops (Cock et al. 2016). Among natural enemies, endoparasitoids have especially shown to be more effective against pests than others, in advance, many parasitoids are host-specific which reduces risk for negative impacts on non-targeted organisms (Seehausen et al 2021).

## 3.2 Strawberry evolution & production in Sweden

*Fragaria x ananassa,* which is the strawberry as we know it today, is a relatively young fruit species with one of its wild relatives first introduced to Europe in the year 1712 (Mangelsdorf, 1927). The strawberry belongs to the eudicot plant family Rosaceae and in botanical terms, it's not a berry but an aggregate accessory fruit derived from the receptacle where each seed is classified as a stone fruit also called achene (Liston et al. 2014). It has evolved from a polyploid evolution and is a result from both natural occurring hybridization and human domestication (Edger et al. 2019). Its heritage originates from a hybridization of the two octoploid progenitors; the North American Virginia strawberry *Fragaria virginiana,* and the South American Chilean strawberry *Fragaria chiloensis*. (Edger et al. 2019)

In Sweden, strawberries are one of the most economically and culturally important horticultural crops grown in Sweden (Sundgren A. 2014) with 50% of total production based in Skåne county in the south of Sweden (Jordbruksverket 2024). Despite that the field production of strawberries has decreased in Sweden in total, the same amount is being harvested. This can be explained due to an increased productivity in tunnels where the yields are accounted to be three times higher (Jordbruksverket 2024). Despite that most strawberries are still being produced in open-field production, tunnel production has increased from 41 to 143 hectares between year 2014 to 2023 and from 5- 7% between 2020- 2023 according to statistics from Jordbruksverket (2024).

[3] Pålsson, conversation 2025-04-11

## 3.3 Thrips

Thrips (Thysanoptera: Thripidae) are one of the most common pests in greenhouse and tunnel cropping systems in Sweden (Nielsen et al. 2021; Pålsson[4] 2025), where the most common species are *Frankliniella occidentalis* (Pergande), *Frankliniella intonsa* (Trybom) and *Thrips tabaci* (Lindeman) (Nielsen et al. 2021). The risk of thrips damages increases during the season, especially since some species can reproduce in other crops in the landscape and spread to nearby strawberry crops (Pålsson[5] 2025). In addition, the risk of thrips increases in everbearing varieties in greenhouse and tunnel systems (Jordbruksverket 2020; Pålsson[6] 2025; Håkansson[7] 2025).

The life cycle of thrips consists of six life stages which are similar to all species belonging to the family Thripidae with one egg, two active feeding larval stages followed by the inactive prepupa and pupal stage and finally the adult life stage. Thrips larvae and adults can most often be found in hidden places of the strawberry plant as foliage, floral buds and developing fruits which is one reason why thrips are difficult to control in strawberry crops. The Females lay the eggs inside leafy tissue, petioles, flower bracts, petals, and developing fruit (Reitz 2009).

The damage on strawberries crops occurs by thrips when larvae and adults are feeding on plant parts by sucking out the content of leaves and fruits tissues which causes severe damage to strawberries crops with symptoms such as fruit bronzing and deformation, petal browning, premature withering and fruit abortion (Parker et al. 2013; Reitz 2009). Besides the direct visible damages, thrips can also act as vectors and spread several tospoviruses to several crops (Parker et al. 2013).

The development time and optimal temperature for some thrips species may vary. The Chili thrips (*scirtothrips dorsalis* Hood*)* which originates from southeast Asia*,* has now been reported in many other countries as USA and Spain and are invasive and causes severe damage in chili, strawberry and blueberry crops. An optimal temperature for *S. dorsalis* is reported to be between 24 °C- 28 °C which results in an average development time of 12 to 15 days. (Busuulwa et al. 2024)

A warmer and drier climate, prolonged growing seasons and increasing trade of plants around the world are expected to increase thrips infestation and damage of present and new exotic species in the Nordic countries in the future (Parikka & Tuovinen 2014).

4 Pålsson conversation 2025-04-11
5 Pålsson, conversation 2025-04-11
6 Pålsson, conversation 2025-04-11
7 Thilda Håkansson, advisor, HIR skåne, phone conversation 2025-04-16

## 3.4 Natural enemies and biological control agents against thrips

The most common biological control agents against thrips in Swedish tunnel and greenhouse strawberry crops are the predatory mite *Neoseiulus cucumeris, Amblyseius swirskii and Orius majusculus. N. Cucumeris* is commonly applied in preventative purposes, in addition a larger quantity of *N. Cucumeris* is added for ongoing infestations in combination with *Orius majusculus* and potentially also *A. Swirskii* (Pålsson[8] 2025)

In open-field strawberry cropping systems biological control is rarely used as it is work intensive and thus costly to spread natural enemies in larger areas, therefore synthetic insecticides remain the most used strategy to control thrips infestations in Sweden today (Pålsson[9] 2025).

In conservation biological control strategies, attraction of natural arthropods is referred to the attraction of natural inhabitants in the surrounding landscape. In a Swedish context, examples of natural enemies against thrips are the minute pirate bug, lacewings and mites. The hypothesis from science is that manipulating the landscape by addition of floral resources, so called companion plants or banker plants, will enhance the presence of natural enemies in strawberry crops by offering food, shelter and oviposition sites on plants. However, it remains a challenge to attract beneficial insects while repelling potential pests in adjacent crops (Alhmedi et al. 2024; Busuulwa et al. 2024).

[8] Pålsson, conversation 2025-04-11

[9] Pålsson conversation 2025-04-11

# 4. Method

A literature review was carried out by one structured literature search on April 25th 2025, on Web of science database based on topic containing the following search terms:

("thrip*" OR thysanoptera) AND (“Biological control” OR Biocontrol OR BCA OR "Biocontrol agent*") AND (strawberr* OR "F. Ananassa" OR "Fragaria Ananassa").

Inclusion criteria for the chosen articles were limited to articles including the topic of biological control of thrips and natural enemies in open-field, greenhouse or tunnel strawberry crops. To obtain a manageable quantity of articles for the timeframe of this thesis, articles published earlier then 2015 were excluded. In addition, articles were selected based on the following inclusion criteria:

- Scientific articles.
- Articles that are peer-reviewed.
- Articles published between 2015- 2025.
- Articles written in English.

Articles that did not meet the above-mentioned inclusion criteria were excluded. Extraction of relevant data included year of publication, country, cropping system, strawberry variety, method, biological control strategy, thrips species and biological control agents that was included and explored in the articles. Outcomes as thrips on crop, crop damage and yield were compared between articles. In addition, information of Swedish pests and natural enemies in strawberry cultivation was collected from three advisors via conversations on phone and video meeting.

# 5. Result

The result from the literature search on Web of science conducted the 25th of April gave 71 hits published between year 2015-2025. After removing replicates and articles that did not fulfil the inclusion criteria, a total of 11 articles including 1 article in natural biological control (NBC), 4 articles in conservation biological control (CBC) and 6 articles in augmentative biological control (ABC) strategies in open-field and protected cropping systems were analysed (Appendix 1, 2 & 3).

## 5.1 Efficacy of Biological control strategies

Strategies in natural biological control covers the effect of landscape complexity and type on greenhouse cropping systems. Strategies in conservation biological control covers methods such as plantation of wild or commercial flower strips mixes or the use of banker plants (companion plants). Strategies included in argumentative biological control strategies included release of predatory arthropods and fungal and nematode entomopathogens in open-field tunnel and greenhouse cropping systems. The articles covering augmentative biological control strategies used different strawberry varieties in their research while the variety for most of the articles covering conservation- or natural biological control strategies were missing or unspecified (Appendix 1).

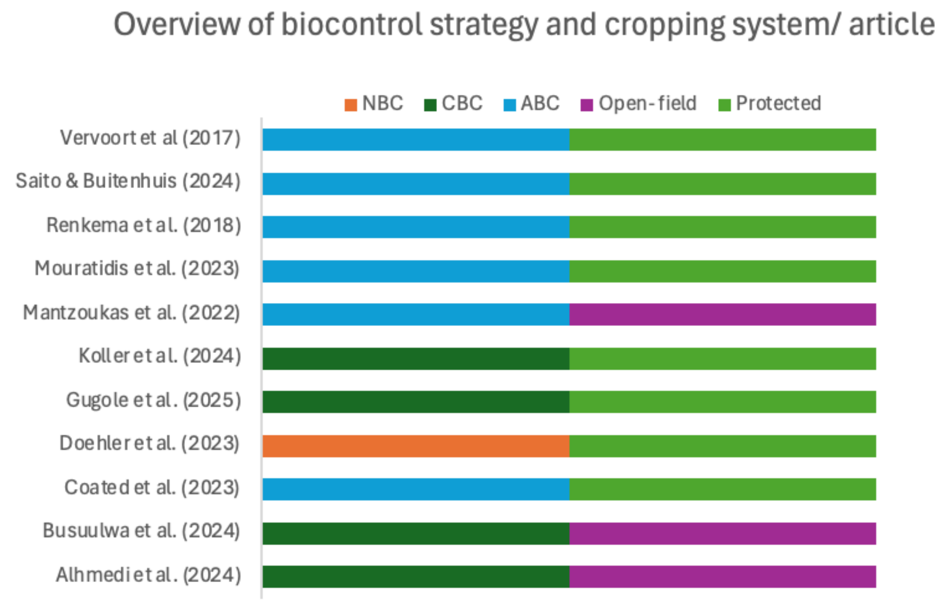


*Figure 1. Overview of biocontrol strategy per article divided into Natural biological control (NBC- Orange), conservation biological control (CBC- dark green) and augmentative biological control (ABC- blue) strategy and cropping system per article divided into open- field and protected.*

### 5.1.1 Natural biological control strategies

One of the extracted articles explored the effect of natural biological control and the effect of the surrounding landscape (Doehler et al. 2023). Natural enemies and presence of main pests were assessed in 32 strawberry greenhouse cultivations in the southwest of France during two growing seasons. The main interesting outcome of this study was that the presence of thrips is positive correlating with woodlands and negative correlation with more complex landscapes. The theory behind the driving mechanisms is explained by the authors as a more complex landscape has a greater variety of all kinds of organisms as thrips but also natural enemies which suppresses the thrips populations. Whereas areas with more woodland could potentially benefit thrips populations more than their natural enemies by providing appropriate food and shelter (Doehler et al. 2023).

### 5.1.2 Conservation biological control strategies & plant species

Enhancing the presence of natural enemies to promote biological control of thrips by planting flowering plants, is a conservation biological control strategy that is explored by four of the articles included in this paper (Alhmedi et al. 2024; Busuulwaet al. 2024; Gugole Ottaviano et al. 2015; Koller et al. 2024).

The main findings is that mainly *Cyanus segetum* and *Helianthus annuus* attracted thrips in combination in a intercropped and border flower strip while other species as *Centaurea cyanus, Echium vulgare, Chenopodium album and Calendula officinalis* especially attracted generalist predators as the minute pirate bug, ladybirds, hoverflies, lacewings and parasitoids (alhmedi et al. 2024) (Figure 2). Two of the articles have mixed results regarding effects on thrips by planting *Lobularia maritima* as a banker plant beside strawberry crops (Busuulwa et al. 2024; Koller et al. 2024) (Figure 3). One of the articles presents no change on the presence of thrips in the strawberry crops (Busuulwa et al. 2024) while the other article shows a reduction of thrips in crops while increasing on *L. maritima* (Koller et al. 2024) (Figure 3). Regarding natural enemies, results indicate that *L. maritima* is attracting natural enemies as Orius spp., Geocoris spp. and *Macrolophus pygmaeus.* One of the articles reveals an increase in crop damage (Busuulwa et al. 2024) while the other one shows no significant change (Koller et al. 2024) in the presence of *L. maritima*. In comparison, Busuulwa et al. (2024) highlights the potential in ornamental pepper (*Capsicum annuum* L.) as a push plant with repelling effects on thrips, reducing thrips in strawberry crops (Figure 3; Appendix 2). The last article (Gugole Ottaviano et al. 2015) highlights that pollen from different wild plant as *Urtica urens, Lamium amplexicaule, Convolvulus arvensis, Sonchus oleraceous* and *Galega officinalis* can enhance the colonization of the predatory mite and the natural enemy *Neoseiulus californicus* by offering food throughout the whole season (Figure 2; Appendix 2). Two of the articles are missing results on crop damage and yield (Alhmedi et al. 2024; Gugole Ottaviano et al. 2015), one article reports mixed results on crop damage depending on banker plant and no change for yields (Busuulwa et al. 2024) while the last article reports no change in crop damage and missing result on yields (Koller et al. 2024) (Figure 3; Appendix 2).

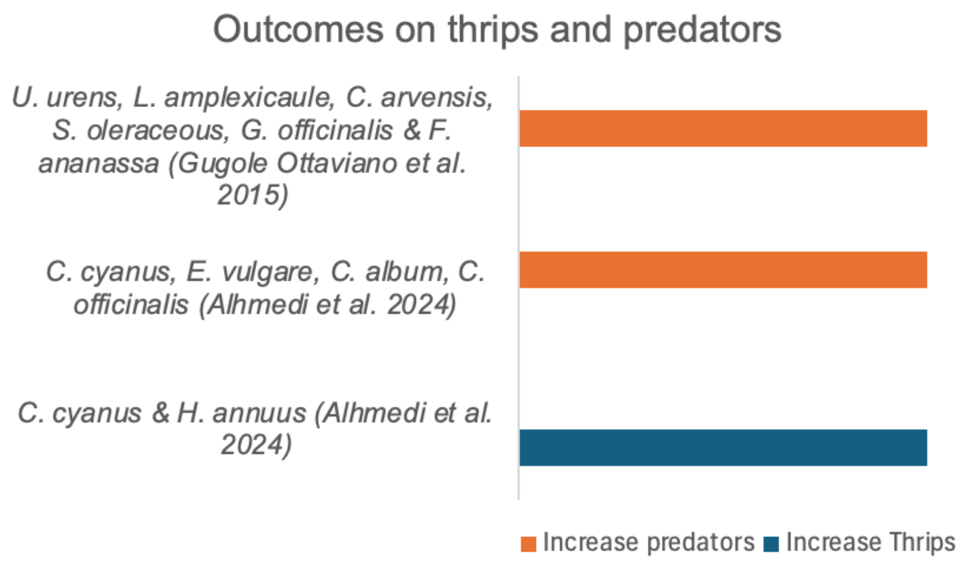


*Figure 2. Main outcomes of the presence of thrips and predators on flowering species included in intercropped and/ or border flower strips in vicinity of strawberry crops.*

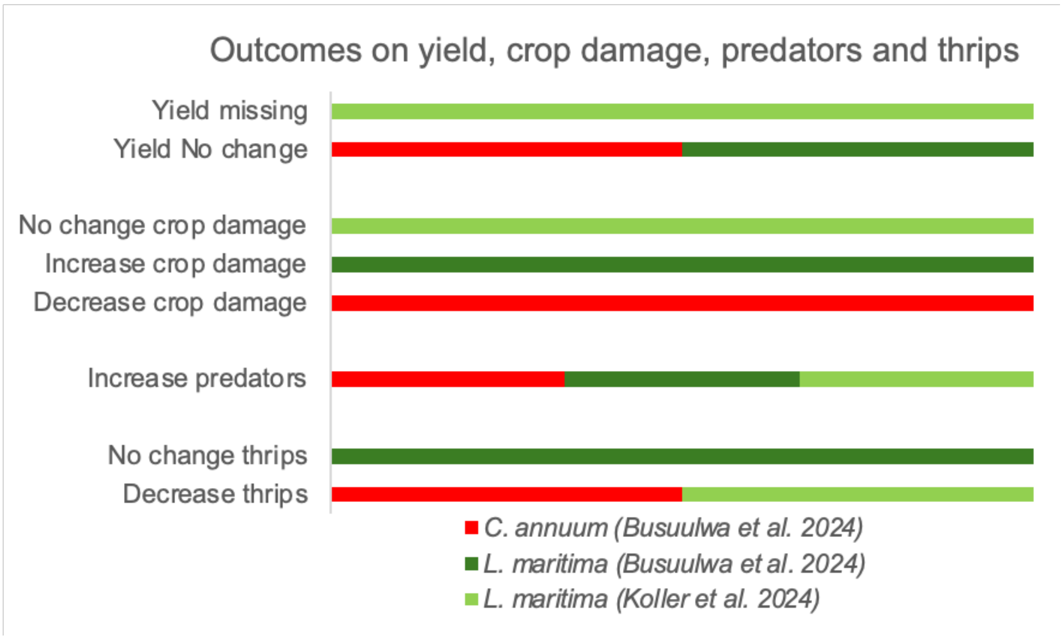


*Figure 3. Main outcomes on the presence of thrips, damage and yield of strawberry crops for different banker plants presented per article and outcomes of the presence of predators on each banker plant per article.*

Alhmedi et al. (2024) performed an open-field trial in Belgium 2020- 2021 with the aim to assess the effect of different flowering plants in a flower strip on beneficial insects (predators, parasitoids and bees) and biological control outcome for aphids and thrips in strawberry open-field cropping systems. The two different strategies that were explored and compared were flower strips grown on the border to the crop field and intercropping flower strips where 25 different flowering species were included in the flower seed mix. The result interesting for this paper is that especially two flower species; Cornflower (*Centaurea cyanus)* and Sunflower (*Helianthus annuus)* seems to attract and host thrips while the natural enemy; *Orius* nymphs and adults were mainly found on *C. cyanus* and blueweed (*Echium vulgare)*. However, while the study revealed the food web and between common pests and presence of natural enemies in the flower strips, it did not reveal how efficient the different flowering plants were in terms of biological control strategy to fight thrips in the strawberry crop. Furthermore, the authors conclude that a mix of border and intercropped flower strips promotes the presence of natural enemies by having flowering resources temporal and spatial available during the season. The authors highlight the importance of planning and managing the flower strip by autumn sowing of flowers to offer an early food source for adult natural enemies in spring and another sowing in early spring to supply food to promote offspring. The disadvantage with this study is that intercropping flower systems gave a 20% loss of harvest due to land use for flowering resources. The authors conclude that more trials have to be conducted to assess if smaller intercropping flower strips can act as effective to promote natural enemies as a biological control method (Alhmedi et al. 2024).

Another study in Argentine explores the effect of the pollen from different wild flowering plants on the community structure of thrips, mite predator *Neoseiulus californicus* and other arthropods (Gugole Ottaviano et al. 2015). The hypothesis was that pollen from wild plants and the strawberry plant contributed to survival of *N. californicus* population periods when no prey was available. Samples were taken each month from wild plants grown adjacent to the strawberry plants at the edge of the beds and from wild plants in a vegetation strip beside the strawberry crops. The strawberry crops grow in low plastic tunnels in a polyculture farm in Argentina (Gugole Ottaviano et al. 2015). The main findings were that *Urtica urens, Lamium amplexicaule* and *Sonchus oleraceous* could promote persistence of the predatory mite *N. californicus* during autumn and winter while *Convolvulus arvensis and Galega officinalis* could offer food in late summer when the flowering of strawberry crops has ended. However, *U. urens* and *S. oleraceous* are also plants that are hosting thrips which should be considered. It is concluded that the presence of wild species in connectivity to flower crops could suppress the pest *Tetranychus urticae* but no other conclusions are directly drawn of the suppression of thrips as the main aim of the study was to explore the effect on presence of the main predator *N. californicus* and the pest two spotted spider mite *Tetranychus urticae*. However, to increase the understanding of interactions between wild plant species and potential predators of thrips is of importance to understand community structures interactions and promising strategies to reduce thrips populations.

Another study explores habitat manipulation by the effect of adding different banker plants to offer food and habitat for natural enemies against the invasive thrips specie *Scirothrips dorsalis* in USA (Busuulwa et al. 2024). The plant species explored were cowpea (*Vigna unguiculata),* sweet alyssum (*Lobularia maritima)*, buckwheat (*Fagopyrum esculentum* Moench) (Caryophyllales: Polygonaceae), ornamental pepper (*Capsicum annum* L.) and sunn hemp (*Crotalaria juncea* L.) The trials were performed in open-field strawberry

cropping systems with raised beds in Florida (Busuulwa et al. 2024). The main outcomes were that sweet alyssum and ornamental pepper had the longest flowering period where ornamental pepper gave significant decrease of leaf damage and suppressed *S. dorsalis* infestations on strawberry plants when placed within 3,7m to the crop compared to control. The author's theory is that ornamental pepper can work in two ways; repelling the effect of the chili thrips and attracting effect on natural enemies while the theory is that sweet alyssum attracted the predators too efficiently as the predators did not disperse in the strawberry crops. However, compared to the commonly used pesticide spinetoram (in USA) had still the highest efficiency to reducing leaf damage on strawberry plants compared to polyculture with both banker plants.
The authors conclude that both ornamental pepper and sweet alyssum were attracting thrips predators such as *Geocoris* spp. and *Orius* spp. but in very low numbers. They also found that the closer the banker plants were placed to the strawberry crops, the more increased suppression of thrips *S. dorsalis*. Other key findings were that the ornamental pepper as a banker plant led to a significant decrease of leaf damage on strawberry plants where the driving mechanism is thought to be due to its repelling effect on thrips rather than attracting natural enemies. The pest-repellent ornamental pepper is suggested to be implemented into IMP programs in combination with one early release of natural enemies as *Orius* spp., predatory mites and *Geocoris* spp. to prevent growth of *S. dorsalis* populations and multiple release of natural enemies and disperse of insecticides throughout the growing season. (Busuulwa et al. 2024)

While Sweet alyssum (*Lobularia maritima)* (Oleracea family), has mainly been explored and pointed out for its ability to attract natural enemies to reduce common pests as thrips (Busuulwa et al. 2024), another study made in Switzerland explored the potential of *L. maritima* to be utilized as a trap crop, in other words, it´s ability to attract pests as thrips to avoid damage on strawberry crops (koller et al. 2024). The potential of *L. maritima* was tested in 3 trials, where two of the trials addressed strawberries applied in two different cropping systems: Open field with flower strips of L. maritima beside the crop and in a tunnel with *L. maritima* plants hanging under the gutters with strawberries.
The outcome effects of *L. maritima* strips beside strawberry crops were fewer thrips. However, similar damage levels were observed on strawberry crops. The outcomes from *L. maritima* hanging under the gutters reduce thrips damage by 50%. The theory is that adult thrips are laying the eggs in *L. maritima* which have difficulty to travel up to the strawberry plant when they are in their larvae and juvenile stages. Therefore, the physical separation of *L. maritima* and strawberry is an effective strategy to reduce the damage by thrips in greenhouse crops in raised gutters. However, *L. maritima* also increased the presence of *lygus spp.* which is another pest in strawberry crops. The positive aspects of *L. maritima* is the potential to act as a nursery for beneficial insects and potential to be trap crops for thrips and the author suggests that more trials are needed to decide in which settings the plant can be utilized to lower the amount of synthetic pesticide against thrips (Koller et al. 2024).

### 5.1.3 Augmentative biological control strategies & efficiency

Six of the included articles covered the topic augmentative biological control where three of the articles mainly explore the potential in arthropods as a biological control agent including predatory mites, generalist predators as the minute pirate bug (*Orius spp.)* and the damsel bug (*Nabis americoferus)* (Vervoort et al. 2017; Mouratidis et al. 2023; Saito & Buitenhuis 2024) (Appendix 3). Three of the articles explored the potential in different strains of the endophytic entomopathogenic fungi *Beauveria bassiana* (Coated et al. 2023; Mantzoukas et al. 2022; Saito & Buitenhuis 2024) and one article explored the potential in the entomopathogenic nematode *Steinernema feltiae* (Renkema et al. 2018) (Appendix 3).

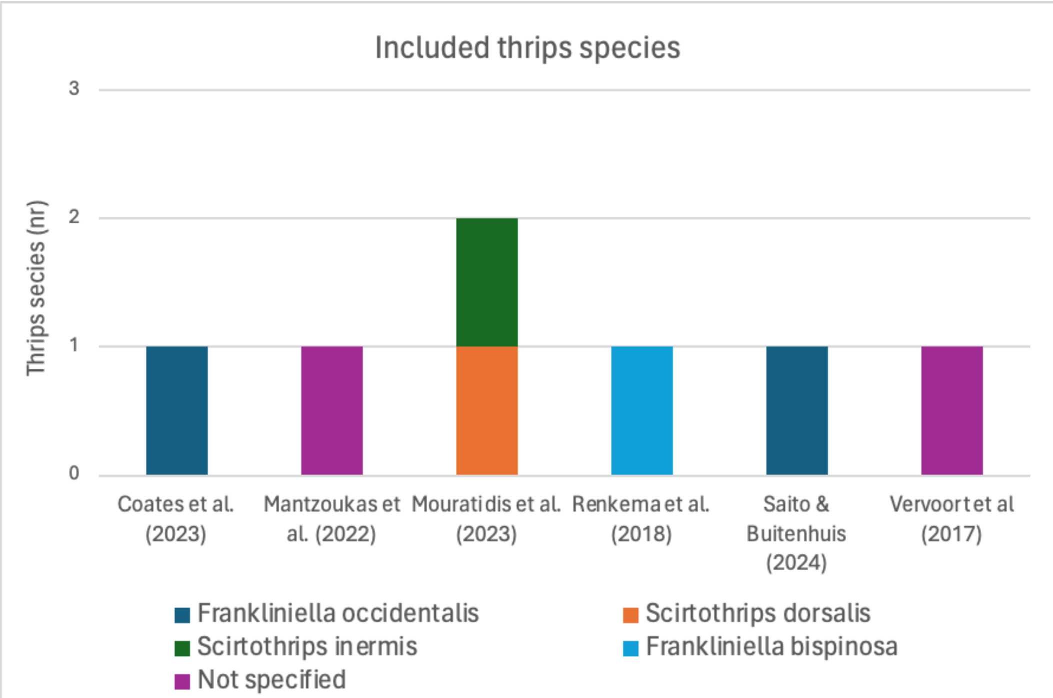


*Figure 4. Thrips species (nr) included in each article covering augmentative biological control (Appendix 3).*

The majority of the articles reported a decrease in thrips infestation using different biocontrol agents (Coated et al. 2023; Mantzoukas et al. 2022; Mouratidis et al. 2023; Saito & Buitenhuis 2024) while one article each reported no change (Rankema et al. 2018) and one reported missing result (Vervoort et al. 2017) (Figure 6; Appendix 3). Regarding the outcome crop damage, three of the articles had a missing result (Coated et al. 2023; Mouratidis et al. 2023; Saito & Buitenhuis 2024), while one reported no change (Renkema et al. 2018) and two articles had mixed results as decrease or no change for each biological control agent (Mantzoukas et al. 2022; Vervoort et al. 2017) (Appendix 3). The biocontrol agents that showed a decreased crop damage was *B. Bassiana* PPRI 5339, *B. Bassiana* AP0101 (Mantzoukas et al. 2022), *Amblydromalus limonicus, Orius laevigatus and Amblyseius swirskii (*Vervoort et al. 2017) (Appendix 3). While most included articles is missing results on yield, one article is reporting positive outcomes on yield by addition of 3 strains of entomopathogenic fungi *B. bassiana* (Mantzoukas et al. 2022) and one article reports no change by addition of the nematode *S. feltiae* (Rankema et al. 2018) (Appendix 3).

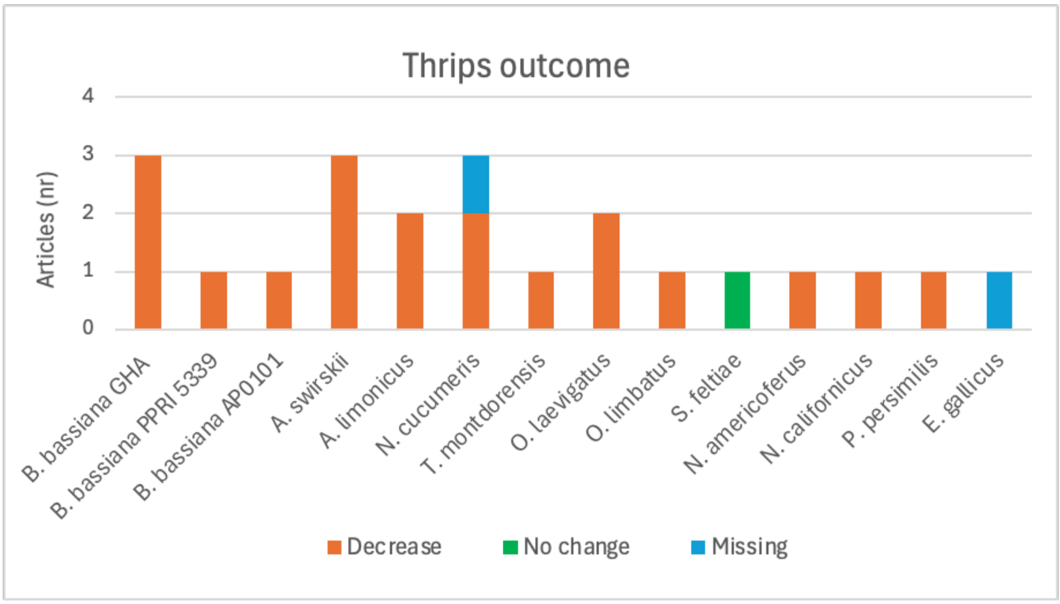


*Figure 5. Outcome on thrips present in strawberry crops presented as increase, decrease, no change or missing by addition of each biocontrol agent covered by included articles (Appendix 3).*

Two of the included articles explored and compared the potential in different predatory mite species to control thrips infestations (Vervoort et al. 2017; Mouratidis et al. 2023). Vervoort et al. (2017) performed trials in multiple strawberry cropping systems in different temperatures aiming to enable a more efficient thrips control all year around. The included mite species in the first article were *Euseius gallicus*, *Neoseiulus cucumeris*, *Amblydromalus limonicus* and *Amblyseius swirskii*, in addition, they also combined some mites species with *Orius laevigatus* (Vervoort et al. 2017). The authors first performed cage trials in different temperatures to discover which predatory mite species gave the best thrip control followed by greenhouse and open-field trials. The conclusion was that *Amblydromalus limonicus*, *Amblyseius swirskii* and *Orius laevigatus* decreased the number of thrips and damage on strawberry crops significantly. The results also reveal that *Amblydromalus limonicus* controls thrips best in mild conditions (T 18:10°C, RV 70:80%, DL 12:12h) while *Amblyseius swirskii* was able to control thrips most efficiently in warmer conditions.

Similar results were obtained from Mouratidis et al. (2023) which compared predation and oviposition on larval stages on the two *scirtothrips* species *S. dorsalis* and *S. inermis. Amblydromalus limonicus and Amblyseius swirskii* managed to increase their population size fastest by increasing oviposition rate and thus, fed more thrips and reduced the population faster. The included species in the second article were *A. swirskii, A. limonicus, N. cucumeris, Transeius montdorensis, O. laevigatus* and *O. limbatus* were all predators reduced the presence of *S. inermis* in a trial in a glass greenhouse strawberry cropping system. In comparison with vervoort et al. (2017), Mouratidis et al. (2023) did not evaluate the quality and yield of the strawberry plants.

In similarity to Vervoort et al. (2017) and Mouratidis et al. (2023), the third article (Saito & Buitenhuis 2024) were also looking into predatory mites to control *Frankliniella occidentalis*. In addition, they explore the potential in the damsel bug *Nabis Americoferus* and its intra-guild predation between biological control agents consisting of predatory mites and the fungi *B. bassiana* GHA strain which is currently used in biological control programs in strawberry crops in Canada. The study was performed in laboratory and greenhouse cage trials. The laboratory trial revealed that *N. americoferus* was compatible with *Phytoseiulus persimilis* and *A. swirskii* in combination with complimentary food by placing out frozen butterfly eggs from *Ephestia Kuehniella* while it was not compatible with the fungi *B. bassiana* GHA. In the greenhouse cage trial, they release *N. americoferus* on one banker plant (barley) in addition to *N. cucumeris* and *N. californicus.* The aim of the greenhouse trial was to find and improve the current biological control program during the winter month, as it is a challenge to sustain the predator populations in accordance with Vervoort et al. (2017). The main findings were that the repeated dosage of predator mites' sachets could be reduced by half in combination with *N. americoferus* and provide a better control of *Frankliniella occidentalis* compared to using only predatory mites. This is an economic implication to mix and use different predators together to control thrips infestation in greenhouse strawberry crops (Saito & Buitenhuis 2024).

Furthermore the authors (Vervoort et al. 2017) highlights the importance of monitoring present pests and beneficials in order to create an efficient IPM program to control multiple pests and promote beneficials. The introduction of one species can give multiple outcomes for the population's dynamics and intra-guild predation which should be considered by farmers before implementing a combined biological control strategy. They also highlight that it's important to choose species that can quickly colonize to reduce damage on crops. The success story behind Amblydromalus limonicus can be explained by its ability to feed on two larval stages of thrips and its ability for quick colonization. The conditions the beneficial is thriving and which pests or other beneficials that are affected should be considered for combining pest control to prevent any unforeseen negative outcomes (Vervoort et al. 2017).

Another article Mantzoukas et al. (2022) discovered a decrease in thrips infestation on open-field strawberry crops by inoculation of two different commercially available strains (GHA (Botanigard) and PPRI 5339 (Velifer® ES) and one wild isolated strain AP0101 of the fungal endophytes *Beauveria bassiana* (Hypocreales: Cordycipitaceae) found in Greece. The effect by colonization of all strains of *B. bassiana* on plant surfaces seems to increase the induced systemic plant response which led to a decrease of thrips compared to the untreated controls. This article highlights the potential in other non-commercially available strains as the local wild strains were most effective to reduce thrips and increase plant growth. Endophytic fungi strains target the pest in a multidimensional way and acts both as an endophyte, entomopathogen and as a promoter of plant growth which makes them one of the most promising available biocontrol agents (Mantzoukas et al. 2022). The authors encourage more research in the field to be able to meet the goal of increasing organic farming from 8- 25% and reduce the use of pesticide by 2030 according to the `green deal´ in the European union.

The second article exploring entomopathogens is looking into how the release of conidia from *Beauveria bassiana* GHA by apivectoring effects thrips infestation in greenhouse strawberry crops (Coated et al. 2023). In accordance with Mantzoukas et al. (2022), this strain could decrease naturally occurring thrips where 75% of *Frankliniella occidentalis* thrips were infected of the fungus *B. bassiana*.

Since biological control strategies of thrips in open-field cultivation is a challenge due to lack of efficient methods to spread the biological control agent (Pålsson[10] 2025), Coated et al. (2023) provides a promising result by utilizing bumblebees to spread the biological control agents more efficiently. However, this study is focusing on strawberry cropping systems in greenhouses and not open-field which implies that more research is needed in biological control of thrips in open-field cropping systems. Another challenge that Coated et al. (2023) also are highlighting is the difficulty to distribute *B. Bassiana* evenly in the crop as most inoculum is found near the bumblebee hives.

The last article explores the potential of the nematode *Steinernema feltiae* as a biological control agent and its ability to control thrips infestation compared to two insecticides, Spinetoram and Sulfoxaflor (Vervoort et al. 2017). The outcome was that *S. feltiae* did not reduce numbers of thrips on strawberry plants or crop damage in comparison to the control treated with water and the two insecticides. The authors conclude that hot and dry climate conditions most likely limited the survival of the nematode *S. feltiae* in these trials (Vervoort et al. 2017).

[10] Pålsson, conversation 2025-04-11

# 6. Discussion

## 6.1 Efficacy of conservation biological control strategies

The results from the literature review show varied outcomes regarding effectiveness of conservation biological control strategies to reduce thrips infestation in strawberry cropping systems. A reduction of thrips seems to be possible to overcome by various mechanisms by implementing companion plants beside the crop with repelling or attracting effects on pests and natural enemies. However, while two of the articles covering conservation biological control strategies revealed a decrease of thrips in strawberry crops (Busuulwa et al. 2024; Koller et al. 2024), two articles did not measure outcomes on thrips number in the strawberry crop (Alhmedi et al. 2024; Gugole Ottaviano et al. 2015). Furthermore, one of the articles revealed an increase of thrips on *C. Cyanus* and *H. annuus* included in a flower strip which could be a result worth noting for improving future biological control strategies with flower strips (Alhmedi et al. 2024). While some plant species as *C. Cyanus* can attract pests as thrips, others can repel as one article demonstrated with ornamental pepper which seems to be a promising companion plant to reduce thrips by its pest repelling effects explained by its high content of capsaicinoids and capsaicin (Busuulwa et al. 2024). Whether ornamental pepper could be suitable as a repelling companion plant in protected and open-field strawberry cropping systems in other countries and areas, should be further explored.

Two of the articles exploring *L. maritima* for its potential beneficial effect in reducing thrips revealed mixed results (Busuulwa et al. 2024; Koller et al. 2024). One article reveals that *L. maritima* reduced thrips in strawberry crops by attracting thrips and its potential as a trap crop (Koller et al. 2024) while the other article gave no change on thrips in strawberry crops (Busuulwa et al. 2024). The authors argue the possibility that *L. maritima* attracted other prey than thrips that was preferable for the predators which could be an explanation for the outcome (Busuulwa et al. 2024). Another explanation is that the complexity and coverage of surrounding landscape potentially hosted thrips to a greater extent compared to natural enemies (Doehler et al. 2023). Other research confirms that plant composition in combination with land cover composition has the primary impacts on present arthropod composition which could explain the mixed result in the articles of the presence of thrips in strawberry crops (Tobisch et al. 2023). This is an implication that landscape analysis should be done before implementing conservation biological control strategies even for protected cropping systems such as greenhouse and tunnels as there is normally an influx of arthropods even in protected cropping systems (Doehler et al. 2023). Doehler et al. (2023) also highlights the importance of identification of present thrips species as not all species act as a pest and feed on the crop. In addition, identification of thrips species in future studies of conservation biocontrol strategies is preferable to improve comparability between articles made in different countries and geographic areas, as thrips populations may vary widely depending on climate, area, trade of plants and influx of new exotic species etc.

Few studies in conservation biological control strategies are measuring yield as an outcome while the majority is focusing on the presence of thrips and natural enemies in flowering plants and on strawberry crop. However, one of the articles using *L. maritima* and ornamental pepper as a companion plant gave no change in yield. Important to note, is that the comparison for this result is made between the control treated with fertilizers, fungicides, and herbicides and that higher yields were obtained for crops treated with the insecticide spinetoram (Busuulwa et al. 2023). Another outcome is `crop damage´ which also gave a mixed result as not all included articles collected data for crop damage. It is important to note that changes in crop damage are not always correlating with the presence of thrips in crops or in adjacent companion plants which is the case for *L. maritima* in both articles (Busuulwa et al. 2023; Koller et al. 2023). However, one of the companion plants gave positive correlations between the presence of thrips and natural enemies regarding crop damage which was the case for ornamental pepper (Busuulwa et al. 2023).

Another general disadvantage which is raised by two of the included articles is the concerns of increased production costs by managing and implementing conservation biological control strategies such as intercropping flower strips and banker plants (Alhmedi et al. 2024; Busuulwa et al. 2023). The knowledge about to what extent and what distance from flower strips that is positively affected when it comes to yield is still not clear (Albrecht et al. 2020). Previous research is highlighting the need for designing schemes for spatial placement of flower strips (Garibaldi et al. 2011) and to facilitate cost- benefit assessments as an important improvement to decrease the barrier for farmers to implement flower trips as a biocontrol strategy (Blaauw & Isaacs 2014).

## 6.2 Efficacy of Augmentative biological control strategies

The results from the literature review gave varied outcomes regarding effectiveness of reducing thrips by augmentative biological control strategies whereas a majority of the articles reported a decrease of thrips in strawberry crops. When it comes to choosing a biocontrol agent, there are many factors to be considered before implementation, which biocontrol agents that are available and approved on the market, specific demands on temperature and humidity and potential risks of intra-guild predation when combining several biocontrol agents together to improve the effect as pest control.

Saito & Buitenhuis (2024) reported an improved biocontrol effect of *Frankliniella occidentalis* by combining *Nabis americoferus* with a reduction of predatory mites *N. cucumeris* and *N. californicus*. As *Nabis americoferus* is a species found in central and North America, there are several other species in the family Nabidae with similar behaviour holding potential as a biocontrol agent as it exists globally (Saito et al. 2023). Regarding biocontrol agents in Sweden, several species of predatory mites and the minute pirate bug are commonly used in greenhouses as *Orius majusculus, N. cucumeris* and *A. swirskii* (Pålsson[11] 2025). Hence, it´s an implication to explore native species included in the family Nabidae for its potential as augmentative biocontrol agent in greenhouse settings in other countries.

It's important to point out that Coated et al. (2023) are using *Bombus impatiens* for disperse of *B. bassiana,* which is a bumblebee species that does not exist in Sweden. Hence, it would be interesting to explore the ability of apivectoring of other arthropods to facilitate the spread of biological control agents as *B. bassiana to* control thrips and other pests in larger areas in open-field conditions in Sweden. It should also be considered that the conidia from *B. bassiana* can also be spread by the wind which is another challenge that remains unsolved to offer an efficient and reliable solution of this type of biological control agents for a controlled and evenly distribution in open-field settings (Coated et al. 2023).

Furthermore, Pålsson[12] (2025) and Rännbäck[13](2025) confirms that harvest of nearby thrips attracting crops in Sweden as ley, has a high impact on influx of thrips in nearby strawberry crops. Augmentative biological control strategies should therefore be implemented in a preventative purpose before harvest to increase the growth and colonization of *Orius majusculus* or other biocontrol agent as thrips outbreak is expected at harvest of nearby ley.

[11] Pålsson, conversation 2025-04-11
[12] Pålsson, conversation 2025-04-11
[13] Rännbäck, Conversation 2025-04-16

# 7. Conclusions

The aim of this thesis was to explore which biocontrol strategies have been shown to be effective in reducing thrips infestations in greenhouse and open- field strawberry crops.

Regarding augmentative biological control strategies, the result reveals twelve different biocontrol agents that significantly reduced thrips in open-field and protected strawberry cropping systems consisting of predatory mites, the minute pirate bug (*Orius* spp.), damsel bugs (*N. americoferus)* and entomopathogenic fungi *B. bassiana.* Regarding conservation biological control strategies, some key plants species was identified for the potential as companion plants to increase the presence of natural enemies and decrease crop damage including ornamental pepper (*Capsicum annuum* L.) and sweet alyssum (*Lobularia maritima)*. Pollen from wild plants has shown to benefit predatory mites which could be a result of importance for development of effective conservation biological control strategies in open- field crops. What role the landscape structure possesses to promote the presence of natural enemies is another knowledge gap of importance for development of conservation biological control strategies in the future. Other identified knowledge gaps where outcome measurements on yield, which is wanted in future research to increase the incentives for Swedish farmers to implement conservation biocontrol strategies. Other identified knowledge gaps is the current lack of solutions enabling effective application of biocontrol agents in open- field crops and the cost- benefits of implementing flower strips and companion plants for Swedish farmers.

Due to climate change impact and increasing temperatures, resistance among thrips and trade of plants in the world, thrips is expected to become a growing issue in Swedish strawberry crops. Since tunnel cultivation are increasing in Sweden, there are high incentives to further development of augmentative biocontrol strategies. This strategy can be combined with conservation biocontrol strategies such as companion plants or to spread pollen to sustain predators to optimize the cost- benefits for farmers. In addition, a combined biocontrol strategy holds tremendous potential for open-field crops to reduce the negative impacts from synthetic insecticides on the ecosystems and human health.

The findings from this literature review highlights some key research areas for development of biocontrol strategies for managing thrips in open-field and protected strawberry cropping systems in Sweden. The review offers a summary of the most updated scientific findings and can be used as a guidance for researchers, farmers and advisors who seeks sustainable alternatives for pest control of thrips in strawberry crops.

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# Appendix 1

An overview of analysed articles including country, year of publication, targeted cropping system, included strawberry variety and biological control (BC) strategy divided into Natural (NBC)- conservation (CBC)- and augmentative biological control (ABC) and method/ mechanism used for enhancement/ spreading of the biological control agent.

| Article | Country | Year | System | Variety | BC strategy | Method |
|---|---|---|---|---|---|---|
| **Alhmedi et al. (2024)** | Belgium | 2024 | Open- field | Missing | CBC | Commercial Flowerstrip |
| **Busuulwa et al. (2024)** | USA | 2024 | Open- field | Florida Brilliance | CBC | Bankerplant |
| **Coated et al. (2023)** | Canada | 2023 | Greenhouse | Sanadrian and Albion | ABC | Release of *B. bassiana* by apivectoring |
| **Doehler et al. (2023)** | France | 2023 | Plastic- & glass greenhouses, open and closed high tunnels with and without insect-proof nets | Missing | NBC | Landscape analysis |
| **Gugole et al. (2025)** | Argentina | 2015 | Low plastic tunnel | Missing | CBC | Wild Flowerstrip |
| **Koller et al. (2024)** | Switzerland | 2024 | greenhouse & tunnel | Missing | CBC | Banker plant |
| **Mantzoukas et al. (2022)** | Greece | 2022 | Open- field | Fortuna | ABC | Release of *B. bassiana* |
| **Mouratidis et al. (2023)** | Spain | 2023 | Greenhouse | Portola | ABC | Release of arthropods |
| **Renkema et al. (2018)** | USA | 2018 | Open- field | Radiance | ABC | Release of arthropods |
| **Saito & Buitenhuis (2024)** | Canada | 2024 | Laboratory & Greenhous | Albion | ABC | Release of arthropods |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Vervoort et al (2017)** | Belgium | 2017 | Cage trials in open air, Glass greenhouse, plastic greenhouse & Plastic tunnel and trials without cage in glass greenhouses | Elsanta & Clery | ABC | Release of predatory mite species in different climate conditions |

# Appendix 2

Overview of main plants of interest and outcomes from each article with significant results with on present thrips and/ or predator (nr) on strawberry plants or on non-crop plants when strawberry crop is missing in the article. Crop damage and yield were recorded as increase, decrease, no change compared with controls or missing.

| Article | Thrips specie | Predator | Plants | Thrips outcome | Predator outcome | Crop damage | Yield |
|---|---|---|---|---|---|---|---|
| **Alhmedi et al. (2024)** | Missing | | *C. cyanus* & *H. annuus* | Increase | Missing | Missing | Missing |
| | | Orius spp. nymphs & adults | *C. cyanus* & *E. vulgare* | Missing | Increase | | |
| | | Ladybirds | *C. album* & *C. cyanus* | | | | |
| | | Hoverflies offspring | *C. album* & *C. cyanus* | | | | |
| | | Lacewings offspring | *E. vulgare* & *C. cyanus* | | | | |
| | | Parasitoid mummies | *C. album* *C. officinalis* | | | | |
| **Busuulwa et al. (2024)** | *Scirtothrips dorsalis* | Orius spp. & Geocoris spp. | *Capsicum annuum L.* (ornamental pepper) | Decrease In strawberry | Increase on banker plant | Decrease | No change |
| | | | *Lobularia maritima (Sweet alyssum)* | No change on strawberr. | | Increase | |
| **Gugole Ottaviano et al. (2015)** | Missing | *Neoseiulus californicus* | *Urtica urens, Lamium amplexicaule, Convolvulus arvensis, Sonchus oleraceous, Galega officinalis &* | Missing | Increase | Missing | Missing |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Fragaria x ananassa* | | | | |
| **Koller et al. (2024)** | Missing | *Orius laevigatus* & *Macrolophus pygmaeus* | *L. maritima* | Decrease on crop, Increase on *L. maritima* | Increase on *L. maritima* | No change | Missing |

# Appendix 3

Overview of included thrips species, biological control agents (BCA) and outcomes on the number (nr) of thrips and crop damage recorded as increase, decrease, no change or missing.

| Article | Thrips | BCA | Thrips (nr) | Crop damage | Yield |
|---|---|---|---|---|---|
| **Coated et al. (2023)** | *Frankliniella occidentalis* | *Beauveria bassiana* GHA | Decrease | Missing | Missing |
| **Mantzoukas et al. (2022)** | Not specified | *B. bassiana* GHA | Decrease | No change | Increase |
| | | *B. bassiana* PPRI 5339 (Velifer® ES) | Decrease | Decrease | |
| | | *B. bassiana* AP0101 | Decrease | Decrease | |
| **Mouratidis et al. (2023)** | *Scirtothrips dorsalis* & *Scirtothrips inermis* | *Amblyseius swirskii* | Decrease of both thrips? | Missing | Missing |
| | | *Amlydromalus limonicus* | | | |
| | | *Neoseiulus cucumeris* | | | |
| | | *Transeius montdorensis* | | | |
| | | *Orius laevigatus* | | | |
| | | *Orius limbatus* | | | |
| **Renkema et al. (2018)** | *Frankliniella bispinosa* | *Steinernema feltiae* | No change | No change | No change |
| **Saito & Buitenhuis (2024)** | *Frankliniella occidentalis* | *Nabis americoferus* | Decrease | Missing | Missing |
| | | *Neoseiulus cucumeris* | | | |
| | | *Neoseiulus californicus* | | | |
| | | *Phytoseiulus persimilis* | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | *Amblyseius swirskii* | | | |
| | | *B. bassiana* GHA | | | |
| **Vervoort et al. (2017)** | Not specified | *Euseius gallicus* | Missing | Missing | Missing |
| | | *Amblydromalus limonicus* | Decrease | Decrease | |
| | | *Orius laevigatus* | Decrease | Decrease | |
| | | *Neoseiulus cucumeris* | Missing | No change | |
| | | *Amblyseius swirskii* | Decrease | Decrease | |

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☒ JA, jag, Josefin Mebius har läst och godkänner avtalet för publicering samt den personuppgiftsbehandling som sker i samband med detta

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