Predators and Parasitoids-in-First: From Inundative Releases to Preventative Biological Control in Greenhouse Crops

Juliette Pijnakker*, Dominiek Vangansbeke, Marcus Duarte, Rob Moerkens and Felix L. Wäckers

R&D Department, Biobest Group NV, Westerlo, Belgium

Repeated mass introductions of natural enemies have been widely used as a biological control strategy in greenhouse systems when the resident population of natural enemies is insufficient to suppress the pests. As an alternative strategy, supporting the establishment and population development of beneficiaries can be more effective and economical. The preventative establishment of predators and parasitoids, before the arrival of pests, has become a key element to the success of biological control programs. This “Predators and parasitoids-in-first” strategy is used both in Inoculative Biological Control (IBC), and in Conservation Biological Control (CBC). Here, we provide an overview of tools used to boost resident populations of biocontrol agents.

Keywords: biological control, conservation, standing army, bodyguards, predators, factitious prey, pollen, nectar

INTRODUCTION

Biological control in greenhouses dates back almost 100 years, when Speyer (1927) at the Cheshunt Experimental Station first described the control of greenhouse whitefly Trialeurodes vaporariorum (Westwood) by the specialist parasitoid Encarsia formosa Gahan (Hussey et al., 1969). This example was followed in the fifties by the use of the natural enemies against mealybugs (Doutt, 1951) and in the sixties, by the introductions of the specialist predatory mite Phytoseiulus persimilis Athias-Henriot for the control of spider mites (Bravenboer and Dosse, 1962). Biological control in greenhouses has since been extended by the addition of generalist biocontrol agents to complement the specialist beneficials (Janssen and Sabelis, 2015). The release of generalists, that can feed on a range of prey, but may also exploit non-prey food, made it possible to maintain populations of natural enemies in crops in absence of the target pest, thus facilitating the preventative use of natural enemies.

Thirty years ago, Ramakers (1990) proposed the concept of “predator-in-first” and stated that the availability of supplementary foods, such as pollen and nectar, is essential for early establishment of generalist natural enemies. However, many cropping systems lack these floral resources (Wäckers et al., 2005). As a result, most biological control programmes rely on inundative release strategies, where natural enemies are periodically introduced in large numbers to control pest problems (Stinner, 1977; Van Lenteren et al., 2003; Collier and Van Steenwyk, 2004). The pest control in inundative strategies often relies on the released individuals, rather than their progeny (De Bach, 1964). In ornamentals especially, cheap predators and parasitoids are released weekly in crops without necessarily accomplishing establishment (Hoddle et al., 1997, 1998; Buitenhuis et al., 2014, 2015). Manual and automatized blowers of beneficials have been specially designed for that purpose.
Inundative biological control strategies have among others the drawback to exclude more costly, but more efficient natural enemies, like predatory bugs. In recent years, there has been an increased interest in strategies to allow a preventative establishment of natural enemies (standing army) (Messelink et al., 2014; Pijnakker et al., 2017). Both Inoculative Biological Control (IBC), which aims at establishing mass-reared natural enemies, and Conservation Biological Control (CBC), that seeks to conserve or enhance naturally occurring biocontrol organisms, can benefit by providing natural enemies with missing resources (Hagen, 1986; Zemek and Prenerová, 1997; Wäckers, 2005). In biological control programs substantial advancements have been made in the use of factitious prey, pollen (extrafloral) nectar, and honeydew as food supplements (Van Rijn et al., 2002; Wäckers et al., 2005; Lundgren, 2009; Messelink et al., 2014). In addition, some predators can feed on plant tissues, which facilitates their establishment in periods of prey scarcity or in the absence of prey (Euibanks and Denno, 1999; Lucas and Alomar, 2001; Pappas et al., 2017). Besides the role of non-prey food, establishment of predators can also be supported through the provisioning of additional non-food resources, like shelter and oviposition sites (Messelink et al., 2014; Pekas and Wäckers, 2017). The advances in the use of supplementary resources to support early establishment of natural enemies in greenhouse crops are the focus of this review. Microbial control is not developed in this review, as preventative use of insect-pathogenic and antagonistic fungi is complex, there are few studies and results are inconsistent (Elliot et al., 2000).

**PLANT-TISSUE FEEDING**

While plant feeding by omnivorous biocontrol organisms can potentially cause plant damage (see below), using tissue-feeding omnivores as biological control agents has many advantages. They have been traditionally underestimated in inundative release biocontrol strategies (Castañé et al., 2011); however, several recent studies emphasize its importance (Coll and Guershon, 2002; Euibanks and Styrsky, 2005; Wäckers et al., 2005; Castañé et al., 2011; Pappas et al., 2017). Plant-tissue feeding plays a major role in the survival of several omnivores, as it has been shown to occur broadly in heteropterans (Ridgway and Jones, 1968; Naranjo and Gibson, 1996), as well as in a number of phytoseid mites (Tanigoshi et al., 1993). In Heteroptera it provides nutrients that are essential to successful development (Gillespie and McGregor, 2000; Sinia et al., 2004) and may help them persist in periods of drought. Plant-tissue feeding is also assumed to provide some crucial resources that facilitate prey consumption. When consuming prey, some predatory Heteroptera require a source of water to dilute the digestive enzymes they inject into their prey (Cohen, 1985). Plant-tissue feeding may allow the Heteroptera to balance nutrients, proteins, carbohydrates, vitamins and minerals that would otherwise be restricted in a carnivorous diet (Polis et al., 1989; Coll, 1998). Particular plant species allow a full development of omnivorous Heteroptera in absence of prey. As omnivores can rely on tissue feeding, the risk of dying or leaving the crop at low prey densities is probably limited (Crawley, 1975; Pimm and Lawton, 1978), but will depend on the plant species.

While the induction of plant resistance mechanisms in response to herbivore feeding has been widely studied, few studies have addressed the effect of plant-tissue feeding by omnivore natural enemies in terms of plant defense induction (Stout et al., 1997; Agrawal et al., 1999; Agrawal and Klein, 2000; Agrawal, 2005a,b; Pappas et al., 2017). Induced plant resistance mechanisms include the production of secondary metabolites, part of which are released as volatile chemicals (Herbivore-induced plant volatiles, HIPVs) (Paré and Tumlinson, 1999). HIPV’s play an important role in protecting the damage sites against entry by pathogens. The induced change in plant chemistry can reduce plant attractiveness to herbivores, as well as herbivore performance (Turlings et al., 1990, Bolter et al., 1997; Karban and Baldwin, 1997; De Moraes et al., 2001; Kalberer et al., 2001; Wakefield et al., 2005), thus representing an important example of direct plant defense. An indirect defense mechanism is involved when HIPV’s are used by the herbivore’s natural enemies to locate their prey/hosts (Turlings and Wäckers, 2004). In addition, plant-tissue feeding also elicits the production of extrafloral nectar, an indirect defensive trait which allows plants to recruit ants and other nectar feeding omnivores, which in turn protect the plants by attacking the herbivores (Wäckers and Bonifay, 2004; Kost and Heil, 2005). Several studies have now demonstrated that plant-tissue feeding by predators also activates plant defense mechanisms (Pérez-Hedo et al., 2015a,b; Naselli et al., 2016; Pappas et al., 2016; Zhang et al., 2018). Plants with activated defense systems are less attractive to the tobacco whitefly Bemisia tabaci (Gennadius), but more attractive to the whitefly parasitoid E. formosa. Pappas et al. (2015) showed that the zoophytophagous predator Macrolophus pygmaeus Rambur induces defense of tomato plants, making them less susceptible to the two-spotted spider mite Tetranychus urticae Koch, but without affecting the greenhouse whitefly T. vaporariorum. Zhang et al. (2018) demonstrated that T. urticae and Western flower thrips Frankliniella occidentalis (Pergande) laid fewer eggs on sweet pepper plants previously inoculated with M. pygmaeus. As this also applied to newly produced leaves, which were not directly exposed to the omnivore, this suggests that the induced plant response is systemic. The development time of F. occidentalis larvae feeding on leaves previously exposed to M. pygmaeus was also prolonged.

The introduction of omnivores as biological control agents can create complex interactions. The ability of omnivores to feed on multiple trophic levels may not improve biological control. The possible benefits of plant-tissue feeding are omnivore specific and dependent on the developmental stage, prey availability and plant nutritional composition (Naranjo and Gibson, 1996). The complexity of food choice by omnivores remains poorly understood: in some cases, prey consumption is reduced when both prey and plant diets are available (Crum et al., 1998, Kiman and Yeargan, 1985, Weiser and Stamp, 1998). Feeding on high-quality plant food may provide a highly nutritious preferred food source and decrease the consumption of a particular prey species (Abrams, 1987). Omnivorous bugs consumed fewer prey.
on plants presenting lima bean pods in a study by Eubanks and Denno (1999). Plant-tissue feeding often facilitates survival rather than reproduction probably because of low nitrogen contents (De Clercq and Degheele, 1992). Population dynamics can be strongly influenced by the developmental stage (Coll and Guershon, 2002), the period of phytophagy of the omnivores (Cisneros and Rosenheim, 1997) or by the competition for plant food between omnivores and prey (Polis and Holt, 1992; Coll and Izraylevich, 1997).

Concerning the impact of induced changes in host plant chemistry on pests and beneficials, Ode (2006) underlined that this aspect has been insufficiently explored and reviewed negative tritrophic effects of inducible plant defenses on natural enemies. In a study by Agrawal et al. (2002), predatory mites were less attracted to plants that produced cucurbitacins than cucurbitacin-free plants and had a reduced fecundity when feeding on herbivores that feed on defended plants when compared to those that fed on plants free of cucurbitacins. Induced plant resistance is thus not always favorable to biological control.

Using phytophagous beneficials also has the consequence that their plant feeding exposes them to systemic pesticides (Coll, 1998; Smith and Krischik, 1999, Arnó and Gábarra, 2011; Prabhaker et al., 2011; Put et al., 2015). Plant feeding by omnivores can also result in crop damage or reduced crop growth, in particular at high omnivore populations. Omnivores can cause direct mechanical feeding injuries, injuries to plant vascular tissues or damage through the salivary enzymes killing plant cells (Castañé et al., 2011). Plant-tissue feeding heteropterans can also disturb plant hormonal balances (Zhang et al., 2018). In tomatoes, fruit damage by heteropterans is often reported, reflecting a preference for the more nutritious tomato fruit (Salamero et al., 1987; Alomar et al., 1991; Lucas and Alomar, 2002; Albajes et al., 2006; Castañé et al., 2011). Nesidiocoris tenuis (Reuter) is known to cause injuries on the aerial parts of tomato plants (necrotic rings on stems, shoots, leaf petioles and flower stalks), leading to flowers and fruits abortion, and, reduced growth (Arnó et al., 2010). Gillespie et al. (2007) reported damage on gerbera flowers, Castañé et al. (2003) and Sengonça et al. (2003) on cucumber and zucchini fruit.

Despite the above negative aspects, omnivores are crucial elements in biological control strategies, especially mirids in tomato crops and anthocorids in sweet pepper crops. Current biological control programmes are supported with different tools like smart-phone applications to register and follow crop injuries and sticky traps to monitor omnivores and the pests. This allows growers to maximize benefits of omnivores and avoid risks. Omnivorous predators are commonly used in greenhouse crops and their establishment is even stimulated by provision of alternative food (Lenfant et al., 2000; Castañé et al., 2006; Put et al., 2012; Moerkens et al., 2017; Brenard et al., 2019; Sade et al., 2019). Growers try to avoid applications of systemic pesticides, which are not compatible with omnivores. Resistance breeding does not yet take plant suitability for omnivores into account, but this might change as we gain further insights in the complex interactions involving omnivores.

PEST FEEDING (PEST-IN-FIRST)

The “pest-in-first” (PIF) strategy is one of the oldest strategies to allow the establishment of a biocontrol “standing army” in greenhouses. Here an early introduction of natural enemies is combined with a controlled (pre-) release of the pest. This concept can also be used to allow early establishment of specialist natural enemies, which cannot be supported by factitious prey or pollen. One of the first examples of a successful PIF strategy is the release of two-spotted spider mites to reinforce the establishment of the predatory mite *P. persimilis* (Hussey et al., 1965; Gould et al., 1969; Markkula and Tiittanen, 1976; Havelka and Kindlmann, 1984; Waite, 2001; Bolckmans and Tetteroo, 2002). Other pest-in-first strategies have been evaluated, such as the introduction of low numbers of greenhouse whitely *T. vaporariorum* in tomato followed by timed releases of its parasitoid *E. formosa* (Parr et al., 1976). Growers, however, are typically reluctant to release pests due to the risks of causing crop damage (Parr et al., 1976; Stacey, 1977, Starý, 1993). Instead, they prefer to wait until the pest develops naturally before introducing biocontrol, as releasing *P. persimilis* in naturally occurring *T. urticae* hot spots is often cheaper. Alternatively, they opt for calendar introductions of biocontrol agents.

FACTITIOUS PREY

To allow early establishment of generalist predators, growers can use factitious prey (i.e., foods which the predators usually do not encounter in their natural habitat). Some factitious prey, such as eggs of the Mediterranean flour moth, *Ephesia kuehniella* Zeller, decapsulated cysts of the brine shrimp *Artemia* spp. and astigmatid mites (*Hoogerbrugge et al., 2008; Midthassel et al., 2013; Nguyen et al., 2014a; Delisle et al., 2015a; Labbé et al., 2018) can be excellent food sources for a wide range of generalist predators. Studies on these supplemental foods are summarized in Table 1. Some of these factitious prey, especially *E. kuehniella* eggs and astigmatid prey mites, are also used in the commercial production of biological control agents.

Astigmatid Prey Mites

In greenhouses, breeding sachets of *Neoseiulus cucumeris* Athias-Henriot have been developed to allow slow releases of predatory mites in the crop and thus reduce handling costs (Sampson, 1998). These rearing systems consist of predators, astigmatid mites as food and carrier material. They allow for a release of predators for periods up to four (sometimes even eight) weeks. In crops like roses or potted plants, that do not feature pollen, astigmatid prey mites do not establish on the plant, and where pests cannot be tolerated, predatory mite populations cannot build up on the crop and sachets need to be renewed regularly.

In potted plants, the spread of the predatory mites released from the breeding sachet is limited because plants are widely spaced; the majority of the predators remain on the plant, which received the sachet (Buitenhuys et al., 2010, 2014). To tackle these problems, strategies like using one (small) sachet per plant have been developed to provide each plant an open rearing system (Valentin, 2017) or predators and prey are blown over the crop.
TABLE 1 | Examples of facticious prey.

| Factious prey | Category natural enemy | Natural enemy | Source |
|---------------|------------------------|---------------|--------|
| Astigmatids: Carpoglyphus lactis L.; Tyrophagus putrescentiae (Schrank) | Anthocorids | Orosia naivashae (Poppius); Orius tshipoborus (Hesse) | Bernardo et al., 2017; Bonte et al., 2017 |
| Astigmatids: Aleuroglyphus ovatus (Toupet); Austroglycyphagus lukoschusi (Fain); Blomia tropicalis; Carpoglyphus lactis L.; Suidasia medanensis (Oudemans); Tyrophagus cracentiseta Barbosa | Predatory mites | Amblydromalus ilmonicus Garman and McGregor; Amblyseius eharai Amitai and Swirski; Amblyseius tamatavensis Blommers; Amblyseius swirski (Athias-Henriot); Euseius scutalis (Athias-Henriot); Ichneumus degenerans (Berlese); Neoseiulus cucumeris (Oudemans) | Zeller |
| Cysts of Artemia spp. | Anthocorids | Orius laevigatus (Fieber); Orius majusculus (Reuter); Orius naivashae (Poppius); Orius strigicolls (Poppius); Orius tshipoborus (Hesse) | Arijs and De Clercq, 2001; De Clercq et al., 2005a; Riudavets et al., 2006; Bonte and De Clercq, 2008; Bonte et al., 2012; Nishimori et al., 2016; Oveja et al., 2016; Sade et al., 2019 |
| Cysts of Artemia spp. | Coccinelli | Harmonia axyridis (Pallas); Coleomegilla maculata (DeGeer) | Tavela and Arzone, 1996; Callebaut et al., 2004; Castañé et al., 2006; Riudavets et al., 2006; Vandekerkhove et al., 2006, 2009; Messelink et al., 2015; Hligers et al., 2016; Oveja et al., 2016; Moerkens et al., 2017; Arvani et al., 2018; Brendan et al., 2018, 2019, 2020; Ghassamzadeh and Gharekhani, 2019; Owaishi et al., 2020 |
| Cysts of Artemia spp. | Mirids | Dicyphus errans (Wolff); Macrolophus pygmaeus Rambur; Nesiocoris tenus (Reuter) | Vantornhout et al., 2004; Oveja et al., 2012; Audenaert et al., 2013; Nguyen et al., 2014b, 2015; Vandekerkhove et al., 2014b,c, 2016a,b; Leman and Messelink, 2015; Su et al., 2019 |
| Sterilized eggs of Ephesia kuehniella Zeller | Anthocorids | Orius spp.; Orius albidippennis Reuter; Orius insidiosus (Say); Orius laevigatus (Fieber); Orius majusculus (Reuter); Orius naivashae (Poppius); Orius niger Wolff; Orius sauteri (Poppus); Orius strigicolis (Poppius); Orius tshipoborus (Hesse); Orius tristicolor (White) | Salas-Aguilar and Ehler, 1977; Richards, 1992; Tommasini and Nicoli, 1993; Chyzik et al., 1995; Richards and Schmidt, 1995; Schmidt et al., 1995; Cocuzzza et al., 1997; Arijs and De Clercq, 2001, 2004; Van Lenteren and Tommasini, 2003; De Clercq et al., 2005a; Riudavets et al., 2006; Ferkovich et al., 2007; Bonte and De Clercq, 2008; Yano et al., 2009; Vandekerkhove and De Clercq, 2010; Bonte et al., 2012, 2017; Oveja et al., 2012; Pumarinho and Alomar, 2012, 2014, 2016; Nishimori et al., 2016; Bernardo et al., 2017; Sade et al., 2019 |
| Sterilized eggs of Ephesia kuehniella Zeller | Chrysopids | Chrysoperla carnea (Stephens); Chrysoperla externa (Hagen); Chrysoperla rufilabris (Burmeister) | Zheng et al., 1993; Kathiar et al., 2015; Bezerra et al., 2017 |
| Sterilized eggs of Ephesia kuehniella Zeller | Coccinelli | Adalia bipunctata L.; Coleomegilla maculata DeGeer; Cryptolaemus montrouzieri Mulsant; Harmonia axyridis (Pallas) | Hongo and Obayashi, 1997; De Clercq et al., 2005b; Berkvens et al., 2007; Riddick, 2009; Attia et al., 2011; Maes et al., 2014; Riddick and Wu, 2015 |
| Sterilized eggs of Ephesia kuehniella Zeller | Mirids | Campyloneuroseris infirmata (Carvalho); Dicyphus errans (Wolff); Dicyphus hesperus Knight; Dicyphus tamaninii Wagner; Ectypus varians (Distant); Macrolophus basicornis (Stål); Macrolophus pygmaeus Rambur; Nesiocoris tenus (Reuter) | Fauvel et al., 1987; Grenier et al., 1989; Constant et al., 1996; Tavela and Arzone, 1996; Gillespie and McGregor, 2000; Iriarte and Castañé, 2001; Sanchez et al., 2003, 2004; Callebaut et al., 2004; Castañé and Zapata, 2005; Messelink et al., 2005; Alomar et al., 2006; Castañé et al., 2006; Riudavets et al., 2006; Vandekerkhove et al., 2006, 2009; Oveja et al., 2012; Put et al., 2012; Molla et al., 2014; Van Holstein and Messelink, 2015; Hligers et al., 2016; Perdikis and Arvaniti, 2017; Moerkens et al., 2017; Arvaniti et al., 2018; Brenard et al., 2019; Bueno et al., 2018; Ghassamzadeh and Gharekhani, 2019; Owaishi et al., 2020 |
| Sterilized eggs of Ephesia kuehniella Zeller | Lygids | Geocoris varius (Uhler); Geocoris proteus Distant | Oda and Kadono, 2012; Igarashi and Nomura, 2013 |
| Sterilized eggs of Ephesia kuehniella Zeller | Predatory mites | Amblydromalus ilmonicus Garman and McGregor; Amblyseius swirski (Athias-Henriot); Euseius scutalis (Athias-Henriot); Ichneumus degenerans (Berlese); Neoseiulus barneri (Hughes) | Romeih et al., 2004; Vantornhout et al., 2004; Momen and El-Laithy, 2007; Audenaert et al., 2013; Nguyen et al., 2014a; Vandekerkhove et al., 2014a,b,c; Leman and Messelink, 2015 |
with purpose built automatized blowers. Supplying predatory mites with factitious (astigmatid) prey mites as food has recently gained popularity among growers. The following feeding mites could be used to improve the reproduction and survival of predatory mites: *Tyrophagus putrescentiae* (Schrank) (Pirayeshfar et al., 2020), *Carpoglyphus lactis* (L.) (Nguyen et al., 2013), *Thyreophagus entomophagus* (Laboulbene), *Suidasia medanensis* (Oudemans) (Sánchez et al., 2019), and *Auleuroglyphus ovatus* (Troupeau) (Xia et al., 2012; Ferrero et al., 2016; Rueda-Ramírez et al., 2018). However, very few trials have been performed at plant level (Hoogerbrugge et al., 2008; Vila et al., 2017; Pirayeshfar et al., 2020) and studies on the actual effect of these strategies on pest control are limited. Pirayeshfar et al. (2020) succeeded in increasing *Amblyseius swirskii* Athias-Henriot numbers on chrysanthemum plants by providing living *T. putrescentiae* per plant, but failed to do so using frozen *T. putrescentiae*. Pirayeshfar et al. (2020) suggested that the different diets used to rear the prey mites may have an influence on the population increase of the predatory mites. Nowadays, some growers disperse the astigmatid mites *C. lactis* or *T. entomophagus* to supplement the released predatory mites with food. Ferrero et al. (2016) developed a gel product protecting astigmatid mites’ eggs when they are dispersed, and increasing their shell-life on the crops. This product resulted in high population levels of *A. swirskii* on cucumber plants and a better biological control of sweet potato whitefly than with the use of breeding sachets. Using astigmatid mites as food supplement has the advantage that they are relatively cheap (Ramakers and van Lieburg, 1982; Castagnoli, 1989). The main drawback of mass application of astigmatid mites lies in the fact that they can cause health issues for users including dermatitis, allergies and anaphylaxis (Iglesias-Souto et al., 2009; Fernández-Caldas et al., 2014; Liu and Zhang, 2017; Mullen and O’Connor, 2019; Pirayeshfar et al., 2020). Furthermore, *Tyrophagus spp.* can cause plant damage (Czaikowska et al., 1988; Buxton, 1989; Fischer, 1993; Fan and Zhang, 2007; Yasukawa et al., 2011).

Muñoz-Cárdenas et al. (2017) proposed another approach using astigmatid mites in combination with mulch layers to provide food to crop-inhabiting predatory mites. Prey mites were introduced in the litter to stimulate the predatory mite *A. swirskii* on above-ground plant parts. In cage experiments with rose plants this increased predatory mite numbers 4-fold, as compared to control plants. Thrips control was increased and leaf- and flower damage was reduced as a result. It was shown that *A. swirskii*, which is usually considered to be a leaf-inhabiting species, actually moved between rose foliage and mulch to feed on the astigmatid mites. Similarly, Grosman et al. (2014) increased biocontrol of thrips and whiteflies with *A. swirskii* using mulch layers in different ornamental crops. Adding mulches with, for example bran, yeast or Biotop®, waste product of the potato industry (Grosman and de Groot, 2011), organic matter (Settle et al., 1996; Neves Esteca et al., 2020), animal manure (Navarro-Campos et al., 2012) to boost fungi, decomposers and plankton feeders can increase predators’ population levels. Despite promising results in small-scale experiments, this strategy has not been adopted by growers. This is probably due to the increased labor when mulching, and the fact that the system is often effective on the short term only. Grosman et al. (2014) found that this approach produced predators for up to 6 weeks, which is comparable to the longevity of breeding sachets. These methods carry also the risk that the predators switch from feeding on herbivores to soil organisms (apparent mutualism, Holt, 1977) as reported by Birkhofer et al. (2008), or, are out-competed by other soil predators, that also benefit from the substrate manipulation (Messelink and Van Holstein-Saj, 2007, 2011).

**Mediterranean Flour Moth Eggs**

To support establishment of predatory bugs, growers mainly use eggs of the Mediterranean flour moth *E. kuehniella*. The high nutritional value of *E. kuehniella* eggs ensures development, reproduction and survival of many arthropods (Table 1). In *M. pygmaeus*, higher reproduction rates were found when the mirids were fed on the moth eggs, as compared to whitefly pupae (Fauvel et al., 1987; Alomar et al., 2006). Sprinkling of *E. kuehniella* eggs on crop plants was the first supplemental food strategy widely adopted by growers on a large scale. They are typically used on the points where predatory bugs *Orius* spp. (sweet pepper) and mirid bugs *M. pygmaeus*, *N. tenuis*, and *Tupiocoris cucurbitaceus* (Spinola) (mainly tomato) are introduced (Put et al., 2012; Moerkens et al., 2017; Brenard et al., 2018).

The main factor limiting the use of *E. kuehniella* eggs is their cost, with prices of 400 EUR/kg (Nguyen et al., 2014a). They also need to be kept frozen. Furthermore, the eggs tend to dry out once applied on the crop, or when the relative humidity is too high, they become moldy on the leaves. Due to their cost, *E. kuehniella* eggs are not used to feed predatory mites. However, this food source was found to be suitable for oviposition of *Iphiseius degenerans* (Berlese) (Vantornhout et al., 2004), *A. swirski* and *Amblydromalus limonicus* Garman and McGregor (Nguyen et al., 2014a; Vanganskebe et al., 2014c), *Gaeolaelaps aculeifer* Canestrini and *Stratiolaelaps scimitus* (Womersley) (Navarro-Campos et al., 2016), as well as for the pest *F. occidentalis*. The performance of predatory mites on *E. kuehniella* eggs can vary (Vanganske be et al., 2014c; Leman and Messelink, 2015) depending on egg storage conditions and ambient humidity in the crop. Liu and Zhang (2017) observed that immatures of *A. limonicus* exhibited difficulties to pierce the chorion of *E. kuehniella* eggs that hardened at low ambient humidity.

**Cysts of the Brine Shrimp**

Several cheaper options have been investigated to replace the use of *Ephestia* moth eggs in commercial production as well as in field applications (Table 1). Out of the options tested, the most promising substitute of flour moth eggs for feeding generalist predators was found to be dry cysts of the brine shrimp *Artemia* spp. Having been used widely as fish food, *Artemia* cysts have the advantage that they can be stored for years in dry form, and do not require freezing as required for *E. kuehniella* eggs (Arijs and De Clercq, 2001). They keep their nutritional value longer than *E. kuehniella* eggs when applied on crops (De Clercq et al., 2005a; Messelink et al., 2016; Moerkens et al., 2017), they do not become moldy on plants (Vandekerkhove et al., 2009) and

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**Table 1.** The performance of predatory mites on *E. kuehniella* eggs.

| Predator Type | Food Source | Notes |
|---------------|-------------|-------|
| Orius spp.    | *E. kuehniella* eggs | Sweet pepper |
| *M. pygmaeus* | *E. kuehniella* eggs | Tomato |
| *N. tenuis*   | *E. kuehniella* eggs | Tomato |
| *T. cucurbitaceus* | *E. kuehniella* eggs | Tomato |
| *I. degenerans* | *E. kuehniella* eggs | Berlese |
| *A. swirski* | *E. kuehniella* eggs | Amblydromalus limonicus |
| *A. limonicus* | *E. kuehniella* eggs | Amblydromalus limonicus |

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Nguyen, L., et al. (2014a). *G. aculeifer* Canestrini and *S. scimitus* (Womersley) (Navarro-Campos et al., 2016), as well as for the pest *F. occidentalis*. The performance of predatory mites on *E. kuehniella* eggs can vary (Vanganskebe et al., 2014c; Leman and Messelink, 2015) depending on egg storage conditions and ambient humidity in the crop. Liu and Zhang (2017) observed that immatures of *A. limonicus* exhibited difficulties to pierce the chorion of *E. kuehniella* eggs that hardened at low ambient humidity.

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Several cheaper options have been investigated to replace the use of *Ephestia* moth eggs in commercial production as well as in field applications (Table 1). Out of the options tested, the most promising substitute of flour moth eggs for feeding generalist predators was found to be dry cysts of the brine shrimp *Artemia* spp. Having been used widely as fish food, *Artemia* cysts have the advantage that they can be stored for years in dry form, and do not require freezing as required for *E. kuehniella* eggs (Arijs and De Clercq, 2001). They keep their nutritional value longer than *E. kuehniella* eggs when applied on crops (De Clercq et al., 2005a; Messelink et al., 2016; Moerkens et al., 2017), they do not become moldy on plants (Vandekerkhove et al., 2009) and
are, depending on the quality, up to 30 times cheaper than flour moth eggs (Nguyen et al., 2014a). However, Artemia cysts vary substantially in nutritional quality, and the high quality product is roughly the same price as E. kuehniella eggs. When used at high densities, Artemia cysts can leave a “fishy smell” on the crop. Brine shrimp cysts have been tested as prey for several natural enemies for production purposes (Table 1).

In field crops, Hoogerbrugge et al. (2008) and Leman and Messelink (2015) found either no or poor establishment of A. swirskii when fed with a commercial strain of Artemia sp. cysts alone in a chrysanthemum crop. In contrast, Vantornhout et al. (2004), Nguyen et al. (2014a) and Vangansbeke et al. (2014c, 2016b) showed in laboratory studies complete development of, respectively, I. degenerans, A. swirskii and A. limonius on a diet of decapsulated cysts of a non-commercial Artemia franciscana Kellogg strain. Vangansbeke et al. (2016a) succeeded in establishing A. swirskii on chrysanthemum and ivy plants using this Artemia strain, but not when using a commercial decapsulated Artemia cyst product. Inconsistent results between studies might be explained by the incomplete decapsulation of the cysts or their level of hydration (Castañé et al., 2006) and by the substantial variation in Artemia product quality. De Clercq et al. (2005a) showed differences of composition and nutritional quality between Artemia cysts of diverse origins, which can have an impact on the nutritional value as well (Bloemhard et al., 2018; Sade et al., 2019). Overall, Artemia cysts have become a valuable complement in biological control programs in greenhouse vegetable crops, as most tomato and sweet pepper growers release M. pygmaeus with this alternative food, either by itself or in combination with E. kuehniella.

The provision of brine shrimp cysts and Mediterranean flour moth eggs is now a common practice on introduction points of predatory bugs in vegetable crops. As astigmatid prey mites are concerned, only ornamental growers release them weekly or biweekly, but generally additionally to predatory mites. They tend to use them within their inundative release strategies of predatory mites instead of seeking for an early establishment of predators after a few release. Besides their use to stimulate predatory mites, astigmatid mites might also hold potential to support field populations of predatory bugs, as they were found to be a suitable food source for Orius spp. (El-Husseinak and Sermann, 1992; Husseini et al., 1993; Nagai et al., 1998; Gomaa and Agamy, 2002; Yang et al., 2009; Bernardo et al., 2017; Bonte et al., 2017; Song et al., 2018). This application is still at an experimental stage at growers.

**BANKER PLANT SYSTEMS**

Supplementation of food resources and oviposition places for natural enemies can be done by providing secondary plants, so-called “banker plants” or “open rearing systems” (Bennison, 1992; Bennison and Corless, 1993). The principle of the banker plant system is the use of plants, usually different from the crop, to provide beneficials with alternative (non-pest) prey and/or plant-provided food resources. This method was developed for the introduction of parasitoid wasps to control aphids (Stary, 1969; Lyon, 1973) and whiteflies (Stacey, 1977). The banker plant method is often seen as a further development of the “Pest-in-first” method in greenhouses as the initial banker plant systems introduced additional crop plants carrying the target pest (Table 2) (Parr and Stacey, 1975; Stacey, 1977).

The advantages of using banker plants have been widely described. They aid survival, reproduction and development of naturally occurring or introduced natural enemies even in absence of pests (Pratt and Croft, 2000). When introducing beneficials, they can be released onto the banker plants where they find essential resources for survival and reproduction. Once the target pest appears, they then move from the banker plants into the crop. Successful banker plant systems allow for early season augmentation of beneficials and can replace “repeated inundative releases” (Hansen, 1983) thereby reducing costs (Huang et al., 2011). Furthermore, when using potted banker systems, these banker plants can be moved for “hot spot treatment” of pest colonies (Ramakers and Voet, 1995). When selecting banker plants, one should consider the natural enemies’ affinity for the plant, as well as the plant’s capacity to carry suitable alternative prey or other (food) resources (Jacobson and Croft, 1998; Goolsby and Ciomerluk, 1999). Nutritional, allelochemical and plant morphological traits (Price et al., 1980; Grevstad and Klepetka, 1992, Desneux and Ramirez-Romero, 2009) are taken into account when selecting candidate banker plant-prey combinations. It is known that morphological plant characteristics (e.g., toughness of leaves and stems, number of nectar glands, flowering period, number of flowers, plant pubescence, acarodomatia, trichomes) can be correlated with the dispersal, oviposition, developmental and reproductive success of arthropods (Walter and O’Dowd, 1992a,b; Pfannenstiel and Yeargan, 1998; Lucas and Brodeur, 1999, Lundgren et al., 2008; Parolin et al., 2012a). In addition, banker plants must be capable to survive temperatures and light conditions as the ones used in greenhouse production (Van der Linden, 1992).

Banker plant systems can be divided into two groups: (1) plants providing non-pest prey/host (2) plants producing non-prey food sources (pollen and nectar). Diverse publications provide complete inventories of the banker plant systems and their potential (Osborne et al., 2005; Frank, 2010; Huang et al., 2011; Ying et al., 2012; Miller et al., 2017; Miller, 2018; Payton Miller and Rebek, 2018). An overview of banker plant systems is given in Tables 2–4.

**Banker Plant Systems (Non-pest Prey)**

Most banker plant systems using alternative prey/hosts (Table 3) were designed to control aphids, such as Myzus persicae Sulzer on sweet peppers or Aphis gossypii Glover on cucumbers. Hansen (1983) first evaluated a banker plant system using broad bean infected with Megoura viciea Bucken, to rear Aphidoletes aphidimyza (Rondani). Other banker plant systems consist of sorghum, rye, barley or wheat seedlings infested with cereal aphids which are harmless to greenhouse crops, such as Rhopalosiphum padi Linnaeus, Sitobion avenae Fabricius, Metopolophium dirhodum (Walker), Melanaphis sacchari (Zehntner), or Schizaphis graminum (Rondani) (Kuo-Sell, 1987; Abe et al., 2011; Nagasaka et al., 2011; Yano et al., 2011).
### TABLE 2 | Examples of (pest prey) banker plant systems.

| Banker plant (common name) | Banker plant (Latin name) | Prey/host | Category natural enemy | Natural enemy | Source |
|----------------------------|---------------------------|-----------|------------------------|---------------|--------|
| Borage                    | Borago officinalis L.    | Myzus persicae (Sulzer) | Parasitoids           | Aphidius colemani Viereck | Fujinuma et al., 2010 |
| Bush bean                 | Phaseolus vulgaris L.    | Tetranychus urticae Koch | Mites                | Phytoseius persimilis Athias-Henriot | Matteoni, 2003 |
| Castor bean               | Ricinus communis L.      | Bemisia tabaci (Gennadius) | Parasitoids           | Eretmocerus hayati (Zolnerovich and Rose); Encarsia sophia (Girault and Dodd) | Kidane et al., 2018 |
| Corn                      | Zea mays L.              | Tetranychus urticae Koch | Mites                | Phytoseius persimilis Athias-Henriot | Miller et al., 2017; Miller, 2018 |
| Kidney bean               | Phaseolus vulgaris L.    | Tetranychus urticae Koch | Mites                | Amblyseius fallacis Garman | Lester et al., 2000 |
| Laurustinus               | Viburnum tinus L.        | Tetranychus urticae Koch | Mites                | Neoseiulus californicus (McGregor); Phytoseius persimilis Athias-Henriot | Parolin et al., 2013; Bresch et al., 2015 |
| Melon                     | Cucumis melo L.          | Bemisia tabaci (Gennadius) | Parasitoids           | Encarsia sophia (Girault and Dodd); Eretmocerus spp.; Eretmocerus hayati (Zolnerovich and Rose) | Goolsby and Ciomperlik, 1999; Pickett et al., 2004; Kidane et al., 2018 |
| Pumpkin                   | Cucurbita maxima “Uchiki Kuri” | Trialeurodes vaporariorum Westwood | Parasitoids           | Encarsia tricolor Foélinster | Laurenz and Meyhöfer, 2017 |
| Rhododendron              | Rhododendron sp. “Ana Kruschke” | Oligonychus ilicis (McGregor) and Oligonychus ununguis (Jacobi) | Mites                | Neoseiulus fallacis (Garman) | Pratt and Croft, 2000 |
| Riverbank grape           | Vitis riparia (Michx.)   | Tetranychus urticae Koch | Mites                | Neoseiulus californicus (McGregor); Phytoseius persimilis Athias-Henriot | Parolin et al., 2013; Bresch et al., 2015 |
| Rose                      | Rosa sp.                 | Macrosiphum rosae L. | Parasitoids           | Praon volucre Haliday | Maisonneuve, 2002 |
| Swedes                    | Brassicae napus rapifera Metzg. | Myzus persicae (Sulzer) | Parasitoids           | Ephedrus cerasicola Starý | Hägvar and Hofsvang, 1994 |
| Sweet pepper              | Capsicum annuum L.       | Myzus persicae (Sulzer) | Parasitoids           | Ephedrus cerasicola Starý | Hägvar and Hofsvang, 1979 |
| Sweet pepper              | Capsicum annuum L.       | Aphids     | Parasitoids           | Aphidius colemani Viereck; Aphidius ervi Haliday | Matteoni, 2003 |
| Sweet pepper              | Capsicum annuum L.       | Aphids     | Gall midges           | Aphidoletes aphidimyza (Rondani) | Matteoni, 2003 |
| Tobacco                   | Nicotiana tabacum L.     | Trialeurodes vaporariorum Westwood | Parasitoids           | Encarsia formosa (Gahani) | Schmidt, 1996 |
| Tomato                    | Lycopersicon esculentum Mill. | Trialeurodes vaporariorum Westwood | Parasitoids           | Encarsia formosa (Gahani) | Parr and Stacey, 1975; Stacey, 1977; Rumei, 1991 |
| Watermelon                | Citrullus lanatus (Thunb.) | Bemisia tabaci (Gennadius) | Parasitoids           | Eretmocerus hayati (Zolnerovich and Rose) | Goolsby and Ciomperlik, 1999 |

Parasitoids, such as *Aphidius colemani* Viereck, *Aphidius ervi* Haliday, and *Aphidius matricariae* Haliday, and, the predatory gall midge *A. aphidimyza* can reproduce on these banker plant systems and thus be pre-established once crop aphids appear (Table 3). Abe et al. (2011) succeeded in maintaining *A. aphidimyza* for at least 3 months with such a system. Banker plant systems with non-pest prey used to be broadly implemented (Walters and Hardwick, 2000; Nagasaka and Oya, 2003; Yano, 2006). Some growers produce the banker plants themselves. However, a majority of growers are reluctant to adopt...
### TABLE 3 | Examples of (non-pest prey) banker plant systems.

| Banker plant (common name) | Banker plant (Latin name) | Prey/host | Category natural enemy | Natural enemy | Source |
|----------------------------|---------------------------|-----------|------------------------|---------------|--------|
| Arborvitae                 | Thuja occidentalis L.     | Oligonychus ilicis (McGregor) and Oligonychus ununguis (Jacobi) | Predatory mites | Neoseiulus fallacis (Garman) | Pratt and Croft, 2000 |
| Barley                     | Hordeum vulgare L.        | Rhopalosiphum padl L. | Coccinellids | Scymnus creperus Mulsant | Miller et al., 2017 |
| Barley                     | Hordeum vulgare L.        | Rhopalosiphum padl L. | Gall midges | Aphidoletes aphidimyza (Rondani) | Ramakers and Maaswinkel, 2002; Yano et al., 2009; Nagasaka et al., 2010; Hemenik and Yano, 2012; Higashida et al., 2016; Miller et al., 2017 |
| Barley                     | Hordeum vulgare L.        | Rhopalosiphum padl L. | Parasitoids | Aphidius colemani Viereck; Aphidius matricariae Haliday; Syrphophasus sp.; Alloxysta sp.; nr victrix (Westwood); Dendrocerus laticeps (Hedicke) | Goh et al., 2001; Matsuo, 2003; Nagasaka and Oya, 2003; Ode et al., 2005; Saito, 2005 Van Driesche et al., 2008; Nagasaka et al., 2010, 2011; Jandricic et al., 2014; Prado and Frank, 2014; Miller et al., 2017; Miller, 2018 |
| Barley                     | Hordeum vulgare L.        | Rhopalosiphum padl L. | Parasitoids | Aphidius colemani Viereck; Aphidius gifuensis (Ashmead) | Goh et al., 2001; Ohta and Honda, 2010 |
| Barley                     | Hordeum vulgare L.        | Rhopalosiphum padl L. | Parasitoids | Aphidius gifuensis (Ashmead) | Kim, 2003; Kim and Kim, 2004; Ode et al., 2005; Sun et al., 2017 |
| Barley                     | Hordeum vulgare L.        | Sitobion akebiae (Shinj) | Parasitoids | Aphidius gifuensis (Ashmead) | Ohta and Honda, 2010 |
| Black elder                | Sambucus nigra L.         | Aphis sambuci L. | Syrphids | Several hoverflies species | Briossia et al., 2005; Wojciechowicz-Zytko and Jankowska, 2016 |
| Bluegrass                  | Poa spp.                  | Rhopalosiphum padl L. or Schizaphis graminum (Rondani) | Parasitoids | Lysaphlebus testaceipes (Cresson) | Miller et al., 2017; Miller, 2018 |
| Broad bean                 | Vicia faba L.             | Acyrthosiphon pisum (Harris) | Parasitoids | Aphidius gifuensis (Ashmead) | Ohta and Honda, 2010 |
| Buckwheat                  | Fagopyrum esculentum Moench | Sitobion avenue (Fabricius) | Syrphids | Several hoverflies species | Fischer, 1997 |
| Corn                       | Zea mays L.               | Oligonychus pratensis (Banks) | Gall midges | Feltiella acarsuga (Vallo) | Xiao et al., 2011b |
| Corn                       | Zea mays L.               | Oligonychus pratensis (Banks) | Predatory mites | Amblyseius swirski (Athias-Henriot); Neoseiulus californicus (McGregor); Phytoseiulus persimilis Athias-Henriot | Parker and Popoenoe, 2008; Popoenoe and Osborne, 2010 |
| Corn                       | Zea mays L.               | Rhopalosiphum padl L. | Parasitoids | Aphidius colemani Viereck | Jacobson and Croft, 1998; Payton Miller and Retek, 2018 |
| European columbine         | Aquilegia vulgaris         | Aleyrodes lonicerae Walker | Parasitoids | Encarsia tricolor Foérster | Laurenz and Meyhöfer, 2017 |
| European black nightshade  | Solanum nigrum L.         | Aphis fabae solanella Theobald | Mirids | Macrolaphus pygmaeus Rambur | Lykuressis et al., 2008 |
| Finger millet              | Eleusine coracana Gaertn. | Sitobion avenue (Fabricius) | Parasitoids | Aphelinus abdominalis Dalman; Aphidius ervi Haliday; Praon volucre Haliday | Fischer, 1997; Fischer in Huang et al., 2011 |

(Continued)
| Banker plant (common name) | Banker plant (Latin name) | Prey/host | Category natural enemy | Natural enemy | Source |
|----------------------------|---------------------------|-----------|------------------------|---------------|--------|
| Finger millet              | Eleusine coracana Gaertn. | Rhopalosiphum padi L. | Parasitoids | Aphidius colemani Viereck; Lysiphlebus testaceipes (Cresson) | Delgado, 1997; Fischer and Leger, 1997; Schoen and Martin, 1997; Vergniaud, 1997; Martin et al., 1998; Schoen, 2000; Boll et al., 2001a,b |
| Finger millet              | Eleusine coracana Gaertn. | Sitobion avenae (Fabricius) | Syrphids | Epi syrphus sp. | Fischer, 1997 |
| Greater celandine          | Chelidonium majus L.      | Aleyrodes proletella L. | Parasitoids | Encarsia formosa Gahan | Van der Linden and van der Staaij, 2001 |
| Kale                       | Borecole oleracea L.      | Aleyrodes proletella L. | Parasitoids | Encarsia formosa Gahan | Laska and Zelenkova, 1988 |
| Lucerne                    | Medicago sativa L.        | Acrystosiphon pisum (Harris) | Parasitoids | Encarsia formosa Gahan | Cameron et al., 1984 |
| Melon                      | Cucumis melo L.           | Bemisia tabaci (Gennadius) | Parasitoids | Encarsia sophia (Girault and Dodd); Eretmocerus spp.; Eretmocerus hayati (Zolnerowich and Rose) | Goolsby and Comperlik, 1999; Pickett et al., 2004; Kidane et al., 2018 |
| Nipplewort                 | Lapsana communis L.       | Aleyrodes proletella L. | Parasitoids | Encarsia formosa Gahan | Van der Linden and van der Staaij, 2001 |
| Oat                        | Avena sativa L.           | Metopolophium dirhodum (Walker) | Gall midges | Aphidoletes aphidimyza (Rondani) | Götte and Sell, 2002 |
| Oat                        | Avena sativa L.           | Rhopalosiphum padi L. or Schizaphis graminum (Rondani) | Parasitoids | Aphelinus abdominalis Dalman; Aphidius colemani Viereck | Andorno and López, 2014; Miller et al., 2017; Miller, 2018 |
| Papaya                     | Carica papaya L.          | Trialeurodes variabilis (Quaintance) | Coccinellids | Delphastus pusillus (LeConte) | Osborne et al., 2005 |
| Papaya                     | Carica papaya L.          | Trialeurodes variabilis (Quaintance) | Parasitoids | Encarsia transvena Timberlake; Encarsia sophia (Girault and Dodd) | Osborne et al., 2005; Xiao et al., 2011a |
| Persian buttercup          | Ranunculus asiaticus L.   | Phytomyza caulinaris Hering | Parasitoids | Dacnusa sibirica Telenga; Diglyphus isaea Walker | Van der Linden, 1992 |
| Potato                     | Solanum tuberosum L.      | Macrosiphum euphorbiae (Thomas) | Parasitoids | Aphelinus abdominalis Dalman | Blümel and Hausdorf, 1996 |
| Rhododendron               | Rhododendron sp.          | Oligonychus illicis (McGregor) and Oligonychus ununguis (Jacobi) | Predatory mites | Neoseiulus fallacis (Garman) | Pratt and Croft, 2000 |
| Rye                        | Secale cereale L.         | Rhopalosiphum padi L. | Parasitoids | Aphidius colemani Viereck | McClure, 2014; McClure and Frank, 2015 |
| Rye                        | Secale cereale L.         | Rhopalosiphum maidis (Fitch) | Parasitoids | Aphidius colemani Viereck; Aphidius ervi Haliday | Matteoni, 2003 |
| Rye                        | Secale cereale L.         | Rhopalosiphum maidis (Fitch) | Gall midges | Aphidoletes aphidimyza (Rondani) | Matteoni, 2003 |
| Ryegrass                   | Lolium multiflorum L.     | Rhopalosiphum padi L. | Parasitoids | Aphidius colemani Viereck | Jacobson and Croft, 1998; |
| Ryegrass                   | Lolium multiflorum L.     | Rhopalosiphum padi L. or Schizaphis graminum (Rondani) | Parasitoids | Lysiphlebus testaceipes (Cresson) | Miller et al., 2017; Miller, 2018 |
| Savoy cabbage              | Brassica oleracea L.      | Brevicoryne brassicae L. | Parasitoids | Diaeretiella rapae McIntosh | Freuler et al., 2001, 2003 |
| Sorghum                    | Sorghum bicolor L.        | Rhopalosiphum padi L. | Parasitoids | Aphidius colemani Viereck | Payton Miller and Rebek, 2018 |
| Sorghum                    | Sorghum bicolor L.        | Rhopalosiphum maidis (Fitch) | Parasitoids | Diaeretiella rapae McIntosh | Ceballos et al., 2011 |
| Sorghum                    | Sorghum bicolor L.        | Schizaphis graminum (Rondani) | Parasitoids | Lysiphlebus testaceipes (Cresson) | Rodrigues and Bueno, 2001; Miller et al., 2017; Miller, 2018 |
the system, due to inconsistent efficacy, labor (handling and maintenance), sink effects, and/or issues with hyperparasitoids (Jacobson and Croft, 1998; Van Driesche et al., 2008; McClure and Frank, 2015; Payton Miller and Rebek, 2018). Furthermore, the parasitoid species reared on banker plant systems are not necessarily efficient against all occurring target pest species, such as the potato aphid, Macrosiphum euphorbiae (Thomas), and the foxglove aphid, Aulacorthum solani (Kaltenbach) (Van Driesche et al., 2008; Nagasaka et al., 2010; Prado et al., 2015). Development of parasitoid wasps (Jandricic et al., 2014) on the banker plant systems may be insufficient due to the provided aphids being of insufficient size. This can lead to a reduction of survival and male biased sex ratio of the parasitoids (Hoddle et al., 1998; Chau and Mackauer, 2001; Henry et al., 2005). Gall midges produced on aphid species of poor nutritional value can also suffer in terms of size and fecundity (Kuo-Sell, 1989). Natural enemies may be reluctant to switch from aphids on the banker plant to the crop aphids (Lester et al., 2000; Coyle et al., 2011) which can hamper the establishment of beneficia\nls on the crop. This can be due to an acquired adaptation to the banker plant aphid through associative learning processes (Hoddle et al., 1998, Keasar et al., 2001, Ode et al., 2005, Prado and Frank, 2014). For all these reasons, the use of non-pest prey banker plant systems is relatively limited, relative to other methods supporting preventative establishment.

**Banker Plant Systems (Nectar and Pollen)**

Natural enemies can also be boosted by banker plants providing pollen and nectar (Table 4). The use of castor beans as banker plants has been based on this principle, as it provides a copious and steady supply of pollen and extra-floral nectar, making it a suitable host plant for generalist phytoseiid predatory mites, such as *I. degenerans* and *Euseius spp.* (Van Rijn and Tanigoshi, 1999b). Castor bean bankers hosting about 2000 predatory mites have been used by growers allowing growers to move the plants to crop spots where pests were detected or where predatory mites

### TABLE 3 | Continued

| Banker plant (common name) | Banker plant (Latin name) | Prey/host | Category natural enemy | Natural enemy | Source |
|----------------------------|--------------------------|-----------|------------------------|---------------|--------|
| Sorghum                    | Sorghum bicolor          | Melanaphis sacchari (Zehntner) | Gall midges | Aphidoletes aphidimyza (Rondani) | Abe et al., 2011; Yano et al., 2011; Higashida et al., 2017 |
| Wheat                      | Triticum aestivum L.     | Diuraphis noxia (Morvidko) | Parasitoids | Aphidius matricariae Haliday | Miller and Gerth, 1994 |
| Wheat                      | Triticum aestivum L.     | Rhopalosiphum padl L. | Parasitoids | Alluostia sp. m victrix (Westwood); Aphidius colemani Viereck; Dendrocerus laticeps (Hedicle); Aphidius matricariae Haliday; Syrphophagus sp. | Bennison, 1990; Lamparter, 1992; Albert, 1995; Conte, 1998; Jacobson and Croft, 1998; Van Schelt, 1999; Nagasaka and Oya, 2003; Saijo, 2005; Nagasaka et al., 2010, 2011; Jandricic et al., 2014; McClure, 2014; McClure and Frank, 2015; Miller et al., 2017; Miller, 2018; Payton Miller and Rebek, 2018 |
| Wheat                      | Triticum aestivum L.     | Schizaphis graminum (Rondani) | Parasitoids | Aphidius gifuensis (Ashmead); Aphidius colemani Viereck; Lysiphlebus testaceiceps (Cresson) | Stary, 1993; Miller et al., 2017; Sun et al., 2017; Miller, 2018 |
| Wheat                      | Triticum aestivum L.     | Sitobion avenue (Fabricius) | Parasitoids | Aphidius ervi Haliday; Aphidius gifuensis (Ashmead); Aphelinus asychis Walker | Van Schelt, 1999; Wang et al., 2016; Miller et al., 2017; Miller, 2018; Sun and Song, 2019 |
| Wheat                      | Triticum aestivum L.     | Sitobion avenue (Fabricius) | Syrphids | Episyphus balseatus DeGeer | Ankersmit et al., 1986 |
| Banker plant (common name) | Banker plant (Latin name) | Category natural enemy | Natural enemy | Source |
|----------------------------|----------------------------|-------------------------|--------------|--------|
| African marigold           | Tagetes erecta L.          | Anthocorids             | Orius insidiosus say | Bueno et al., 2009 |
| Apple mint                 | Mentha suaveolens Ehrh.    | Anthocorids             | Orius laevigatus (Fieber) | Cano et al., 2009, 2012 |
| Basil                      | Ocimum basilicum L.        | Anthocorids             | Orius spp.    | Cano et al., 2012 |
| Bishop's weed              | Ammi majus L.              | Syrphids                | Episyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| Brown hemp                 | Crotonaria junceae L.      | Anthocorids             | Orius spp.    | Calvert et al., 2019 |
| Buckwheat                  | Fagopyrum esculentum L.    | Chrysopids              | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Buckwheat                  | Fagopyrum esculentum L.    | Syrphids                | Several hoverflies species | Colley and Luna, 2000; Wäckers and van Rijn, 2012 |
| Borage                     | Borago officinalis L.      | Chrysopids              | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Castor bean                | Ricinus communis L.        | Anthocorids             | Orius insidiosus Say | Waite et al., 2014 |
| Castor bean                | Ricinus communis L.        | Predatory mites         | Amblyseius andersoni (Chant); Amblyseius swirski (Athias-Henriot); Iphiseius degenerans (Berlese); Neoseiulus cucumeris (Oudemans) | Ramakers and Voet, 1995; Van Rijn and Taniogoshi, 1999b; Miller et al., 2017; Miller, 2018 |
| Chamomile                  | Matricariae camomilla L.   | Chrysopids              | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Chamomile                  | Matricariae camomilla L.   | Syrphids                | Episyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| Chenille bush              | Acalypa hispida Bur. f.    | Anthocorids             | Orius laevigatus (Fieber) | Armando and Yates, 2011 |
| Chrysanthemum              | Chrysanthemum segetum L.   | Chrysopids              | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Chrysanthemum              | Chrysanthemum segetum L.   | Syrphids                | Episyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| Cilantro                   | Coriandrum sativum L.      | Syrphids                | Several hoverflies species | Colley and Luna, 2000 |
| Coriander                  | Coriandrum sativum L.      | Syrphids                | Several hoverflies species | Pineda and Marcos-Garcia, 2008 |
| Corn                       | Zea mays L.                | Mites                   | Amblyseius andersoni (Chant); Neoseiulus californicus (McGregor); Neoseiulus cucumeris (Oudemans) | Miller et al., 2017; Miller, 2018 |
| Corn flower                | Centaurea cyanus L.        | Chrysopids              | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Corn flower                | Centaurea cyanus L.        | Syrphids                | Episyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| False yellowhead           | Dittrichia (= Inula) viscosa L. | Mirids                  | Macrolophus melanoctoma Costa; Macrolophus pygmaeus Rambur; Neodioicos tenuis (Reuter) | Vila, 2004; Perdikis et al., 2007; Cano et al., 2012 |
| Feverfew                   | Tanacetum parthenium L.    | Anthocorids             | Orius insidiosus Say | Waite, 2012; Waite et al., 2014 |
| Field Marigold             | Calendula arvensis L.      | Mirids                  | Neodioicos tenuis (Reuter) | Vila, 2004 |
| Floss flower               | Ageratum mexicanum Sims    | Predatory mites         | Several predatory mite species | Huang et al., 2011 |
| French marigold            | Tagetes patula L.          | Anthocorids             | Orius spp.    | Imura and Kamikawa, 2012 |
| Geranium                   | Geranium sp.               | Mirids                  | Neodioicos tenuis (Reuter) | Vila, 2004; Cano et al., 2012 |
| Gerbera daisy              | Gerbera jamesonii L. “Festival” | Anthocorids             | Orius insidiosus Say | Waite, 2012, Waite et al., 2014 |
| Golden Crownbeard          | Verbesina encelioides Benth and Hook | Anthocorids             | Orius laevigatus (Fieber) | Armando and Yates, 2011 |

(Continued)
**TABLE 4 | Continued**

| Banker plant (common name) | Banker plant (Latin name) | Category natural enemy | Natural enemy | Source |
|----------------------------|---------------------------|------------------------|---------------|--------|
| Great basil                | Ocimum basilicum L.       | Anthocorids            | Orius laevigatus (Fieber) | Cano et al., 2012 |
| Gypsophila                 | Gypsophila elegans M. Bieb. | Chrysopids            | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Gypsophila                 | Gypsophila elegans M. Bieb. | Syrphids              | Epiusyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| Hidalgo Stachys            | Stachys albotomentosa L.  | Mirids                 | Dicythus hesperus Knight | Sanchez et al., 2004 |
| Kale                       | Brassica oleracea L. var. Acephala | Parasitoids | Diadegma insulare (Cresson) | Gourdin et al., 2003 |
| Lance-leaf Coreopsis       | Coreopsis lanceolata L.   | Anthocorids            | Orius laevigatus (Fieber) | Armand et al., 2011 |
| Male trees of blush macaraga | Macaranga tanarius Müll. Arg | Anthocorids | Orius laevigatus (Fieber) | Armand et al., 2011 |
| Marigold                   | Tagetes patula L. “Lemon Gem” | Anthocorids | Orius insidiosus Say | Waite, 2012; Waite et al., 2014 |
| Mint                       | Mentha sp.                | Mirids                 | Nesidiocoris tenuis (Reuter) | Vila, 2004 |
| Mulein                     | Verbascum thapsus L.      | Anthocorids            | Orius insidiosus Say | Miller et al., 2017 |
| Mulein                     | Verbascum thapsus L.      | Mirids                 | Dicythus hesperus Knight | Matteoni, 2003; Sanchez et al., 2003, 2004; Lambert et al., 2005; Gillespie et al., 2012; Nguyen-Dang et al., 2016; Miller et al., 2017 |
| Mustard                    | Brassica juncea L.        | Syrphids               | Several hoverflies species | Colley and Luna, 2000 |
| Ornamental pepper          | Capsicum annuum L. “Black Pearl,” “Purple Flash” | Anthocorids | Orius insidiosus Say | Valentin, 2011; Wong and Frank, 2012, 2013; Brownbridge et al., 2013; Waite et al., 2014; Miller et al., 2017 |
| Ornamental pepper          | Capsicum annuum L. “Masquerade,” “Red Missile,” “Explosive Ember,” “Baick pearl” | Predatory mites | Amblyseius andersoni (Chant); Neoseiulus californicus (McGregor); Neoseiulus cucumeris (Oudemans); Amblyseius swirskii (Athias-Henriot) | Popenoe and Osborne, 2010; Xiao et al., 2012; Avery et al., 2014; Kumar et al., 2014, 2015; Miller et al., 2017; Miller, 2018 |
| Parsol leaf tree           | Macaranga tanarius L.     | Anthocorids            | Orius spp. | Calver et al., 2019 |
| Parsnip                    | Pastinaca sativa L.       | Chrysopids            | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Parsnip                    | Pastinaca sativa L.       | Syrphids              | Epiusyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| Phacelia                   | Phacelia tanacetifolia Benth. | Syrphids | Several hoverflies species | Wnuk and Wojciechowicz-Zytko, 2007; Wojciechowicz-Zytko and Wnuk, 2012 |
| Perennial alyssum          | Aurinia saxatilis L.      | Syrphids               | Several hoverflies species | Colley and Luna, 2000 |
| Pot marigold               | Calendula officinalis L.  | Anthocorids            | Orius sauteri (Poppius) | Zhao et al., 2017 |
| Pot marigold               | Calendula officinalis L.  | Syrphids               | Several hoverflies species | Colley and Luna, 2000 |
| Sage-leaved rock-rose      | Cistus salviolus L.       | Mirids                 | Nesidiocoris tenuis (Reuter) | Vila, 2004 |
| Sesame                     | Sesannum indicum L.       | Mirids                 | Nesidiocoris tenuis (Reuter) | Nakaishi et al., 2011; Biondi et al., 2016 |
| Sowthistle                 | Sonchus spp.              | Anthocorids            | Orius spp. | Ferragut and González-Zamora, 1994 |
| Spanish lupine             | Lupinus hispanicus (Boiss and Reuter) | Anthocorids | Orius majusculus (Reuter) | Alomar et al., 2006 |
| Sunflower                  | Helianthus annuus L. “Choco sun” | Anthocorids | Orius insidiosus Say | Waite, 2012; Waite et al., 2014 |
| Sunflower                  | Helianthus annuus L.      | Chrysopids            | Chrysoperla carnea (Stephens) | Wäckers and van Rijn, 2012 |
| Sunflower                  | Helianthus annuus L.      | Syrphids              | Epiusyrphus balteatus (De Geer) | Wäckers and van Rijn, 2012 |

(Continued)
were scarce (Ramakers and Voet, 1995). However, this banker plant requires a lot of maintenance due to its rapid growth and the predatory mites do not always move into the crop. Additionally, castor bean can become a source of certain pests. The usefulness of castor bean plants was also limited in sweet pepper crops, as pepper produces pollen and floral nectar. Only a limited number of ornamental growers is still using castor bean plants. Many banker plant systems were developed to maintain predatory bugs, especially the anthocorid *Orius* spp., primarily used for the control of thrips. Establishing this predator requires pre-y, and a range of plant derived food, including pollen (Kiman and Yeargan, 1985; Richards and Schmidt, 1996; Corey et al., 1998), nectar (Yokoyama, 1978), and plant sap (Kiman and Yeargan, 1985; Richards and Schmidt, 1996; Lundgren et al., 2008). In addition, the plant structures need to be acceptable as oviposition substrate (Lundgren et al., 2008). The predator establishes easily in sweet pepper crops where it utilizes the floral resources of the pepper plants. However, most ornamental crops lack these resources. This hampers establishment of beneficials as well as the short crop cycle of many ornamentals. As repeated introductions of *Orius* spp. are too onerous and expensive for growers, a range of banker plant systems have been designed to support establishment of the predator. Several studies have used ornamental peppers "Black pearl" or "Purple Flash" and the perennial Sweet Alyssum (Valentin, 2011; Wong and Frank, 2013). The use of Sweet Alyssum with its long lasting flowering period results not only in higher densities of *Orius* spp. (Picó and Retana, 2000; Alomar et al., 2008; Bennison et al., 2011; Hogg et al., 2011; Pumariño and Alomar, 2012, 2014) but also benefits hoverflies, predatory Heteroptera (Pease and Zalom, 2010) and several parasitoids (Johanowicz and Mitchell, 2000; Berndt and Wratten, 2005; Begum et al., 2006; Pease and Zalom, 2010). However, the adoption of this method has been limited due to the fact that Sweet Alyssum is also exploited by pollen-feeding pest species, such as thrips. Several banker plant systems have also been designed to attract and sustain reproductive populations of predatory mirids. These include tobacco plants for *M. pygmaeus*, mullen for *Dicyphus hesperus* Knight and sesame for *N. tenuis* (Table 4).

| Banker plant (common name) | Banker plant (Latin name) | Category natural enemy | Natural enemy | Source |
|----------------------------|---------------------------|------------------------|--------------|--------|
| Sweet alyssum              | Lobularia maritima (L.) Desv. | Anthocorids | *Orius* spp.; *Orius laevigatus* (Fieber); *Orius majusculus* (Reuter) | Picó and Retana, 2000; Alomar et al., 2008; Bennison et al., 2011; Hogg et al., 2011; Pumariño and Alomar, 2012, 2014 |
| Sweet alyssum              | Lobularia maritima (L.) Desv. | Parasitoids | Diadegma insulare (Cresson); *Trissolcus* spp.; *Gyron obesum* Masner | Berndt and Wratten, 2005 |
| Sweet alyssum              | Lobularia maritima (L.) Desv. | Syrphids | Several hoverflies species, *Eupeodes fumipennis* (Thomson) | Colley and Luna, 2000; Pineda and Marcos-García, 2008; Hogg et al., 2011 |
| Sweet alyssum              | Lobularia maritima (L.) Desv. | Parasitoids | Several parasitoids, *Cotesia marginiventris* (Cresson); Diadegma insulare (Cresson); *Trissolcus* spp.; *Gyron obesum* Masner | Johanowicz and Mitchell, 2000; Berndt and Wratten, 2005; Begum et al., 2006; Pease and Zalom, 2010 |
| Sweet pepper               | Capsicum annuum L.         | Anthocorids | *Orius laevigatus* (Fieber) | Van den Meiracker and Ramakers, 1991 |
| Tamarillo                  | Cyphomandra betacea (Cav.) Sendtn. | Mirids | Macrolophus pygmaeaus Rambur | Fischer and Terrettaz, 2003 |
| Tobacco                    | Nicotiana tabacum L.       | Mirids | Dicyphus hesperus Knight; Macrolophus pygmaeaus Rambur | Amó et al., 2000; Ridray et al., 2001; Fischer, 2003; Fischer and Terrettaz, 2003; Schoen, 2003; Sanchez et al., 2004; Bresch et al., 2014 |
| Tree marigold              | Tithonia diversifolia (Hemsl.) | Anthocorids | *Orius laevigatus* (Fieber) | Armando and Yates, 2011 |
| Vetch                      | Vicia sativa L.            | Anthocorids | *Orius majusculus* (Reuter) | Alomar et al., 2006 |
| Vetch                      | Vicia sativa L.            | Parasitoids | Several species | Wäckers and van Rijn, 2012 |
| Vetch                      | Vicia sativa L.            | Syrphids | Epiophus balteatus (De Geer) | Wäckers and van Rijn, 2012 |
| White rocket               | Diplotaxis erucoides L.    | Anthocorids | *Orius* spp. | Ferragut and González-Zamora, 1994 |
| Wild carrot                | Daucus carota L.           | Parasitoids | Diadegma insulare (Cresson) | Idris and Grafius, 1995, 1996; Johanowicz and Mitchell, 2000 |
| Wild carrot                | Daucus carota L.           | Chrysopids | *Clytus australis* (Cresson) | Wäckers and van Rijn, 2012 |
| Wild mustard               | Brassica kaber L.          | Parasitoids | Diadegma insulare (Cresson) | Idris and Grafius, 1995, 1996; Johanowicz and Mitchell, 2000 |
| Yellow rocket              | Barbarea vulgaris R. Br.   | Parasitoids | Diadegma insulare (Cresson) | Idris and Grafius, 1995, 1996 |
and Terretaz (2003) managed even to successfully overwinter *M. caliginosus* on tobacco and tamarillo as banker plants, thus allowing the establishment of the predatory bug into the new tomato crops the next spring. Other examples of banker plant systems maintaining predatory bugs are summarized in Table 4. Addition of factitious prey on banker plants, as discussed earlier, is often suggested to increase survival, longevity and fecundity of the predatory bugs (Pumariño and Alomar, 2012, 2014).

The complexity of banker plant systems in greenhouse crops limited their adoption. Since the last decade, more straightforward methods have been developed to support the establishment and retention of beneficials in greenhouse. However, some sweet pepper growers still use them against aphids before the appearance of hyperparasitoids and there is an increased interest for banker plants to maintain predatory bugs in ornamental crops. Few attempts were made to use cover crops in or next to greenhouses and to grow combined crops, alternating rows of tomato, sweet pepper and egg plants in one greenhouse (Janmaat et al., 2014) to benefit from the vegetational diversity (Letourneau, 1983, 1990). Despite good technical results, these strategies failed in practice because of the complexity of their management. In open fields, we recently see an increased interest for the use of banker plant systems.

**POLLEN**

Providing pollen as a protein rich food in crops is another approach to boost establishment of pollen-feeding natural enemies, especially predatory mites. Pollen has been used extensively to support populations of generalist predatory mites (McMurtry and Scriven, 1966; Kennett et al., 1979; Van Rijn and Sabelis, 1990, 1993; Van Rijn and Tanigoshi, 1999a; Messelink et al., 2009; Nomikou et al., 2010; Hoogerbrugge et al., 2011; Maoz et al., 2014; Ranabhat et al., 2014, Vangansbeke et al., 2016a).

In greenhouse crops, bee-collected pollen has been tested in a number of studies, either as dry pellets or in suspension (Ramakers, 1995; Kolokytha et al., 2011; Goleva and Zebitz, 2013; Montserrat et al., 2013; Duarte et al., 2015). However, as the grains absorb water and become moldy, bee pollen was judged inappropriate by growers for crop applications (Ramakers, 1995). Attempts of using pollen providing banker plant systems, like castor beans (Ramakers and Voet, 1995; Van Rijn and Tanigoshi, 1999b), also failed, for reasons described previously. Pollen started to be used on a large scale by growers in July 2013, when commercial supplements based on narrowleaf cattail pollen were made available for crops where pollen sources are lacking (Pijnakker et al., 2014). This allowed preventative establishment of predatory mites in crops like cucumbers (which are parthenocarp and do not produce pollen), as well as ornamentals where no pests are tolerated.

Pollen can provide proteins, free amino acids, lipids, and phytosterols, nitrogen, carbohydrates, vitamins, and other inorganic minerals for many arthropods (Goss, 1968; Standifer et al., 1968; Stanley and Linskens, 1974; Rabie et al., 1983; Day et al., 1990; Roulston and Cane, 2000; Patt et al., 2003; Somerville and Nicol, 2006; Li et al., 2007; You et al., 2007; Campos et al., 2008; Lundgren, 2009). Pollen supports development, survival, and longevity of a range of natural enemies (Fauvel, 1974; Overmeer, 1985; Wäckers and van Rijn, 2005). Many studies (Table 5) show that several natural enemies are capable of reproducing and developing solely on pollen or in combination with other plant material in the absence of prey (Cocuzza et al., 1997; Beckman and Hurd, 2003; Berkvens et al., 2007; Carrillo et al., 2010). Among many studies on predatory mites, Onzo et al. (2005) showed increased survival and longevity of predatory mites when corn pollen was supplemented to the prey diet. Cloutier and Johnson (1993) and Buitenhuys et al. (2014) suggested that pollen feeding can benefit juvenile stages of predatory mites, since it is more difficult for them to attack thrips larvae, which usually show aggressive defensive behavior (Bakker and Sabelis, 1989). The nutritional value of the pollen depends on the pollen type (Todd and Bretherick, 1942; Saito and Mori, 1975; Van Rijn and Tanigoshi, 1999a; Goleva and Zebitz, 2013) and can differ between pollen consumers (Van Rijn and Tanigoshi, 1999a; Delisle et al., 2015a,b). Lundgren and Wiedenmann (2004) demonstrated that pollen quality can also vary within a given plant species. Van Rijn and Tanigoshi (1999a) showed the benefits of feeding on different pollen for predatory mites in the absence of prey. Pollen of Betulaceae, Euphorbiaceae, Leguminosae, Rosaceae, and Typhaceae seem, in general, to be suitable food sources for predatory mites (Table 5). The variations in nutritional value of pollen can be partly explained by the differences in the content of amino acids and lipids of pollen (Stanley and Linskens, 1974, Wäckers, 2005; Goleva and Zebitz, 2013). Also, pollen may contain secondary metabolites, that can reduce their suitability as food sources for arthropods (Rivest and Forrest, 2020); some types of pollen can even be toxic (Ranabhat et al., 2014; Goleva et al., 2015; Rivest and Forrest, 2020). In addition to variation in pollen nutrient composition, differences exist between natural enemies in their utilization of pollen from different plant species (McMurtry and Scriven, 1964; Van Rijn and Tanigoshi, 1999a; Adar et al., 2012). Part of this variation can be explained by the degree in which the phytoseiids have adapted to pollen feeding. While some predatory mites are specialized pollen feeders; others use it to complement their diet, while some specialist predators like *Phytoseiulus* do not consume pollen (McMurtry and Croft, 1997). Van Rijn and Tanigoshi (1999a) showed that *I. degenerans* could develop and reproduce on Betulaceae pollens whereas *N. cucumeris* failed to do so. Both predatory species did not perform on pollen from the conifer Pinopsida, but reproduced well on common cattail pollen. Goleva and Zebitz (2013) suggested that the morphology of the different pollens and their odor (Dobson and Bergrström, 2000) are likely to influence their acceptance as food by a predator. Among insects, the coccinellids *Coleomegilla maculata* (DeGeer) and *Harmonia axyridis* (Pallas) use pollen as a supplemental food, allowing the ladybugs to survive during prey scarcity (Smith, 1960a,b; Koch, 2003; Lundgren and Wiedenmann, 2004; Lundgren et al., 2005; Michaud and Grant, 2005; Berkvens et al., 2007; Hodek and Honěk, 2013). The predatory bug *Orius* spp. has been frequently shown to be able to reproduce and develop on a sole diet of specific pollen (Fauvel, 1974; Naranjo and Gibson,
| Plant (common name) | Plant (Latin name) | Category natural enemy | Natural enemy | Source |
|---------------------|-------------------|------------------------|--------------|--------|
| African oil palm    | Elaeis guineensis Jacq. | Predatory mites | Amblyseius aelialis Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Alfafa              | Medicago sativa L. | Predatory mites | Euseius scutalis (Athias-Henriot) | Al-Shammery, 2011 |
| Almond              | Prunus amygdalis Baths; Prunus dulcis (Mill.) D. | Predatory mites | Iphiseius degenerans (Berlese); Euseius stipulatus (Athias-Henriot); Euseius tularensis (McGregor); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Typhlodromus foenilis Oudemans | Ouyang et al., 1992; Van Rijn and Tanigoshi, 1999a; Bouzas and Papadoulis, 2005; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011; Khanamani et al., 2017 |
| Amazonian palm      | Euterpe oleracea Mart. | Predatory mites | Amblyseius aelialis Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Aninga              | Monichardia finifera (Arr.) Schott | Predatory mites | Amblyseius aelialis Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Annual mercury      | Mercurialis annua L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Apple               | Malus domestica L.; Malus sylvestris Mill. | Predatory mites | Amblyseius swirskii (Athias-Henriot); Euseius finlandicus Oudemans; Iphiseius vulcanus (Berlese); Neoseiulus cucumeris (Oudemans); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Typhlodromus foenilis Oudemans | Ouyang et al., 1992; Van Rijn and Tanigoshi, 1999a; Broufas and Koveos, 2000; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011; Delisle et al., 2015a,b |
| Apricot             | Prunus armeniaca L. | Predatory mites | Amblyseius swirskii (Athias-Henriot); Iphiseius degenerans (Berlese); Euseius finlandicus Oudemans; Neoseiulus cucumeris (Oudemans); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Typhlodromus foenilis Oudemans | Van Rijn and Tanigoshi, 1999a; Broufas and Koveos, 2000; Bouzas and Papadoulis, 2005; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011; Fadaie et al., 2018; Soltanyi et al., 2018 |
| Avocado             | Persea americana Mill. | Predatory mites | Euseius hibisci (Chant) | McMurtry and Sivven, 1964 |
| Bermuda buttercup   | Oxalis pes-caprae L.; Oxalis sp. | Predatory mites | Typhlodromus pyri (Sheuten); Cydnodromus picanus Ragusa | Raguas et al., 2000; Bermúdez et al., 2010 |
| Betulaceous plants  | Alnus incana (L.) Muench; Betula pubescens Erhhr.; Betula pendula Roth.; Carpinus betulus L.; Corylus avellana L.; Corylus americana Marsh.; Alnus rubra Bong.; Tumera ulmifolia L. | Predatory mites | Amblydromalus linnicus (Garman and McGregor); Amblyseius andersoni Chant; Amblyseius laroensis (Muma); Amblyseius swirski (Athias-Henriot); Euseius addoensis (van der Merwe and Rijke); Euseius finlandicus (Oudemans); Iphiseius vulcanus (Berlese); Neoseiulus cucumeris (Oudemans); Typhlodromus pyri (Sheuten) | Saito and Mori, 1975; Overmeer, 1981; Engiert and Maixner, 1988; Grout and Richards, 1992; Engel and Ohnesorge, 1994; Kostiainen and Hoy, 1994; Schausberger, 1997; Van Rijn and Tanigoshi, 1999a; Addison et al., 2000; Goleva et al., 2015; Ferreira et al., 2020 |
| Bitter melon        | Momordica charantia L. | Anthocorids | Orius sauteri (Poppius) | Zhou and Wang, 1989 |
| Brazilian oil palm  | Elaeis oleifera Cort. | Predatory mites | Amblyseius aelialis Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Broad bean          | Vicia fabae L. | Predatory mites | Iphiseiodes degenerans (Berlese); Neoseiulus cucumeris (Oudemans) | Van Rijn and Sabelis, 1990; Van Rijn and Tanigoshi, 1999a; Nomikou et al., 2001 |
| Castor bean         | Ricinus communis L. | Predatory mites | Amblyseius gossypii Elbadry; Amblyseius herbicicolus (Banke); Amblyseius idaeus (Denmark and Muma); Amblyseius laroensis (Muma); Amblyseius zaheri/Youcef and El-Bordossy; Euseius hibisci (Chant); Euseius mesembrinus (Dean); Euseius scutalis (Athias-Henriot); Euseius tularensis (McGregor); Euseius youcefizer and El-Bordossy; Iphiseius degenerans (Berlese); Neoseiulus cucumeris (Oudemans); Phytoseius plumpier (Canestrini and Fanzago); Typhlodromus aripo DeLeon; Typhlodromus negevi Swirski and Amtili; Typhlodromus pyri Schuten | Dossé, 1961; McMurtry and Sivven, 1964; McMurtry and Johnson, 1965; Rasmy and El-Banhawy, 1975; Momen and El-Saway, 1993; Tanigoshi et al., 1993; Yue et al., 1994; Ramakers and Voet, 1995; Yue and Tsai, 1996; Van Rijn and Tanigoshi, 1999a; Van Rijn et al., 2002; Momen, 2004; Gnanvossou et al., 2005; Skirvin et al., 2006; Momen et al., 2009; Al-Shammery, 2011; Rodriguez-Cruz et al., 2013 |
| Cat grass           | Dactylis glomerata L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |

(Continued)
| Plant | Common name | Latin name | Natural enemy | Source |
|-------|-------------|------------|---------------|--------|
| Cattail | Typha angustifolia L.; Typha domingensis Pers.; Typha latifolia L.; Typha orientalis Presl. | Predatory mites | Amblydromalus limonicus (Garman and McGregor); Amblyseius andersoni Chant; Amblyseius herbicola (Banks); Amblyseius lagenopsis (Muma); Amblyseius swirskii (Athias-Henriot); Iphiseius degenerans (Berlese); Euseius concordis (Chant); Euseius finlandicus (Oudemans); Euseius gallicus (Kreiter and Tixier); Euseius hibisci (Chant); Euseius ovalis (Evans); Euseius stipulatus (Athias-Henriot); Euseius maseinimius (Dean); Neoseius californicus (McGregor); Neoseius cucumeris (Oudemans); Proprioseiopsis asetus (Muma); Typhlodromus (Anthoseius) athenas (Swirski and Ragusa) | Kennett et al., 1979; Ouyang et al., 1992; Kostjainen and Hoy, 1994; Yue et al., 1994; Yue and Tsai, 1996; Van Rijn et al., 1999; Nomikou et al., 2002; Nomikou, 2003; Emmert et al., 2008; Messelink et al., 2008; Park et al., 2010, 2011; Tuovinen and Lindqvist, 2010; Kolokytha et al., 2011; Goleva and Zebitz, 2013; Nguyen et al., 2013; 2014a,b; Pijnakker et al., 2014, 2016; Vangansbeke et al., 2014a, 2016a; Nguyen et al., 2015; Duarte et al., 2015; Leman and Messelink, 2015; Samaras et al., 2015; Massaro et al., 2016; Beitrà et al., 2017; Liu and Zhang, 2017; Muñoz-Carénenas et al., 2017; De Figueiredo et al., 2018; Liu et al., 2019; Ferreira et al., 2020; Pascua et al., 2020 |
| Cherry (sweet) | Prunus avium L. | Predatory mites | Iphiseius degenerans (Berlese); Euseius concordis (Chant); Euseius finlandicus (Oudemans); Euseius stipulatus (Athias-Henriot); Neoseius cucumeris (Oudemans); Typhlodromus (Anthoseius) athenas (Swirski and Ragusa) | Van Rijn and Tangoshi, 1999a; Bougas and Koveos, 2000; Bouras and Papadoulis, 2005; Papadopoulos and Papadoulis, 2008 |
| Pink | Rosa chinensis L. Rehder and Wils. | Anthocorids | Orius sauteri (Poppius) | Zhou and Wang, 1989 |
| Common henbit | Lamium amplexicaule L. | Predatory mites | Neoseius californicus (McGregor) | Duarte et al., 2015 |
| Common meadow-grass | Poa pratensis L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Common mugwort | Artemisia vulgaris L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Common sowthistle | Sonchus oleraceous L. | Predatory mites | Neoseius californicus (McGregor) | Gugole Ottaviano et al., 2015 |
| Corn | Zea mays L. | Anthocorids | Orius insidiosus (Say); Orius sauteri (Poppius) | Gugole Ottaviano et al., 2015 |
| Corn | Zea mays L. | Coccinellids | Coleorrhagii maculata (De Geer) | Smith, 1960a,b; Hodek et al., 1978; Lundgren and Wiedenmann, 2004; Lundgren et al., 2005; Michaud and Grant, 2005 |
| Corn | Zea mays L. | Predatory mites | Amblydromalus limonicus (Garman and McGregor); Amblyseius swirskii (Athias-Henriot); Euseius concordis Chant; Euseius hibisci (Chant); Euseius fuscus Pritchard and Baker; Euseius scutatus (Athias-Henriot); Iphiseiodes zuluagai Denmark and Muma; Neoseius banneri Hugues; Neoseius californicus (McGregor); Phytoseius plumifer (Canestrini and Fanzago); Typhlodromalus ariep DeLeon; Typhlodromalus manihoi Moraes; Typhlodromus pyri Scheuten | McMurtry and Scriven, 1964; Engel and Ohnesorge, 1994; Gnanvossou et al., 2005; Weintraub et al., 2009; Ōno et al., 2012; Saber, 2012; 2013; Goleva and Zebitz, 2013; Khodayari et al., 2013; Asad et al., 2014; Vieira Marques et al., 2014; Leman and Messelink, 2015; Samaras et al., 2015; Palević, 2016; Rezaie and Askarieh, 2016; Khamanani et al., 2017; Rezaie, 2017 |
| Corn | Zea mays L. | Trichogrammatids | Trichogramma brassicaceae Bezdenko | Zhang et al., 2004 |
| Plant (common name) | Plant (Latin name) | Category natural enemy | Natural enemy | Source |
|---------------------|-------------------|------------------------|---------------|--------|
| Date palm           | Phoenix dactylifera L. | Predatory mites | Amblyseius swirski (Athias-Henriot); Euseius scutalis (Athias-Henriot); Neoseiulus barkeri Huggins; Neoseiulus californicus (McGregor); Proprioseiopsis asetus (Chant) | Fouly, 1997; Al-Shammery, 2011; Abou-Bella et al., 2013; Rezaie and Askarieh, 2016; Rezaie, 2017 |
| Echinocereus        | Echinocereus sp.    | Predatory mites | Amblyseius swirski (Athias-Henriot) | Goelva and Zebitz, 2013 |
| Eucalyptus          | Eucalyptus spp.     | Predatory mites | Euseius hibisci (Chant) | McMurtry and Scriven, 1964 |
| False oat-grass     | Arrhenatherum elatius L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Field bindweed      | Convolvulus arvensis L. | Predatory mites | Neoseiulus californicus (McGregor) | Gugole Ottaviano et al., 2015 |
| Fireweed            | Epilobium angustifolium L. | Predatory mites | Iphiseius degenerans (Berlese); Neoseiulus cucumeris (Oudemans) | Van Rijn and Tanigoshi, 1999a |
| Foxglove-tree       | Paulownia tomentosa Steud. | Predatory mites | Amblyseius swirski (Athias-Henriot) | Goelva and Zebitz, 2013 |
| Galega              | Galega officinalis L. | Predatory mites | Neoseiulus californicus (McGregor) | Gugole Ottaviano et al., 2015 |
| Hazel               | Corylus avellana L. | Coccinellids | Adala bipunctata L. | Blackman, 1967 |
| Henbit dead-nettle  | Lamium amplexicaule L. | Predatory mites | Neoseiulus californicus (McGregor) | Gugole Ottaviano et al., 2015 |
| Hoary mustard       | Hirschfeldia incana (L.) Lagr.-Foss. | Predatory mites | Typhlodromus pyri (Sheuten) | Bermúdez et al., 2010 |
| Honey bee pollen    | different plants | Anthocorids | Orius laevigatus (Fieber); Orius albidipennis (Reuter) | Cocuzzo et al., 1997 |
| Horse-chestnut      | Aesculus hippocastanum L. | Predatory mites | Amblydromalus limonicus (Garman and McGregor); Amblyseius swirski (Athias-Henriot); Neoseiulus cucumeris (Oudemans) | Goelva and Zebitz, 2013; Ranabhat et al., 2014; Goelva et al., 2015 |
| Ice plant           | Carpobrotus edulis (L.); Malephora crocea (Jacq.); Mesembrianthemum sp. | Predatory mites | Amblyseius similoides Buchelos and Pritchard; Cyndodromus californicus (McGregor); Euseius hibisci (Chant); Euseius mesembrinus (Dean); Euseius stipulatus (Athias-Henriot); Euseius tularensis (Congdon); Neoseiulus californicus (McGregor); Neoseiulus cucumeris (Oudemans); Typhlodromus exilaratus (Ragusa); Typhlodromus phialatus (Athias-Henriot) | McMurtry and Scriven, 1964, 1966; Ferragut et al., 1987; Van Rijn and Sabelis, 1990; Castagnoli and Ligouri, 1991; Flechtmann and McMurtry, 1992; Ouyang et al., 1992; Yue et al., 1994; Van Rijn et al., 2002; Villanueva and Childers, 2004; Rugusa et al., 2009; Pina et al., 2012 |
| Maple (honey bee pollen) | Acer spp. | Anthocorids | Orius insidiosus (Say) | Kiman and Yeargan, 1985 |
| Meadow foxtail      | Alopecurus pratensis L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Nettle-leaved Figwort | Scrophularia peregrina L. | Predatory mites | Cyndodromus californicus (McGregor) | Rugusa et al., 2009 |
| Norway spruce       | Picea abies L. | Predatory mites | Typhlodromus pyri (Sheuten) | Engel and Ohnesorge, 1994 |
| Oak                 | Quercus spp.: Quercus agrifolia Nee., Quercus ilex L.; Quercus ithaburensis L.; Quercus virginiana Mill.; Quercus macrocarpa Fisch. and Mey; Quercus robur L. | Predatory mites | Amblyseius andersoni (Chant); Amblyseius herbicola (Chant); Amblyseius lagoensis (Muma); Amblyseius swirski (Athias-Henriot); Euseius hibisci (chant); Euseius mesembrinus (Dean); Euseius scutalis (Athias-Henriot); Euseius tularensis (Congdon); Metaseiulus occidentalis (Nesbitt); Neoseiulus barkeri Huggins; Neoseiulus californicus (McGregor); Neoseiulus cucumeris (Oudemans); Neoseiulus longispinosis (Evans); Neoseiulus paraki (Ehara); Typhlodromus cryptus Athias-Henriot; Typhlodromus exilaratus Ragusa; Typhlodromus pyri (Sheuten) | McMurtry and Scriven, 1964; Swirski, 1967; Calvert and Huffaker, 1974; Saito and Mori, 1975 Castagnoli and Ligouri, 1986; Duso and Camperose, 1991; Ouyang et al., 1992; Engel and Ohnesorge, 1994; Yue et al., 1994; Hodek and Honěk, 1996; Yue and Tsai, 1998; Castagnoli and Simoni, 1999; Preverieri et al., 2006; Camilo et al., 2010; Adar et al., 2014; Goelva et al., 2015 |
| Oak                 | Quercus spp. | Coccinellids | Adala bipunctata; Harmonia axyridis (Pallas) | Hodek and Honěk, 1996; Koch, 2003 |

(Continued)
| Plant (common name) | Plant (Latin name) | Category natural enemy | Natural enemy | Source |
|---------------------|-------------------|------------------------|--------------|--------|
| Oil palm            | Elaeis guineensis Jacq. | Predatory mites | Amblyseius arielius Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Olive               | Olea europaea L.    | Predatory mites | Amblydromalus imonicus (Garman and McGregor); Amblyseius swirski (Athias-Henriot); Euseius tularensis (Congdon); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Neoseiulus cucumeris (Oudemans) | Ouyang et al., 1992; Matsuo et al., 2003; Kolokytha et al., 2011; Kumar et al., 2014; Samaras et al., 2015 |
| Passion fruit       | Passiflora edulis Sims | Predatory mites | Amblyseius arielius Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Peach               | Prunus persica L.   | Predatory mites | Euseius tularensis (Congdon) | Ouyang et al., 1992 |
| Pear                | Pyrus communis L.   | Predatory mites | Iphiseius degenerans (Berlese); Euseius finlandicus Oudemans; Euseius tularensis (Congdon); Neoseiulus cucumeris (Oudemans); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Typhlodromus foeranis Oudemans | Ouyang et al., 1992; Van Rijn and Tanigoshi, 1999a; Broufas and Koveos, 2000; Matsuo et al., 2003; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011 |
| Pistachio           | Pistachio vera L.   | Predatory mites | Neoseiulus californicus (McGregor) | Soltaniyan et al., 2018 |
| Plum                | Prunus domestica L. | Predatory mites | Euseius stipulatus (Athias-Henriot); Typhlodromus (Anthoseius) athenas Swirski and Ragusa; Typhlodromus foeranis Oudemans | Bouras and Papadoulis, 2005; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011 |
| Pygmy date palm     | Phoenix roebelenii O'Brien | Predatory mites | Amblyseius largoensis (Muma) | Yue and Tsai, 1996 |
| Small nettle        | Urtica urens L.     | Predatory mites | Neoseiulus californicus (McGregor) | Gugole Ottaviano et al., 2015 |
| Sour orange         | Citrus aurantium L. | Predatory mites | Euseius scutalis (Athias-Henriot) | Al-Shammery, 2011 |
| Spanish needle      | Bidens pilosa L.    | Predatory mites | Euseius mesembrinus (Dean) | Yue et al., 1994 |
| Spring crocus       | Crocus vernus (L.) Hill | Predatory mites | Amblyseius swirski (Athias-Henriot) | Goleva and Zeibitz, 2013 |
| Squash              | Curcubita pepo L.   | Predatory mites | Iphiseiodes zuluagai Denmark and Muma; Euseius concordis Chant | Viera Marques et al., 2014 |
| Strawberry          | Fragaria x ananassa (West.) | Predatory mites | Iphiseiodes degenerans (Berlese); Neoseiulus californicus (McGregor); Neoseiulus cucumeris (Oudemans) | Van Rijn and Tanigoshi, 1999a; Shaka et al., 2009; Gugole Ottaviano et al., 2015 |
| Sunflower           | Helianthus annuus L. | Predatory mites | Amblyseius zaheri Yousef and El-Boroliassy; Euseius yousef Zaheri and El-Boroliassy; Iphiseiodes degenerans (Berlese); Neoseiulus barkeri Hugues | Van Rijn and Tanigoshi, 1999a; Momen, 2004; Rezaie and Askarieh, 2016; Ferreira et al., 2020 |
| Sunnhemp            | Crotalaria juncea L. | Predatory mites | Amblyseius herbicolaus (Banks) | Rodríguez-Cruz et al., 2013 |
| Sweet orange        | Citrus sinensis L.  | Predatory mites | Amblyseius arielius Muma; Iphiseiodes zuluagai | Ferreira et al., 2020 |
| Sweet pepper        | Capsicum annumum L. cv. Mazurka | Anthocorids | Orinus abdipennis Reuter; Orinus aevigatus (Fieber) | Vacante et al., 1997 |
| Sweet pepper, ornamental pepper, peper | Capsicum annumum L.; Capsicum frutescens L. | Predatory mites | Amblyseius swirski (Athias-Henriot); Euseius hibisci (Chant); Neoseiulus cucumeris (Oudemans) | MCMurtry and Scriven, 1964; Van Rijn and Sabelis, 1990; Kumar et al., 2014 |
| Tea                 | Camellia sinensis L. | Predatory mites | Amblyseius sojaensis Ehara; Neoseiulus cucumeris | Osakabe et al., 1988; Matsuo et al., 2003 |
| Tulip               | Tulipa sp.; Tulipa gesneriana L. | Predatory mites | Neoseiulus cucumeris (Oudemans); Amblyseius swirski (Athias-Henriot) | Ranabhat et al., 2014; Goleva et al., 2015 |
| Turkish pine        | Pinus brutia (Ten.) | Predatory mites | Amblyseius swirski (Athias-Henriot) | Kütük and Yigit, 2011 |
TABLE 5 | Continued

| Plant (common name) | Plant (Latin name) | Category natural enemy | Natural enemy | Source |
|---------------------|-------------------|------------------------|---------------|--------|
| Walnut              | Juglans regia L.  | Predatory mites        | *Amblyseius swirskii* (Athias-Henriot); *Euseius hibisci* (Chant); *Euseius finlandicus* Oudemans; *Neoseius barkeri* Hughes, *Neoseius californicus* (McGregor); *Typhlodromus (Antheoseius) atheras Swirski and Ragusa; *Typhlodromus foenis Oudemans*; *Typhlodromus pyri* (Sheuten) | McMurtry and Scriven, 1964; Engel and Ohnesorge, 1994; Broudas and Koveos, 2000; Papadopoulos and Papadoulis, 2008; Kolokytha et al., 2011; Rezaie and Askarieh, 2016; Rezaie, 2017; Fadaei et al., 2018 |
| Willow              | Salix sp.         | Coccinelids            | *Adalia bipunctata* L. | Blackman, 1967 |

1996; Cocuza et al., 1997; Coll, 1998; Lundgren, 2009). However, the development of *Orius* spp. was prolonged and reproduction and survival reduced on pollen only diet (Salas-Agullar and Ehler, 1977; Kiman and Yeargan, 1985; Funao and Yoshiyasu, 1995; Richards and Schmidt, 1996; Cocuza et al., 1997; Vacante et al., 1997, 1998). As with the phytoseiids, *Orius* performance is dependent on pollen type (Vacante et al., 1997). Pollen feeding also provides benefits for *M. pygmaeus* (Perdikis and Lykouressis, 2000; Vandenekkhove and De Clercq, 2010; Portillo et al., 2012; Put et al., 2012). Cattail pollen doubled the longevity of *M. pygmaeus* females compared to bugs provided only broad beans (Portillo et al., 2012) and promoted its establishment on tomato plants (Put et al., 2012). Also larvae of green lacewings can benefit from (bee) pollen (Patt et al., 2003). For syrphids, sexual maturation requires proteins that can be provided by pollen, allowing the females to mature successive batches of eggs (Schneider, 1948; Pineda and Marcos-García, 2008).

In biological control, pollen has been reported to support population densities of natural enemies when prey densities are low and improve control efficacy against pests. Most of these studies concern predatory mites. In the presence of pollen, predatory mites provided better control of phytophagous mites (McMurtry and Scriven, 1966; Kennett et al., 1979; Ferragut et al., 1987; Pina et al., 2012, 2015; Saber, 2013; Maoz et al., 2014; Duarte et al., 2015; Pijnakker et al., 2016), thrips (Ramakers, 1990; Van Rijn and Sabelis, 1993; Van Rijn et al., 1999) and whiteflies (Nomikou et al., 2001, 2002, 2010; Nomikou, 2003). Van Rijn et al. (1999) were the first to provide clear experimental evidence that supplementing pollen can be an efficient strategy to boost the biological control potential of predatory mites. By supplying the predatory mite species *A. limonicus* and *I. degenerans* with cattail pollen they were able to enhance population levels of the predatory mites, which resulted in increased thrips control and reduced plant damage. Kütük and Yigit (2011) succeeded in pre-establishing *A. swirskii* on sweet pepper by spraying suspensions of pine pollen, thereby maintaining *F. occidentalis*-numbers under the desired threshold. Provision of cattail or corn pollen increased densities of *A. swirskii* and improved thrips control on potted chrysanthemum (Leman and Messelink, 2015). Muñoz-Cárdenas et al. (2017) succeeded in establishing *A. swirskii* in roses before thrips release by weekly provision of cattail pollen and thus managed to realize a decrease of thrips numbers and damage. Nomikou et al. (2002, 2010) showed improved suppression of tobacco whitefly populations by *A. swirskii* on single cucumber plants treated with cattail pollen. Skirvin et al. (2006) achieved a higher density of *N. cucumeris* on chrysanthemum plants with an application of castor bean pollen. Still, it led to an increased infestation of western flower thrips, as only a few predatory mites were recovered. These examples give an idea of the potential of pollen as alternative food but the studies were often performed over short temporal scales and at pest densities higher than those found in commercial greenhouses. Since cattail pollen has been made commercially available in 2013, growers can now apply pollen as part of biocontrol programs. They typically apply pollen weekly (blown at 250 g/ha) or biweekly (at 500 g/ha) (Pijnakker et al., 2016). These dosages correspond to 2.5 to 20 mg per plant. Various devices are available to apply pollen to enhance the establishment of predatory mites on crops (Gan-Mor et al., 2003, 2011; Weintraub et al., 2009; Pijnakker et al., 2016). Other arguments in favor of the use of cattail pollen, next to its high nutritional value, are its low allergenic character (Weber and Nelson, 1985), its relatively low attractiveness to pests and poor nutritional suitability for thrips (Hulshof et al., 2003). The fact that cattail pollen is not attractive to (bumble) bees, means that it does not distract pollinators used in the crop (Schmidt et al., 1989).

However, the use of pollen can have some drawbacks as it can also benefit herbivores (Kirk, 1987; Van Rijn et al., 2002; Chitturi et al., 2006; Wäckers et al., 2007, 2009; Leman and Messelink, 2015; Vangansbeke et al., 2016b). Hulshof et al. (2003) showed at laboratory scale that *F. occidentalis* feeds on pollen, resulting in an enhancement of its growth rate and fecundity. Van Rijn et al. (2002), using simulation models, showed that availability of pollen benefits predators more than thrips and improved predator-prey ratios resulting in enhanced thrips control. This has since been repeatedly confirmed in studies showing the efficacy of the pollen supplementation at plant or crop level (see above). The high reproduction by *A. swirskii* on plants treated with pollen prevented the pest from developing, even if they can feed on the pollen. This represents an example of apparent competition, where the population development of a prey is suppressed by a shared predator when an additional prey or food supplement is present (Nomikou et al., 2010). Despite the fact that *Typha* pollen has been widely shown to be effective in supporting biological control, growers could still run a risk of damage when thrips are too numerous at the start of the
crop or when predators do not establish because of pesticide residues. When applying any food supplement, including pollen, predation per predatory mite will go down due to satiation effects (Skirvin et al., 2007). In addition to predator satiation (Holt and Lawton, 1993, 1994; Shakya et al., 2009) a feeding-switch to pollen may occur. Both mechanisms may result in a temporary reduction in predation rate of the pest (so-called apparent mutualism, Abrams and Matsuda, 1996). High dosage of cattail pollen reduced the predation of thrips by individual A. swirskii by 50% on laboratory scale (Leman and Messelink, 2015). However, these effects are typically short term and are soon outbalanced by the augmentation of natural enemy numbers (Van Rijn et al., 1999).

The use of supplementary food, and pollen in particular, is a powerful tool to help establish predatory mites and improve biocontrol efficacy. The application of exogenous pollen as supplemental food source can be optimized by avoiding excessive doses, as overly high pollen levels may result in satiation of predatory mites and stimulation of thrips (Sabelis and van Rijn, 2006). The choice of the pollen type and the match with the predatory mite can also affect the outcome. However, Typha pollen has proved to be suitable for a broad range of predatory mites (Table 5). Growers succeed in building strong populations of predatory mites with feeding their predators before pest appearance and performing adjustments in their irrigation systems and their spraying data. Some persue the development of the application by automatizing the blowing of this alternative food.

NECTAR/SUGAR SOLUTION

Many natural enemies depend on sugars as their main source of energy. This includes a.o. parasitoids (Wäckers, 2001), syrphids (Van Rijn and Wäckers, 2016), gall midges (Fratoni et al., 2020), chrysopids (Stelzl, 1991; Hogervorst et al., 2007), coccinellids (Pemberton and Vandenberg, 1993), mirids (Portillo et al., 2012), and phytoseiids (Van Rijn and Tanigoshi, 1999b). Natural enemies can feed from a range of carbohydrate sources. Besides floral nectar, they can also exploit extrafloral nectar, as well as honeydew.

Floral nectar has evolved as a food reward in the mutualism between plants and their pollinators. Even though natural enemies, with a few noticeable exceptions (Pekas et al., 2020), are mostly likely not necessarily effective in pollinating flowers, they, nevertheless, can collect floral nectar to provide for their energetic needs. As natural enemies tend to have short mouthparts, their nectar foraging is restricted to those plant species with open and exposed floral nectaries, such as Apiaceae, Euphorbiaceae, or buckwheat (Campbell et al., 2012; Wäckers and van Rijn, 2012; Van Rijn and Wäckers, 2016).

While accessibility of floral nectar can be a bottleneck for natural enemies, some plants also produce nectar outside of the flowers. These so-called extrafloral nectaries tend to be exposed and thus highly accessible. Furthermore, the nectar is often secreted over prolonged periods of time (Wäckers and Bonifay, 2004). These adaptations fit their ecological function, as extrafloral nectar is part of a defensive strategy, allowing plants to recruit ants and other sugar feeding natural enemies. They, in turn, protect the plants when attacking herbivores. Extrafloral nectaries have been described in more than thousand plant species, including a number of important crops, such as cotton, cassava, peaches, plums, cherries, pumpkins, roses, field beans. In a number of plant systems, it has been demonstrated that the presence of extrafloral nectar can translate into both reduced plant damage and increased plant reproductive fitness (Heil, 2015).

Honeydew is a generic term for sugar-rich excretions of phloem-feeding Sternorrhyncha. In agricultural ecosystems, honeydew is often the most prevalent sugar source (Wäckers and Steppuhn, 2003; Hogervorst et al., 2007; Tena et al., 2015). However, honeydew differs from the above-mentioned sugar sources, as it is primarily a waste product. This can reduce the nutritional value of honeydew (Wäckers et al., 2008).

Overall, the nutritional suitability of the above sugar sources depends on composition and concentration of carbohydrates (Wäckers, 2001; Azzouz et al., 2004; Fratoni et al., 2020). Sugar concentration is an important factor determining sugar uptake. At low concentrations, gustatory perception might be impeded (Wäckers, 1999), whereas viscosity at high sugar concentrations can interfere with sugar uptake (Wäckers, 2000; Winkler et al., 2009). Upon the time of nectar secretion, sugar concentrations can already range from 5 to 75% (Dafni, 1992). Environmental conditions may further affect nectar concentrations both indirectly through their effects on the nectar producing plant, and directly through evaporation, hygroscopy or rain dilution (Winkler et al., 2009). Sugar concentrations of undiluted extrafloral nectar range from 5 to more than 80% (Koptur, 1992a,b; Wäckers, 2001). In general, extra floral nectar shows much more variation in terms of sugar concentration than floral nectar from the same plant. Extrafloral nectar tends to be more concentrated, probably due the fact that its exposed nature increases evaporation. The fact that honeydew is typically available as little droplets or as a thin film on the substrate, means that it is even more subjected to evaporation. As a result, sugar concentrations are often at saturation. This is likely to be a limiting factor in honeydew uptake. This problem is accentuated by the specific tendency of the honeydew sugars: raffinose and melezitose, to crystallize rapidly (Wäckers, 2000).

Providing Sugar Sources to Boost Biological Pest Control

It has long been recognized that the lack of sugar sources in agricultural systems can strongly undermine the efficacy of biological control. This problem could be overcome by introducing food sources into our agricultural systems. Recently, we have seen an increasing interest in the use of (flowering) non-crop plants in field margins as a tool to sustain predators and parasitic wasps. Specifically selected seed mixtures are available.
that are intended to attract natural enemies and provide them with nectar sources. When introducing nectar plants, the use of sugar sources is not restricted to beneficial insects. Many pest insects thrive on sweets as well (Wäckers et al., 2007). By choosing plants that primarily benefit natural enemies, the positive impact on pest control can be maximized (Gurr, 2005; Winkler et al., 2010). Banker plants can also be used to provide sugar sources, either in the form of (extra-) floral nectar as in the case of castor bean or broad bean or by providing honeydew (considering the caveats mentioned above). As an alternative to the introduction of nectar- or honeydew providing plants, sugar can also be applied as such. Sugar can be either sprayed onto the crop, or provided in so-called “feeding stations.” Spraying sugar has the advantage that it is an easy and cheap application method resulting in an even coverage and providing an easily accessible sugar source for the predators and parasitoids. The quantity of the sugar applied can be controlled through the choice of sugar concentration, by adjusting the spray volume/spray nozzle, and by varying the walking/driving speed. Yet, there are also obvious drawbacks to the use of sugar sprays. Blanket sprays quickly result in the crop getting sticky. Certain sugars can cause phytotoxicity when sprayed directly on the foliage. In addition, sugars on the plant surface are prone to growth of sooty mold. These drawbacks can be avoided, either by using very weak sugar concentrations (e.g., 0.1–1%) or by applying a higher concentrated solution in a very fine and light mist. For the target arthropods, having minute sugar droplets is often better than having to deal with a sticky sugar layer, as the latter interferes with arthropod mobility. Biological control practitioners have attempted to incorporate artificial sugar sprays as a strategy to cater to the nutritional needs of parasitoids (Mandour et al., 2007; Wade et al., 2008). However, the efficacy of this form of sugar provisioning in biological control programmes has been limited and inconsistent (Heimpel and Jervis, 2005; Wade et al., 2008). Tena et al. (2015) studied the use of sugar sprays in combination with the release of the parasitoid *Aphytis melinus* DeBach (Hymenoptera: Aphelinidae) for the control of the California red scale *Aonidiella aurantii* in a commercial citrus orchard. They demonstrated that sugar supplementation increased the parasitoid population density 2-fold. Parasitoid fecundity on sugar treated trees was shown to be enhanced as well. Higher population densities and the increase in realized fecundity translated in a 2-fold increase in parasitism under crop conditions. The successful examples show that under certain conditions the use of sugars can be an effective element in a conservation biological control strategy.

**DOMATIA**

Shelter and oviposition substrates are other resources that can be essential to successful establishment and efficacy of natural enemies (Gurr et al., 2017). Providing sites of refuge can support reproduction (Pemberton and Turner, 1989; O’Dowd and Willson, 1991; Grostal and O’Dowd, 1994; Walter, 1996) and development, overwintering or aestivation and can protect them from cannibalism (Ferreira et al., 2008; Lee and Zhang, 2016, 2018), predation (Roda et al., 2000; Norton et al., 2001; Faraji et al., 2002a,b; Romero and Benson, 2005; Seelmann et al., 2007; Ferreira et al., 2011) and unfavorable climatic conditions (Walter and O’Dowd, 1992a,b; Grostal and O’Dowd, 1994; Walter, 1996; Sabelis et al., 1999; Norton et al., 2001).

Some plants have special morphological structures, called domatia (from the Latin for home “domus”), that are targeted to either ants, or predatory/fungivorous mites. Ant domatia are represented by hollow thorns or stems and rolled leaf margins. Acarodomatia may take the form of either pits or (dense) tufts of leaf hairs, in which small arthropods may reside (Romero and Benson, 2005). Many studies have demonstrated that the presence of domatia increases the population of predators, that in turn protect the plant against herbivores and in some instances pathogens and weeds (Lundstrom, 1887; Rozario, 1995; Kreiter et al., 2003; Ferreira et al., 2008, 2011; Shenoy and Borges, 2010; Parolin et al., 2013). Predatory mites tend to occur more abundantly on plants bearing acarodomatia (O’Dowd and Willson, 1997; Norton et al., 2000; Roda et al., 2001; Romero and Benson, 2005; Avery et al., 2014) and their survival and reproduction on such plants is enhanced (Pemberton and Turner, 1989; Karban et al., 1995; Agrawal, 1997; Agrawal et al., 2000; Cortesero et al., 2000; Avery et al., 2014; Bresch et al., 2015, 2018). Domatia also act as oviposition substrate. Many predatory mite species show a preference to lay eggs on trichomes. Egg clusters can be frequently seen inside domatia, where predatory mites can molt protected from predators. Besides serving as shelters and oviposition sites, the hair-tufts may trap pollen and fungal spores that the mites can then consume (Roda et al., 2000; Romero and Benson, 2005; Loughner et al., 2008). Thus, acarodomatia can serve a function in providing food as well. Pekas and Wäckers (2017) showed a strong synergistic effect between the availability of fibers and food (pollen and sugar water) in affecting population growth of predatory mites on citrus plants. Romero and Benson (2004) demonstrated the protective role of domatia on the tropical tree *Cupania vernalis* L. By blocking domatia on part of the experimental trees, they showed that domatia increased predatory mite abundance and lowered herbivore damage from eriophyid mites. However, very few studies have investigated their long-term effect on predatory mites, pest or fungi under natural conditions (Norton et al., 2000; Monks et al., 2007; Ferreira et al., 2010). Norton et al. (2000) showed that acarodomatia increased the abundance of the mycophasogous tydeid mite, *Orthotydeus lambi* (Baker), which resulted in the reduction of 48% of grape mildew infestation on the riverbank grape.

Domatia can be provided to beneficials by (1) selecting crop variety with the appropriate properties, (2) by adding suitable non-crop plants to crops (Skirvin and Fenlon, 2001; Van Rijn et al., 2002; Osborne and Barrett, 2005; Frank, 2010; Huang et al., 2011; Parolin et al., 2012b; Kumar et al., 2015), (3) or by using artificial structures (Loughner et al., 2011; Adar et al., 2014; Pekas and Wäckers, 2017). Crop varieties can differ substantially in domatia characteristics. Choosing crop
varieties for their domatia traits could thus help to support establishment of natural enemies. Breeding programmes have actually started to include traits that determine suitability for beneficial organisms (Bottrell et al., 1998; English-Loeb et al., 1999). Some tomato varieties, for example, have been selected for their distorted trichomes to facilitate biological control of tomato russet mites (Van Houten et al., 2013; Legarrea et al., 2020). Another method for applying domatia can be the interplanting of domatia bearing banker plants between crop plants lacking domatia. Parolin et al. (2013) showed an increased spider mite control in roses using the predatory mites P. persimilis and Neoseiulus californicus (MCGregor) when adding lauristinus and frost grape bearing acarodomata as bankerplants. Adding the banker plants in this system enhanced the establishment of predatory mites and increased their efficacy. The method can only be successful if natural enemies disperse from the manipulated habitat to the crop. In practice, growers tend to focus on commercial crops and are reluctant to introduce non-crop (banker) plants. A further strategy could be to use artificial domatia. Various types of artificial domatia have been used in studies to assess the benefits of natural domatia, but also, to improve biological control on crops (Loughner et al., 2010, 2011; Pekas and Wäckers, 2017). Rozario (1994) brought tufts of polyester fibers to grape varieties with low natural domatia to augment populations of Galendromus occidentalis Nesbitt. Agrawal and Karban (1997) supplemented cotton plants with artificial domatia, which enhanced spider mite control and fruit yields. However, thrips numbers were also shown to benefit from domatia. Kawashima et al. (2006a) reported laboratory experiments showing that textured urethane foam and polyethylene shading nets were suitable sites for the reproduction of N. californicus. Kawashima and Jung (2011) suggested using urethane foam as ground cover in apple orchards to increase the survival of N. californicus populations during the winter. Loughner et al. (2011) mimicked domatia on glabrous beans seedlings and Impatiens plants by adding cotton fiber patches and chopped acrylic yarn fibers and found more A. swirskii on plants provided with pollen and artificial domatia than on plants given solely pollen or fibers. In this study, cotton patches and paper pulp supplements augmented and maintained A. swirskii populations, whereas jute and cellufo were not effective. Adar et al. (2014) tested the “pollen on-twine” method (Gan-Mor et al., 2011), using fibers (rayon/viscose 80% and jute 20%) coated with pollen and succeeded in enhancing E. scutalis populations. Oviposition occurred on rayon rather than on jute. Bresch et al. (2018) found wool, silk, polyamide, viscose and polyester to be equally suitable as natural domatia for oviposition by N. californicus. However, none of them improved spider mite control by N. californicus and polyamide even benefitted the pest. Pekas and Wäckers (2017) showed that the combined use of fibers, pollen, and sugar generate synergistic benefits to population growth of Euseius stipulatus (Athias-Henriot) on bitter orange. In orchards, Koike et al. (2000) designed a Phyto trap, which contains wool yarn mimicking the microstructure of spider mites colonies. This tool aims at collecting predatory mites in pear trees to monitor their densities during the seasons and maintain populations (Kawashima and Amano, 2006; Kawashima et al., 2006b). This tool inspired Messelink et al. (2016) to test among others further material with Velcro tape in greenhouse crops, but found that using millet husk or jute both combined with pollen were more effective to enhance the establishment of A. limonicus on anthurium. In spite of these examples showing the potential of using artificial domatia, there are no commercial applications of these artificial domatia yet.

CONCLUSIONS

This review presents the potential, advantages and risks of the concept of “beneficials-in-first” over augmentative biological control in greenhouses and aims at discussing tools thought to preserve natural enemies in biological control programmes. The studies described show that natural enemies’ survival, development, reproduction and efficacy can be enhanced with the use of factitious prey, banker plant systems, pollen, sugars and manipulated habitats. This concept of “beneficials-in-first” is no longer a focus of researchers only, but has been explored by commercial growers over the past two decades. However, despite the trials demonstrating their benefit, some methods to enhance natural enemies’ establishment are still excluded from biological strategies in practice, as they often lead to other issues at large scale. The development of hyperparasitoids or pests on banker plant systems, the possible molting of Ephesia eggs and Artemia cysts, the lack of survival of living factitious prey, the damages caused by Tyrophagus putrescentiae or by mirid predatory bugs when they are too numerous, are such examples. Overhead irrigation can hamper the application of alternative food and artificial domatia in some crops. Artificial domatia are also difficult for growers to introduce in their crop.

Further increasing the adoption of the “beneficials-in-first” concept by growers can be achieved by:

1. Clearly demonstrating efficacy on a larger scale and communicate if the selected resources benefit more natural enemies than the antagonists or pests, decrease pest damage and increase production quality or yield;
2. Increasing the involvement of growers in the process of such large-scale experiments, including costs and handling times;
3. Fine-tuning the amount of supplemental resources, the release techniques, the timing and the frequency with which the tools should be employed (Janssen and Sabelis, 2015; Madadi, 2018);
4. Automatization as it will be the key in expanding the scope of inoculative biological control, both in protected and open-field crops.

In the coming decade, we foresee more applications of feeding stations and nectar plants in crops to enhance the survival of natural enemies. Beside the tools of enhancement of beneficials, the use of methods limiting pest activity in greenhouses will gain more importance like tools of sexual confusion,
distraction of pests such as “push-pull systems” or the use of “repellent substances.”

**AUTHOR CONTRIBUTIONS**

JP: conceptualization, supervision, writing original draft, review, and editing. FW: conceptualization, supervision, writing draft, review, and editing. DV, RM, and MD: review and editing.

**REFERENCES**

Abe, J., Mitsunaga, T., Kumakura, H., and Yano, E. (2011). Comparative studies on development and reproduction of four cereal aphid species reared on sorghum or barley to evaluate as alternative prey for banker plant system. *Japanese J. Appl. Entomol. Zool.* 55, 227–239. doi: 10.1303/jjaez.2011.227

Abou-Elella, G. M., Saber, S. A., and El-Sawi, S. A. (2013). Biological aspects and life tables of the predacious mites, *Typhlodromips swirskii* (Athias-Henriot) and *Euseius scutalis* (Athias-Henriot) feeding on two scale insect species and plant pollen. *Arch. Phytopathol. Pflanzenschutz* 46, 1717–1725. doi: 10.1080/03235408.2013.774715

Abrams, P. A. (1987). On classifying interactions between populations. *Oecologia* 73, 272–281. doi: 10.1007/BF00377518

Abrams, P. A., and Matsuda, H. (1996). Positive indirect effects between prey species that share predators. *Ecology* 77, 610–616. doi: 10.2307/2265634

Adar, E., Inbar, M., Gal, S., Doron, N., Zhang, Z. Q., and Palevsky, E. (2012). Plant-feeding and non-plant feeding phytoseids: differences in behavior and cheliceral morphology. *Exp. Appl. Acarol.* 58, 341–357. doi: 10.1007/s10149-012-9589-y

Adar, E., Inbar, M., Gal, S., Gran-Mor, S., and Palevsky, E. (2014). Pollen on-twine for food provisioning and oviposition of predatory mites in protected crops. *Biocontrol* 59, 307–317. doi: 10.1007/s10526-014-9563-1

Addison, J. A., Hardman, J. M., and Wilde, S. J. (2000). Pollen availability for predaceous mites on apple: spatial and temporal heterogeneity. *Exp. Appl. Acarol.* 24, 1–18. doi: 10.1023/A:1006329819059

Agrawal, A. (1997). Do leaf domatia mediate a plant-mite mutualism? An experimental test of the effects on predators and herbivores. *Ecol. Entomol.* 22, 371–376. doi: 10.1046/j.1365-2311.1997.00088.x

Agrawal, A. A. (2005a). Future directions in the study of induced plant responses to herbivory. *Entomol. Exp. Appl.* 115, 97–105. doi: 10.1111/j.1570-7458.2005.00294.x

Agrawal, A. A. (2005b). Herbivory and maternal effects: mechanisms, ecological consequences and agricultural implications of tri-trophic interactions. *Curr. Opin. Plant Biol.* 3, 329–335. doi: 10.1016/S1369-5266(00)00089-3

Agrawal, A. A., Janssen, A., Bruin, J., Posthumus, M. A., and Abe, J. (2011). A comparative study on sorghum or barley to evaluate as alternative prey for banker plant system. *Japanese J. Appl. Entomol. Zool.* 55, 227–239. doi: 10.1303/jjaez.2011.227

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**Ambylomarus imicus**, in Fourth Meeting of the IOBC Working Group Integrated Control of Plant-Feeding Mites (Paphos), 9–12.
Avery, P. B., Kumar, V., Xiao, Y., Powell, C. A., McKenzie, C. L., and Osborne, L. S. (2014). Selecting an ornamental pepper banker plant for *Amblyomarus swissi* in bioculture crops. *Arthropod Plant Int*. 8, 49–56.

**Azouz, H., Giordano, P., Wackers, F. L., and Kaiser, L. (2004). Effects of feeding frequency and sugar concentration on behavior and longevity of the adult aphid parasitoid: *Aphidius ervi* (Haliday) (Hymenoptera: Braconidae).** *Biocontrol Sci. 31*, 445–452. doi:10.1016/j.bioccost.2004.07.013

**Bakker, F. M., and Sabelis, M. W. (1989). How larvae of *Traps tabaci* reduce the attack success of phytophagous predators.** *Entomol. Exp. Appl.* 50, 47–51. doi:10.1111/j.1570-7458.1989.tb02313.x

**Barbosa, M. F., and de Moraes, G. J. (2015). Evaluation of agastmid mites as nutritious food for rearing four predaceous phytophagous mites (Acari: Astigmata, Phytoseiidae).** *Biocontrol Sci. 91*, 22–26. doi:10.1016/j.biocost.2015.06.010

**Beckman, N., and Hurd, L. E. (2003). Pollen feeding and fitness in praying mantids:** *Appl. Ecol.* 39, 377–385. doi:10.1111/j.1365-2664.2003.00809.x

**Bennison, J. A., and Corless, S. P. (1993). Biological control of aphids on cucumbers:** *Environ. Entomol.* 22, 786–791. doi:10.1093/0046-225X.22.3.786

**Birkhofer, K., Wise, D. H., and Scheu, S. (2008). Subsidy from the detrital food web, but not microhabitat complexity, affects the role of generalist predators in an aboveground herbivore food web.** *Oikos* 117, 491–502. doi:10.1111/j.0030-1299.2008.16361.x

**Blackman, R. L. (1967). The effects of different aphid foods on *Adalia bipunctata* L. and *Coccinella 7-punctata* L. *Ann. Appl. Biol. 59*, 207–219. doi:10.1111/j.1744-7348.1967.tb00428.x

**Bloemhard, C., Catala L., Gerards, B., Shinde, A., Messling, G., van der Salm, C., et al. (2018). Green Challenges: Waar Blijft de Trips? Available online at: https://edeapot.wur.nl/443879 (accessed June 2020).**
Castagnoli, M. (1989). Biology and possibilities of mass rearing of Amblyseius cucumeris (Oud.) (Acari: Phytoseiidae) using Dermatophagoides farinae, ed R. Schuster et al. (Dordrecht: Springer), 231–239.

Castagnoli, M., and Liguori, M. (1986). Development and oviposition times of Tlyphodromus exhalatus Ragusa (Acarina: Phytoseiidae) reared on various types of food. Redua 69, 361–368.

Castagnoli, M., and Liguori, M. (1986). Development and oviposition times of Tlyphodromus exhalatus Ragusa (Acarina: Phytoseiidae) reared on various types of food. *Redua* 69, 361–368.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1986). Development and oviposition times of Tlyphodromus exhalatus Ragusa (Acarina: Phytoseiidae) reared on various types of food. *Redua* 69, 361–368.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.

Castagnoli, M., and Liguori, M. (1989). Biology and possibilities of mass rearing of *Amblyseius cucumeris* (Oud.) (Acari: Phytoseiidae) using *Dermatophagoides farinae* Hughes (Acarina: Pyroglyphidae) as prey. *Redua* 72, 389–401.
Insects: A Protective Mutualism and its Applications (Cambridge: University Press), 341–347. doi: 10.1017/CBO9780511542220.012

Gurr, G. M., Wratten, S. D., Landis, D. A., and You, M. (2017). Habitat management to suppress pest populations: progress and prospects. *Ann. Rev. Entomol.* 62, 91–109. doi: 10.1146/annurev-ento-031616-035050

Hägvar, E. B., and Hofsvang, T. (1994). Colonization behaviour and parasitization by *Ephedrus cerasicola* (Hym., Aphidiidae) in choice studies with two species of plants and aphids. *J. Appl. Entomol.* 118, 23–30. doi: 10.1111/j.1439-0418.1994.tb0774.x

Hagen, K. S. (1986). “Ecosystem analysis: plant cultivars (HPR), entomophagous species and food supplements,” in *Interactions of Plant Resistance and Parasitoids and Predators of Insects*, eds. D. J. Boethel and R. D. Eikenbary (New York, NY: Wiley), 151–197.

Hansen, L. S. (1983). Introduction of *Aphidolepis aphidimyzra* (Rond.) (Diptera: Cecidomyiidae) from an open rearing unit for the control of aphids in glasshouses. *SROP Bull.* 6, 146–150.

Havelka, J., and Kindlmann, P. (1984). Optimal use of the “pest in first” method for controlling *Tetranychus urticae* Koch (Acari, Tetranychidae) on glasshouse cucumbers through *Phytoseiulus persimilis* A.-H. (Acari, Phytoseiidae). *Z. Angew. Entomol.* 98, 254–263. doi: 10.1111/j.1439-0418.1984.tb02710.x

Heil, M. (2015). Extrafloral nectar at the plant-insect interface: a spotlight on chemical ecology, phenotypic plasticity, and food webs. *Ann. Rev. Entomol.* 60, 213–232. doi: 10.1146/annurev-ento-010816-020753

Heimpel, G. E., and Jervis, M. A. (2005). “Does floral nectar improve biological control of a pest in cotton?” in *Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and its Applications* (Cambridge: Cambridge University Press), 267–304.

Hemerik, L., and Yano, E. (2012). Evaluating the banker plant system for biologically controlling the cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae) and its oviposition selection between this system and eggplant (Solanum melongena) as alternative prey. *J. Appl. Entomol.* 136, 113–117. doi: 10.1111/j.1439-0418.1993.tb01176.x

Higashida, K., Yano, E., Mishikawa, S., Ono, S., Okuno, N., and Sakaguchi, T. (2016). Reproduction and oviposition selection by *Aphidolepis aphidimyzra* (Diptera: Cecidomyiidae) on the banker plants with alternative prey aphids or crop plants with pest aphids. *Appl. Entomol. Zool.* 51, 445–456. doi: 10.1007/s13355-016-0420-9

Higashida, K., Yano, E., Toyonishi, H., Nakaeuchi, M., and Abe, J. (2017). Reproduction of *Aphidolepis aphidimyzra* (Diptera: Cecidomyiidae) on a banker plant system of sorghum with *Melanaphis sacchari* (Hemiptera: Aleyrodidae) and its oviposition selection between this system and eggplant with *Aphis gossypii* (Hemiptera: Aphididae). *Appl. Entomol. Zool.* 52, 295–303. doi: 10.1007/s13355-017-0477-0

Hijazi, M. H., Saeed, K. A., Pourjafar, M., and Zare, A. (2017). *Aphidius colemani* (Viereck (Hym.): Aphidiidae) as a new alternative prey. *Entomol. Exp. Appl.* 161, 567–572. doi: 10.1111/1570-7458.12740

Holt, R. D. (1977). Predation, apparent competition, and the structure of prey communities. *Theor. Popul. Biol.* 12, 197–229. doi: 10.1016/0040-5809(79)90042-9

Holt, R. D., and Lawton, J. H. (1993). Apparent competition and enemy-free space in insect host-parasitoid communities. *Ann. Nat. 142, 623–645. doi: 10.1086/285561

Hongo, T., and Obayashi, N. (1997). Use of diapause eggs of brine shrimp, *Artemia salina* (Linne) for artificial diet of coccinellid beetle, *Harmonia axyridis* (Pallas). *Japan. J. Appl. Entomol. Zool.* 41, 101–105. doi: 10.1303/jjaz.41.101

Hogervorst, P. A., Wäckers, F. L., and Romeis, J. (2007). Detecting nutritional state and food source use in field-collected insects that synthesize honeydew oligosaccharides. *Punct. Ecol.* 21, 936–946. doi: 10.1111/j.1439-0418.2007.00129.x

Hogg, B. N., Bugg, R. L., and Daane, K. M. (2011). Attractiveness of common insectary and harvestable floral resources to beneficial insects. *Biol. Control. 56, 74–86. doi: 10.1016/j.biocontrol.2010.09.007

Holt, R. A., and Lawton, J. H. (1994). The ecological consequences of shared natural enemies. *Ann. Rev. Ecol. Syst.* 25, 495–520. doi: 10.1146/annurev.es.25.110194.002431

Hooperbrugge, H., van Houten, Y., van Baal, E., and Bolckmans, K. (2008). Alternative food sources to enable establishment of Amblyseius swirskii (Athias-Henriot) on chrysanthemum without pest presence. *IOBC/WPRS Bull.* 32:79.

Hooperbrugge, H., van Houten, Y. V., Knapp, M., and Bolckmans, K. (2011). Biological control of thrips and whitely on strawberries with Amblydromalus limonicus and Amblyseius swirskii. *IOBC/WPRS Bull.* 68, 65–69.

Huang, N., Enkegaard, A., Osborne, L. S., Ramakers, P. M., Messelink, G. J., Pijnakker, J., et al. (2011). The banker plant method in biological control. *Crit. Rev. Plant Sci.* 30, 259–278. doi: 10.1080/07352689.2011.572055

Hulshof, J., Kjota, E., and Vänninen, I. (2003). Life history characteristics of Frankliniella occidentalis on cucumber leaves with and without supplemental food. *Entomol. Exp. Appl.* 108, 19–32. doi: 10.1046/j.1570-7458.2003.00061.x

Hussein, M., Schumann, K., and Serram, H. (1993). Rearing immature feeding stage of *Orius majusculus* Reut. (Het., Anthocoridae) on the mite *Tyrophagus putrescentiae* Schr. as new alternative prey. *J. Appl. Entomol.* 116, 113–117. doi: 10.1111/j.1439-0418.1993.tb01176.x

Hussey, N. W., Parr, W. J., and Gould, H. J. (1965). Observations on the control of *Tetranychus urticae* kokh on cucumbers by the predatory mite *Phytoseius riegieli* dosse. *Entomol. Exp. Appl.* 8, 271–281. doi: 10.1017/S00175748.1965.tb00861.x

Hussey, N. W., Read, W. H., and Hesling, J. J. (1969). *The Pests of Protected Cultivation. The Biology and Control of Glasshouse and Mushroom Pests.* London: Edward Arnold Ltd.

Idris, A. B., and Grafius, E. (1995). Wildflowers as nectar sources for *Diadegma insulare* (Hymenoptera: Ichneumonidae), a parasitoid of diamondback moth (Lepidoptera: Yponomeutidae). *Environ. Entomol.* 24, 1726–1735. doi: 10.1093/ee/24.6.1726

Idris, A. B., and Graffus, E. (1996). Effects of wild and cultivated host plants on oviposition, survival, and development of diamondback moth (Lepidoptera: Plutellidae) and its parasitoid *Diadegma insulare* (Hymenoptera: Ichneumonidae). *Biocontrol. Sci. Technol.* 6, 221–232. doi: 10.1080/0958315990936321

Ishida, H., and Croft, P. (1998). Strategies for the control of *Aphis gossypii* Glover (Hom.: Aphididae) with *Aphidius colemani* Viereck (Hym.: Braconidae) in protected cucumbers. *Biocontrol. Sci. Technol.* 8, 377–387. doi: 10.1080/09583159830180
N. M., Turlings, T. C., and Rahier, M. (2001). Attraction of a leaf beetle (Oreina cacalia) to damaged host plants. J. Chem. Ecol. 27, 647–661. doi: 10.1023/A:1010389500009

Karban, R., and Baldwin, I. T. (1997). Induced Responses to Herbivory. Chicago, IL: University of Chicago.

Karban, R., English-Loeb, G., Walker, M. A., and Thaler, J. (1995). Abundance of phytoseiid mites on various species: effects of leaf hairs, domatia, prey abundance and plant phylogeny. Exp. Appl. Acarol. 19, 189–197. doi: 10.1016/0013-0082(95)00002-5

Kathir, S. A., Hamad, B. S., and AlMarsoon, M. D. (2015). Effects of different diet levels of Ephesia kuehniella eggs on life history parameters of Chrysoperla carnea (Thysanoptera: Chrysopidae) in the laboratory. Exp. Appl. Acarol. 40, 597–604. doi: 10.1603/EN10276

Koptur, S. (1992a). “Extrafloral nectary-mediated interactions between insects and plants,” in Insect-Plant Interactions, ed E. A. Bernays (Boca Raton, FL: CRC Press), 81–129.

Koptur, S. (1992b). Interactions between insects and plants mediated by extrafloral nectaries. CRC Series Insect/Plant Interact. 4, 85–132.

Kost, C., and Heil, M. (2005). Increased availability of extrafloral nectar reduces herbivory in Lime bean plants (Phaseolus lunatus, Fabaceae). Basic Appl. Ecol. 6, 237–246. doi: 10.1016/j.baae.2004.11.002

Kostaien, T., and Huy, M. A. (1994). Egg-harvesting allows large scale rearing of Amblyseius finlandicus (Acari: Phytoseiidae) in the laboratory. Exp. Appl. Acarol. 18, 155–165. doi: 10.1007/BF02335683

Kreiter, S., Tixier, M. S., and Bourgeois, T. (2003). Do generalist phytoseiid mites (Gamasida: Phytoseiidae) have interactions with their host plants? Int. J. Trop. Insect Sci. 23, 35–50. doi: 10.1017/S1742758400012236

Kumar, V., Wekesa, V. W., Avery, B. P., Powell, C. A., McKenzie, C. L., and Osborne, L. S. (2014). Effect of pollens of various ornamental pepper cultivars on the development and reproduction of Amblyseius swirskii (Acari: Phytoseiidae). Flora. 199, 367–373. doi: 10.1016/j.flora.2014.02.009

Kumar, V., Xiao, Y., McKenzie, C. L., and Osborne, L. S. (2015). Early establishment of the phytoseiid mite Amblyseius swirskii (Acari: Phytoseiidae) on pepper seedlings in a Predator-in-first approach. Exp. Appl. Acarol. 65, 465–481. doi: 10.1007/s10493-015-9895-2

Kuo-Sell, H. L. (1987). “Some bionomics of the predacious aphid midge, Aphidoletes aphidimyza (Rond.) (Diptera: Cecidomyiidae), and the possibility of using the rose grain aphid, Metopolophium dirhodum (Wilk.), as an alternative prey in an open rearing unit in greenhouses,” in Meeting of the BC Experts’ Group (Heraklion: Balkema), 24–26.

Kuo-Sell, H. L. (1989). Cereal aphids as a basis for the biological control of the peach aphid, Myzus persicae (Sulz.), with Apilodates aleopidhysa (Rond.) (Dipt., Cecidomyiidae) in greenhouses. J. Appl. Entomol. 107, 58–64. doi: 10.1111/j.1399-0418.1989.tb02288.x

Kütük, H. (2018). Performance of the predator Amblyseius swirskii (Athias-Henriot) (Acari: Phytoseiidae) on plastic greenhouse pepper sprayed vs unsprayed pine pollen. Derin 35, 135–140. doi: 10.16882/derin.2018.396951

Kütük, H., and Yigit, A. (2011). Pre-establishment of Amblyseius swirskii (Acari: Phytoseiidae) using Penus bratia (Ten.) (Pinales: Pinaceae) pollen for thrips (Thysanoptera: Thripidae) control in greenhouse peppers. J. Appl. Entomol. 135, 95–101. doi: 10.1111/j.1439-0418.1989.tb02288.x

Labbé, R. M., Fleury, G., Comeau, L., Moreau, J., and Osbourn, L. (2005). The function of wind-borne pollens on the population dynamics of Amblyseius hiberni (Acari: Phytoseiidae). Expomathysa 24, 83–98. doi: 10.1007/BF02277513

Janssen, A., and Sabelis, M. W. (2015). Alternative food and biological control by generalist predatory mites: the case of Amblyseius swirskii. Biol. Control 44, 413–418. doi: 10.1016/j.biocontrol.2014.04.007

Jannat, L., Bloemhard, C., and Klempe, R. (2014). Biodiversiteit Onder Glas. Voedel Voor Luizenbestrijders. Available online at: https://www.louisvork.nl/downloads/2819.pdf (accessed June 2020).

Jensen, T., and Osbourn, L. (2003). Biological control of aphids on cucumber in plastic greenhouses. Appl. Entomol. Zool. 38, 81–84. doi: 10.1303/aez.2003.633
Lucas, E., and Brodeur, J. (1999). Oviposition site selection by the predatory midge Aphidoletes aphidimyza (Diptera: Cecidomyiidae). Environ. Entomol. 28, 622–627. doi: 10.1093/ei/28.4.622

Lundgren, J. G. (2009). Relationships of Natural Enemies and non Prey Foods. Progress in Biological Control 7. New York, NY: Springer Science and Business Media.

Lundgren, J. G., Fergen, J. K., and Riedell, W. E. (2008). The influence of plant anatomy on oviposition and reproductive success of the omnivorous bug Orius insidiosus. Anim. Behav. 75, 1495–1502. doi: 10.1016/j.anbehav.2007.09.029

Lundgren, J. G., Huber, A., and Wiedenmann, R. N. (2005). Quantification of consumption of corn pollen by the predator Coleomelitta maculata (Coleoptera: Coccinellidae) during anthesis in an Illinois cornfield. Agr. For. Entomol. 7, 53–60. doi: 10.1111/j.1461-9555.2005.00246.x

Lundgren, J. G., and Wiedenmann, R. N. (2004). Nutritional suitability of corn pollen for the predator Coleomelitta maculata (Coleoptera: Coccinellidae). J. Insect Physiol. 50, 567–575. doi: 10.1016/j.jinsphys.2004.04.003

Lundstrom, A. N. (1887). Pflanzenbiologische Studien. II. Die Anpassungen der Pflanzen an Thiere. Nova Acta Regiae Soc. Sci. Upsal. 3, 1–87.

Lykouressis, D., Giatropoulos, A., Grigoriou, D., and Favas, C. (2008). Assessing the suitability of noncultivated plants and associated insect prey as food sources for the omnivorous predator Macroplophus pygmaeus (Hemiptera: Miridae). Biol. Control 44, 142–148. doi: 10.1016/j.biocontrol.2007.11.003

Lyon, J. P. (1973). Utilisation des entomophages pour la limitation des populations en serre. IOBC/WPRS Bull 4, 47–49.

Madadi, H. (2018). Enhancing predator efficiency, the recent advances. Arch. Phytopathol. Plant Prot. 51, 754–778. doi: 10.1007/s00354-018-14642-2

Maes, S., Antoons, T., Grégoire, J. C., and De Clercq, P. (2014). A semi-artificial rearing system for the specialist predator ladybird Cryptolaemus montrouzieri. Biocontrol 59, 557–564. doi: 10.1007/s10526-014-9585-8

Maisonneuve, J. C. (2002). Biological control in France in greenhouse vegetables and ornamentals. IOBC/WPRS Bull 25, 151–154.

Mandour, N. S., Ren, S. X., and Qiu, B. L. (2007). Effect of Bemisia tabaci honeydew and its carbohydrates on search time and parasitization of Encarsia formosa. J. Appl. Entomol. 131, 645–651. doi: 10.1111/j.1439-0418.2007.01165.x

Maoz, Y., Gal, S., Argov, Y., Domeratzky, S., Melamed, E., Gan-Mor, S., et al. (2014). Efficacy of indigenous predatory mites (Acari: Phytoseiidae) against the citrus rust mite Phytoseiulus oleivora (Acari: Eriophyidae): augmentation and conservation biological control in Israeli citrus orchards. Exp. Appl. Acarol. 63, 295–312. doi: 10.1007/s10493-014-9786-y

Markula, M., and Tiitinen, K. (1976). Pest in first and natural infestation methods in the control of Tetranychus urticae koch with Phytoseiulus persimilis ahtis-henriot on glasshouse cucumbers. Ann. Agr. Fenn. 51, 85–89.

Martin, C., Schoen, L., and Arrufat, A. (1998). “Systèmes de plantes relais en cultures maraîchères, exemple d’application au contrôle intégré d’Apis gossypii Glover en Languedoc Roussillon,” in First transnational workshop on biological, integrated and rational control: status and perspectives with regard to regional and European experiences, Lille, France, (Loosen-Gohelle: Service Régional de la Protection des Végétaux), 31–32.

Massaro, M., Martin, J. P. L., and de Moraes, G. J. (2016). Facititious food for mass production of predaceous phytoseiid mites (Acari: Phytoseiidae) commonly found in Brazil. Exp. Appl. Acarol. 70, 411–420. doi: 10.3390/insects6030772

Matsuo, T., Mochizuki, M., Yara, K., Matsuura, T., and Mochizuki, A. (2003). Suitability of pollen as an alternative diet for Amblyseius cucumeris (Oudeman). Jpn. J. Appl. Entomol. Zool. 47, 153–158. doi: 10.1303/jae.2003.153

Matsuo, T. (2002). Control of cotton aphid on strawberry by banker plants. Plant Prot. 37, 369–372.

Matteoni, J. A. (2003). “Economics of banker plant systems in Canadian greenhouse crops,” in Proceedings of the International Symposium on Biological Control of Arthropods, Honolulu, HI, ed R. G. VanDriesche (Washington, DC: USDA Forest Service, Forest Health Technology Enterprise Team), 154–157.

McCurre, T., and Frank, S. D. (2015). Grain diversity effects on banker plant growth and parasitism by Aphidius colemani. Insects 6, 772–791. doi: 10.3390/insects6030772

McCurre, T. J. (2014). Factors affecting aphid with banker plant systems [Master thesis]. North Carolina State University, Raleigh, NC,United States.
McMurtry, J. A., and Croft, B. A. (1997). Life-styles of phytoseiid mites and their roles in biological control. *Annu. Rev. Entomol.* 42, 291–321. doi: 10.1146/annurev.ento.42.1.291

McMurtry, J. A., and Johnson, H. G. (1965). Some factors influencing the abundance of the predatory mite *Amblyseius hibisci* in southern California (*Acarina: Phytoseiidae*). *Ann. Entomol. Soc. Am.* 58, 49–56. doi: 10.1093/aes/58.1.49

McMurtry, J. A., and Scriver, G. T. (1964). Studies on the feeding, reproduction, and development of *Amblyseius hibisci* (*Acari*: *Phytoseiidae*) on various food substances. *Ann. Entomol. Soc. Am.* 57, 649–655. doi: 10.1093/aes/57.5.649

McMurtry, J. A., and Scriver, G. T. (1966). Studies on predator-prey interactions between *Amblyseius hibisci* and *Oligonychus punicea* (*Acarina*: *Phytoseiidae*, *Tetranychidae*) under greenhouse conditions. *Ann. Entomol. Soc. Am.* 59, 793–800. doi: 10.1093/aes/59.4.793

Messeling, G. J., van Steenpaal, S., and van Wensveen, W. (2005). *Typhlodromips swirskii* (Attilas-Henriot) (*Acari*: *Phytoseiidae*): a new predator for thrips control in greenhouse cucumber. IOBC/WPRS Bull. 28, 183–186.

Messeling, G. J., Bennison, J., Alomar, O., Ingemog, R. L., Tavella, L., Shipp, L., et al. (2014). Approaches to conserving natural enemy populations in greenhouse crops: current methods and future prospects. *Biocontrol* 59, 377–393. doi: 10.1007/s10526-014-9579-6

Messeling, G. J., Bloemhard, C. M. J., Hoogerbrugge, H., Van Schelt, J., Ingegno, M., Midthassel, A., Leather, S. R., and Baxter, I. H. (2013). Life table parameters and development of *Amblyseius swirskii* (Hymenoptera: Aphidiidae), as a parasitoid of *Aphidius matricariae* (*Hymenoptera*: *Aphidiidae*). *Acta Phytopathol. Pl. Prot.* 61, 69–78. doi: 10.1007/s10526-013-9553-8

Momen, F. M., and El-Laithy, A. Y. (2007). Suitability of the scale mite *Neoseiulus tenuis* (L. Koch, 1900) under greenhouse conditions. *Jpn. J. Appl. Entomol. Zool.* 55, 199–205. doi: 10.1111/j.1744-7348.2007.01006.x

Monks, A., O’Connell, D. M., Lee, W. G., Bannister, J. M., and Dickinson, K. J. (2007). Benefits associated with the domatia mediated tritrophic mutualism in the shrub *Cuprosma lucida*. *Oikos* 116, 873–881. doi: 10.1111/j.0030-1299.2007.15654.x

Montserrat, M., Guzmán, C., Sahún, R. M., Belda, J. E., and Hormaza, J. I. (2013). Pollen supply promotes, but high temperatures demote, predatory mite abundance in avocado orchards. *Agric. Ecosyst. Environ.* 164, 155–161. doi: 10.1016/j.agee.2012.09.014

Mullen, G. R., and O’Connor, B. M. (2019). *Mites* (*Acari*): in *Medical and veterinary entomology*. Academic Press. 533–602. doi: 10.1016/B978-0-12-814043-7.00026-1

Muñoz-Cárdenas, K., Ersin, F., Pijnakker, I., van Houten, Y., Hoogerbrugge, H., Leman, A., et al. (2017). Supplying high-quality alternative prey in the litter increases control of an above-ground plant pest by a generalist predator. *Biocontrol* 105, 19–26. doi: 10.1016/j.biocontrol.2016.11.004

Nagasaka, K., Takahashi, N., Okabayashi, T. (2010). Impact of secondary parasitism on *Amblyseius colemani* in the banker plant system on aphid control in commercial greenhouses. *Plant Prot.* 57, 505–509.

Nagasaka, K., Takahashi, N., and Okabayashi, T. (2009). Development of a practical banker plant system for aphid control in commercial greenhouse crops in Japan. *Bull. Nat. Agric. Res. Center* 15, 1–39.

Nakaishi, K., Fukui, Y., and Arakawa, R. (2011). Reproduction of *Nesidiocoris tenuis* (O. Alomar and R. N. Wiedenmann) (Lanham, MD: Entomological Society of America), 57–93.

Nakaishi, K., Fukui, Y., and Arakawa, R. (2011). Reproduction of *Nesidiocoris tenuis* (O. Alomar and R. N. Wiedenmann) (Lanham, MD: Entomological Society of America), 57–93.

Nagai, K., Hirose, Y., Takagi, M., Nakashima, Y., and Hiramatsu, T. (1998). A practical application of a banker plant system for aphid control in greenhouse peppers. *Plant Prot.* 34, 199–205.

Nagasaka, K., and Oya, S. (2003). A practical application of a banker plant system to aphid control in greenhouses. *Plant Prot.* 57, 505–509.

Nagasaka, K., Takahashi, N., and Okabayashi, T. (2009). Development of a practical banker plant system for aphid control in commercial greenhouse crops in Japan. *Bull. Nat. Agric. Res. Center* 15, 1–39.

Nakai, K., Fukui, Y., and Arakawa, R. (2011). Reproduction of *Nesidiocoris tenuis* (O. Alomar and R. N. Wiedenmann) (Lanham, MD: Entomological Society of America), 57–93.

Naganuma, K., and Oya, S. (2003). A practical application of a banker plant system to aphid control in greenhouses. *Plant Prot.* 57, 505–509.

Naganuma, K., and Oya, S. (2003). A practical application of a banker plant system to aphid control in commercial greenhouses in Kochi. *Ipn. J. Appl. Entomol. Zool.* 45, 541–550. doi: 10.1303/aez.2010.541

Naganuma, K., Takahashi, N., Okabayashi, T., Abe, J., and Ohyama, S. (2011). Development of a practical banker plant system for aphid control in commercial greenhouse crops in Japan. *Bull. Nat. Agric. Res. Center* 59, 379–384. doi: 10.1303/aez.2010.541

Naranjo, S. E., and Gibson, R. L. (1996). “Phytophagy in predatory heteroptera: effects on life history and population dynamics,” in *Zoophytophagous Heteroptera: Implications for Life History and Integrated Pest Management*, eds O. Alomar and R. N. Wiedenmann (Lanham, MD: Entomological Society of America), 57–93.

Naselli, M., Urbanneja, A., Siscaro, G., Jaques, J. A., Zappalà, L., Flors, V., et al. (2016). Stage-related defense response induction in tomato plants by *Neodioicoris tenuis*. *Int. J. Mol. Sci.* 17:1210. doi: 10.3390/ijms17081210

Navarro-Campos, C., Bekas, A., Moroza, M. L., Aguilar, A., and García-Marí, F. (2012). Soil-dwelling predatory mites in citrus: their potential as natural enemies of thrips with special reference to *Pezotrips kelyanusa* (*Thysanoptera*: *Thripidae*). *Biocontrol* 63, 201–209. doi: 10.1016/j.biocontrol.2012.07.007

Navarro-Campos, C., Wackers, F. L., and Bekas, A. (2016). Impact of factitious foods and prey on the oviposition of the predatory mites *Gaeolaelaps aculeifer* and *Stratodolaelaps scinitus* (*Acari*: *Elaedoptidae*). *Exp. Appl. Acarol.* 40, 69–78. doi: 10.1007/s10493-016-0691-2

Nevs Esteca, F. D. C., Trandem, N., Klingen, I., Cruz Santos, J., Delalibera Júnior, I., and de Moraes, G. J. I. (2020). Cereal straw mulching in strawberry – a facilitator of plant visits by edaphic predatory mites at night? *Diversity* 12:242. doi: 10.3390/d12060242
(Trialeurodes vaporariorum) on tomatoes. Ann. Appl. Biol. 83, 349–363. doi: 10.1111/j.1744-7348.1976.tb01707.x

Parr, W. J., and Stacey, D. L. (1975). ‘Banker’-plant system of whitely parasitic release on tomatoes. Rep. Glasshouse Crops Res. Inst. 26, 63–66. doi: 10.1111/j.1365-3059.1977.tb01023.x

Pascual, M. S., Rocca, M., Greco, N., and De Clercq, P. (2020). Typha angustifolia L. as an alternative food for the predatory mite Neoseiulus californicus (McGregor) (Acari: Phytoseiidae). Syst. Appl. Acarol. 25, 51–62. doi: 10.11158/saa.25.1.4

Patt, J. M., Wainright, S. C., Hamilton, G. C., Whittinghill, D., Bosley, K., Dietrick, J., et al. (2010). Assimilation of carbon and nitrogen from pollen and nectar by a predaceous larva and its effects on growth and development. Ecol. Entomol. 28, 717–728. doi: 10.1111/j.1365-2313.2003.00556.x

Payton Miller, T. L., and Rebek, E. J. (2018). Banker plants for aphid biological control in greenhouses. J. Integr. Pest Manag. 9, doi: 10.1093/jipm/pyy002

Pease, C. G., and Zalom, F. G. (2010). Influence of non-crop plants on stink bug reproductive success over the extended flowering season of a Mediterranean shrub. Oecologia 163, 626–636. doi: 10.1111/j.1439-0418.2009.01452.x

Pekas, A., de Craecker, I., Boonen, S., Wäckers, F. L., and Morkens, R. (2019). Influence of food supplements on the distribution of eggs in selected field and vegetable crops by Nabis roseipennis and Frankliniella occidentalis as an insectary plant for the conservation of Orius majusculus. IOBC/WPRS Bull. 41, 201–207. doi: 10.1016/j.biocontrol.2012.03.007

Pina, T., Argolo, P. S., Urbanjka, A., and Jacas, J. A. (2012). Effect of pollen quality on the efficacy of two different life-style predatory mites against Tetranychus urticae in citrus. Biol. Control 61, 176–183. doi: 10.1016/j.biocontrol.2012.02.003

Pina, T., Argolo, P. S., Urbanjka, A., Jacas, J. A., and de Investigaciones Agrarias, V. (2015). Pollen Quality Affects Biological Control of Tetranychus urticae in Clementine Mandarins. XII Int. Citrus Cong. Int. Soc Citricult. 1065, 1133–1136. doi: 10.17660/AcataHorticult.2015.1065.143

Pineda, A., and Marcos-Garcia, M. Á. (2008). Use of selected flowering plants in greenhouses to enhance aphidophagous hoverfly populations (Diptera: Syrphidae). Ann. Soc. Entomol. France 44, 487–492. doi: 10.1051/anves:2008012

Polis, G. A., and Holt, R. D. (1992). Intraguild predation: the dynamics of complex trophic interactions. Trends Ecol. Ecol. Evol. 7, 151–154. doi: 10.1016/0169-5347(92)90208-S

Portillo, N., Alomar, O., and Wackers, F. (2012). Nectarity of the plant-tissue feeding predator Macrolophus pygmaeus Rambur (Heteroptera: Miridae): Nutritional redundancy or nutritional benefit? J. Insect Physiol. 58, 397–401. doi: 10.1016/j.jinsphys.2011.12.013

Pirayeshfar, F., Safavi, S. A., Sarrafi Moayeri, H. R., and Messelin, G. J. (2020). The potential of highly nutritious frozen stages of Tyrophagus putrescentiae as a supplemental food source for the predatory mite Amblyseius swirskii. Biocontrol Sci. Technol. 30, 403–417. doi: 10.1080/09583157.2020.1727298

Polis, G. A., and Holt, R. D. (1992). Intraguild predation: the dynamics of complex trophic interactions. Trends Ecol. Ecol. Evol. 7, 151–154. doi: 10.1016/0169-5347(92)90208-S

Prado, S. G., Myers, C. A., and Holt, R. D. (1989). The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu. Rev. Ecol. Syst. 20, 297–330. doi: 10.1146/annurev.es.20.110189.001501

Popenoe, J., and Osborne, L. (2010). Rose nursery banker plants. Proc. Fla. State Hort. Soc. 123, 296–297.

Pineda, A., and Marcos-Garcia, M. Á. (2008). Use of selected flowering plants in greenhouses to enhance aphidophagous hoverfly populations (Diptera: Syrphidae). Ann. Soc. Entomol. France 44, 487–492. doi: 10.1051/anves:2008012

Polis, G. A., and Holt, R. D. (1992). Intraguild predation: the dynamics of complex trophic interactions. Trends Ecol. Ecol. Evol. 7, 151–154. doi: 10.1016/0169-5347(92)90208-S

Polis, G. A., Myers, C. A., and Holt, R. D. (1989). The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu. Rev. Ecol. Syst. 20, 297–330. doi: 10.1146/annurev.es.20.110189.001501

Portillo, N., Alomar, O., and Wackers, F. (2012). Nectarity of the plant-tissue feeding predator Macrolophus pygmaeus Rambur (Heteroptera: Miridae): Nutritional redundancy or nutritional benefit? J. Insect Physiol. 58, 397–401. doi: 10.1016/j.jinsphys.2011.12.013

Prabahker, N., Castle, S. J., Naranjo, S. E., Toscano, N. C., and Morse, J. G. (2011). Compatibility of two systemic neonicotinoids, imidacloprid and thiamethoxam, with various natural enemies of agricultural pests. J. Econ. Entomol. 104, 773–781. doi: 10.1603/EC10362

Prado, S. G., and Frank, S. D. (2014). Optimal foraging by an aphid parasitoid affects the outcome of apparent competition. Ecol. Entomol. 39, 236–244. doi: 10.1111/een.12093

Prado, S. G., Jandricic, S. E., and Frank, S. D. (2015). Ecological interactions affecting the efficacy of Aphidos holosericeus in greenhouse crops. Insects 6, 538–575. doi: 10.3390/insects6020538

Pratt, P. D., and Croft, B. A. (2000). Banker plants: evaluation of release strategies for predatory mites. J. Environ. Hort. 18, 211–217. doi: 10.24266/0738-2898-18.4.211

Prevereri, G., Simoni, S., and Liguori, M. (2006). Suitability of Quercus ilex pollen for rearing four species of phytoseid mites (Acari: Phytoseiidae). Redia. Frienz. 89, 65–71.

Price, P. W., Bouton, C. E., Gross, P., McPherson, B. A., Thompson, J. N., and Weis, A. E. (1980). Interactions among three trophic levels: influence of plants on interactions between insect herbivores and natural enemies. Annu. Rev. Ecol. Syst. 11, 41–65. doi: 10.1146/annurev.es.11.010800.000533

Pumarío, L., and Alomar, O. (2012). The role of omnivory in the conservation of predators: Orius majusculus (Heteroptera: Anthocoridae) on sweet alyssum. Biol. Control. 62, 24–28. doi: 10.1016/j.biocontrol.2012.03.007

Pumarío, L., and Alomar, O. (2014). Assessing the use of Lobularia maritima as an insectary plant for the conservation of Orius majusculus and biological control of Frankliniella occidentalis. IOBC/WPRS Bull. 100, 113–116.

Put, K., Bollens, T., Wackers, F., and Pekas, A. (2015). Non-target effects of commonly used plant protection products in roses on the predatory mite Euseius gallicus Kreiter & Tüxen (Acari: Phytoseiidae). Pest Manag. Sci. 72, 1373–1380. doi: 10.1002/ps.4162

Put, K., Bollens, T., Wackers, F. L., and Pekas, A. (2012). Type and spatial distribution of food supplements impact population development and dispersal
of the omnivore predator Macrolophas pygmaeus (Rambur) (Hemiptera: Miridae). *Biol. Control* 63, 172–180. doi: 10.1016/j.biocontrol.2012.06.011

Rabie, A. L., Wells, J. D., and Dent, L. K. (1985). The nitrogen content of pollen protein. *J. Api. Res.* 22, 119–123. doi: 10.1080/00218839.1985.11100572

Ragusa, E., Tsolakis, H., and Palomero, R. J. (2009). Effect of pollens and preys on various biological parameters of the generalist mite *Cynodromus californicus*. *Bull. Insect.* 62, 153–158.

Ragusa, S., Vargas, R., Tsolakis, H., and Ashbach, R. (2000). Laboratory studies on the influence of various food substances on some biological and life-table parameters of *Cynodromus picanus* Ragusa (Paraflatomers, Phytoseiidae) associated with citrus trees in the Chilean desert. *Physiopathology* 10, 11–23.

Ramakers, P., and van Lieburg, M. (1982). Start of commercial production and introduction of *Amblyseius mckenziei* (Sch. and Pr.) (Acarina: Phytoseiidae) for the control of *Thrips tabaci* Lind. (Thysanoptera: Thripidae) in glasshouses, *Med. Fac. Landbouww. Univ. Gent* 47, 541–545.

Ramakers, P. M. J. (1990). Manipulation of phytoseiid thrips predators in the absence of thrips. *IOBC/WPRS Bull.* 13, 169–172.

Ramakers, P. M. J. (1995). “Biological control using oligophagous predators,” in *Thrips biology and management*, eds B. I. Parker, M. Skinner, and T. Lewis (New York, NY: Plenum Press) 225–229. doi: 10.1007/978-1-4899-1409-5_33

Ramakers, P. M. J., and Maaswinkel, R. H. M. (2002). Pest occurrence and control in organic year-round production of chrysanthemums. *IOBC/WPRS Bull.* 25, 221–224.

Ramakers, P. M. J., and Voet, S. J. I. P. (1995). Use of castor bean, *Ricinus communis*, for the introduction of the thrips predator *Amblyseius degenerans* on glasshouse-grown sweet peppers. *Med. Fac. Landbouww. Univ. Gent.* 60, 885–891.

Ranabhat, N. B., Goleva, I., and Zebitz, C. P. (2014). Life tables of *Neoseiulus cucumeris* exclusively fed with seven different pollens. *Biocontrol* 59, 195–203. doi: 10.1016/j.biocontrol.2014.03.003

Rasmy, A. H., and El-Banhawy, E. M. (1975). Biology and predatory efficiency of *Amblyseius khalidii* (Chauveau) (Acari: Phytoseiidae) on *Ganoderma applanatum* (McGregor) during long-term preservation on maize pollen. *Neotrop. Entomol.* 30, 625–629. doi: 10.1590/S1519-566X2001000400017

Ragusa, E., Rivest, S., and Forrest, J. R. (2020). Defence compounds in pollen: why do they occur and how do they affect the ecology and evolution of bees? *New Phytol.* 225, 1053–1064. doi: 10.1111/nph.16230

Roda, A., Nyrop, J., Dicke, M., and English-Loeb, G. (2000). Trichomes and spidermite webbing protect predatory mite eggs from intraguild predation. *Oecologia* 125, 428–435. doi: 10.1007/s004420000462

Roda, A., Nyrop, J., English-Loeb, G., and Dicke, M. (2001). Leaf pubescence and two-spotted spider mite webbing influence phytoseiid behavior and population density. *Oecologia* 129, 551–560. doi: 10.1007/s004420100762

Rodrigues, S. M., and Bueno, V. H. (2001). Parasitism rates of *Lysiphlebus testaceipes* (Cresson) (Hym.: Aphidiidae) on *Schiziphis graminum* (Rond.) and *Aphis gossypii* Glover (Hem.: Aphididae). *Neopt. Entomol.* 30, 625–629. doi: 10.1590/S1519-566X200000017

Rodriguez-Cruz, F. A., Venzon, M., and Pinto, C. M. F. (2013). Performance of *Epehepsia huyshperi* and *Corycera cephaloncica* eggs as alternative prey for rearing predatory mites. *Egypt. J. Biol. Pest Control* 14, 101–105. doi: 10.1186/1332-9396-14-35

Romero, G. Q., and Benson, W. W. (2004). Leaf domiatia mediate mutualism between mites and a tropical tree. *Oecologia* 140, 609–616. doi: 10.1007/s00442-004-1626-z

Romero, G. Q., and Benson, W. W. (2005). Biotic interactions of mites, plants and leaf domiatia. *Curr. Opin. Plant Biol.* 8, 436–440. doi: 10.1016/j.pbi.2005.05.006

Roulston, T. H., and, Cane, J. H. (2000). Pollen nutritional content and digestibility for animals, *Pl. Ecol. Evol.* 222, 187–209. doi: 10.1590/BF00984102

Rozario, S. A. (1995). Association between mites and leaf domiatia: evidence from Bangladesh, *South Asia J. Trop. Ecol.* 11, 99–108. doi: 10.1017/S0266476400008440

Rozario, S. A. (1994). *Domatia and mites: effects of leaf morphology on beneficial mites in semi–natural and managed systems* [Doctorial dissertation]. Monash University. Retrieved from: https://catalogue.nla.gov.au/Record/2275037 (accessed June 2020)

Rueda-Ramirez, D., Rios-Malver, D., Varela-Ramirez, A., and De Moraes, G. J. (2018). Colombian population of the mite *Gaeolaelaps aculeifer* as a predator of the thrips *Frankliniella occidentalis* and the possible use of an astigmatid mite as its factitious prey. *Syst. Appl. Acarol.* 23, 2359–2372. doi: 10.11158/saa.23.12.8

Rumei, X. (1991). Improvements of the plant-pest-parasitoid (PPP) model and its application on whitely-encarsia population dynamics under different release methods. *J. Appl. Entomol.* 112, 274–287. doi: 10.1111/j.1439-0418.1991.tb03107.x

Sabelis, M. W., Janssen, A., Bruin, J., Bakker, F. M., Dukker, B., Scutareanu, P., et al. (1999). “Interactions between arthropod predators and plants: a conspiracy against herbivorous arthropods?” in *Ecology and Evolution of the Acari* (Dordrecht: Springer), 207–229.

Sabelis, M. W., and van Rijn, P. C. (2006). When does alternative food promote biological pest control? *IOBC/WPRS Bull.* 29,195.

Saber, S. A. (2012). Biological aspects and life parameters of the predacious mite, *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae) consuming food types during immature stages and after adult emergence. *Arch. Phytopathol. Plant Prot. North Jpn* 35, 249–251. doi: 10.1080/03235408.2012.730887

Saber, S. A. (2013). Survival, fecundity and reproductive recovery period of *Neoseiulus californicus* (McGregor) during long-term preservation on maize pollen and after switch to *Tetranychus urticae* Koch. *Arch. Phytopathol. Plant Prot.* 46, 789–795. doi: 10.1080/03235408.2012.752144

Sade, A., Steinberg, S., Salinger-Bulblov, M., Gilboa, E., Klempert, G., Roitman, N., et al. (2019). Improved western flower thrips control through artemia-based early introduction of *Orius laevigatus* in commercial pepper greenhouses. *IOBC/WPRS Bull.* 47, 39–46.

Saito, Y., and Mori, H. (1975). *The Effects of Pollen as an Alternative Food for Three Species of Phytoseiid Mites (Acarina: Phytoseiidae)*. Memoirs of the Faculty of Agriculture-Hokkaido University, 236–246.

Saito, M. (2005). Control of cotton aphid, *Aphis gossypii*, on greenhouse-raised cucumber by releasing *Aphidius colemani* on banker plants. *Annu. Rep. Soc. Plant Prot. North Jpn* 56, 137–140.

Salmeron, A., Gabarra, R., and Albajes, R. (1987). Observations on the predatory and phytophagous habits of *Dicaphus tamaninii* Wagner (Heteroptera: Miridae). *IOBC/WPRS Bull.* 10, 165–169.

Salas-Aguilar, J., and Ehler, L. E. (1977). Feeding habits of *Orius tristicolor*. *Ann. Entomol. Soc. Am.* 70, 60–62. doi: 10.1093/aeas/70.1.60
Sun, H. Z., Wang, X. D., Chen, Y. G., Wang, H. T., Li, S. J., and Song, Y. Q. (2017). Wheat and barley as banker plant in the mass production of *Aphidius gifuensis* Ashmead (Hymenoptera: Braconidae) parasitizing *Schizaphis graminum* Rondani (Homoptera: Aphididae). *J. Plant Dis. Prot.* 124, 305–311. doi: 10.1017/s01431480-016-0059-3

Swirski, E. (1967). Laboratory studies on the feeding, development and oviposition of the predaceous mite *Tylodelphus athiasae* P. and S. (Acarina: Phytoseiidae) on various kinds of food substances. *Israel J. Agric. Res.* 17, 213–218.

Tanigoshi, L. K., Mégevand, B., and Yaninek, J. S. (1993). Non-prey food for subsistence of *Amblyseius idaeus* (Acari: Phytoseiidae) on cassava in Africa. *Exp. Appl. Acarol.* 17, 91–96.

Tavella, L., and Arzone, A. (1996). "Development of *Macrolophus caliginosus* and *Dicyphus errans* reared on different diets (Rhyzochota Miridae);" in *Proceedings of the XXth International Congress on Entomology*. Tipografia TAF Srl (Firenze).

Tena, A., Pekas, A., Cano, D., Wackers, F. L., and Urbanse, A. (2015). Sugar provisioning maximizes the biocontrol service of parasitoids. *J. Appl. Ecol.* 52, 795–804. doi: 10.1111/1365-2664.12426

Todd, F. E., and Brederick, O. (1942). The composition of pollens. *J. Econ. Entomol.* 35, 312–317. doi: 10.1093/jee/35.3.312

Tommasini, M. G., and Nicoli, G. (1993). Adult activity of four *Phytoseius* species reared on two prey. *IOBC/WPRS Bull.* 16, 181–184.

Tuovinen, T., and Lindqvist, I. (2010). Maintenance of predatory phytoseiid *Amblyseius swirskii* when it is also edible to herbivores. *Ecology* 83, 2664–2679. doi: 10.1890/0012-9658(2002)083[2664:HEHAPP]2.0.CO;2

Van Schelt, J., and Vangansbeke, D. (1999). Contribution of extrafloral nectar to survival and reproduction of the predatory mite *Iphiseius degenerans* on *Ricinus communis*. *Exp. Appl. Acarol.* 23, 281–296. doi: 10.1016/0789-9470(94)00028-6

Van Rijn, P. C. J., and Tanigoshi, L. K. (1999a). Pollen as food for predatory mites *Iphiseius degenerans* and *Neoseiulus cucumeris* (Acari: Phytoseiidae); dietary range and life history. *Exp. Appl. Acarol.* 23, 785–802. doi: 10.1023/A:1006227704122

Van Rijn, P. C. J., and Tanigoshi, L. K. (1999b). The contribution of extrafloral nectar to survival and reproduction of the predatory mite *Iphiseius degenerans* on *Ricinus communis*. *Exp. Appl. Acarol.* 24, 221–229. doi: 10.1016/0789-9470(97)00001-9

Van Rijn, P. C. J., van Houten, Y. M., and Sabelis, M. W. (1999). Pollen improves thrips control with predatory mites. *IOBC/WPRS Bull.* 22, 209–212.

Van Rijn, P. C. J., van Houten, Y. M., and Sabelis, M. W. (2002). How plants benefit from providing food to predators even when it is also edible to herbivores. *Ecology* 83, 2664–2679. doi: 10.1890/0012-9658(2002)083[2664:HEHAPP]2.0.CO;2

Van Rijn, P. C. J., van Houten, Y. M., and Sabelis, M. W. (2002). How plants benefit from providing food to predators even when it is also edible to herbivores. *Ecology* 83, 2664–2679. doi: 10.1890/0012-9658(2002)083[2664:HEHAPP]2.0.CO;2

Van Rijn, P. C. J., van Houten, Y. M., and Sabelis, M. W. (1999). Pollen improves thrips control with predatory mites. *IOBC/WPRS Bull.* 22, 209–212.

Van Rijn, P. C. J., and Sabelis, M. W. (1992). Does alternative food always enhance biological control? The effect of pollen on the interaction between western flower thrips and its predators [*Amblyseius cucumeris*]. *OILB SROP Bull.* 16, 123–125.

Van Rijn, P. C. J., and Sabelis, M. W. (1993). Does alternative food always enhance biological control? The effect of pollen on the interaction between western flower thrips and its predators [*Amblyseius cucumeris*]. *OILB SROP Bull.* 16, 123–125.

Van Rijn, P. C. J., and Sabelis, M. W. (2003). "Mass production, storage, shipment and release of natural enemies," in *Quality Control and Production of Biological Control Agents, Theory and Testing Procedures* (Wallfording, CT: CAB International), 181–189.

Van Rijn, P. C., and Wackers, F. L. (2016). Nectar accessibility determines fitness, flower choice and abundance of hoverflies that provide natural pest control. *J. Appl. Ecol.* 53, 925–933. doi: 10.1111/1365-2664.12605

Van Rijn, P. C. J., and Sabelis, M. W. (1990). Pollen as an alternative food source for predatory mites and its effect on the biological control of thrips in greenhouses. *In Proc. Exp. Appl. Entomol.* 1, 44–48.

Van Rijn, P. C. J., and Tanigoshi, L. K. (2017). Using biological control as a first line of defense from 'Start Quality Control and Production of Biological Control Agents, Theory and Testing Procedures' (Wallfording, CT: CAB International), 181–189.

Vangansbeke, D., Van der Linden, A., Nguyen, D. T., Audenaert, J., Gobin, B., Tirry, L., and De Clercq, P. (2016a). Establishment of *Amblyseius swirskii* in greenhouse crops using food supplements. *Syst. Appl. Acarol.* 21, 1174–1184. doi: 10.11158/saa.21.9.2

Vangansbeke, D., Nguyen, D. T., Audenaert, J., Verhoeven, R., Deforce, K., Gobin, B., et al. (2014a). Diet-dependent cannibalism in the omnivorous phytoseiid mite *Amblydromalus limonicus*. *Biological Control* 74, 30–35. doi: 10.1016/j.biocontrol.2014.03.015

Vangansbeke, D., Nguyen, D. T., Audenaert, J., Verhoeven, R., Gobin, B., Tirry, L., et al. (2014b). Food supplementation affects interactions between a phytoseiid predator and its omnivorous prey. *Biological Control* 76, 95–100. doi: 10.1016/j.biocontrol.2014.06.001

Vangansbeke, D., Nguyen, D. T., Audenaert, J., Verhoeven, R., Gobin, B., Tirry, L., et al. (2014c). Performance of the predatory mite *Amblydromalus limonicus* on factitious foods. *Biological Control* 59, 67–77. doi: 10.1016/j.biocontrol.2014.06.001

Vangansbeke, D., Nguyen, D. T., Audenaert, J., Verhoeven, R., Gobin, B., Tirry, L., et al. (2016b). Supplemental food for *Amblyseius swirskii* in the control of thrips: feeding friend or foe? *Pest Manage. Sci.* 72, 466–473. doi: 10.1002/ps.4000

Vantornout, H., Mijnheer, H., and Tirry, L. (2004). Effect of pollen, natural prey and factitious prey on the development of *Iphiseius degenerans*. *Biological Control* 49, 627–644. doi: 10.1016/j.biocontrol.2004.05.280-5

Vergniaud, P. (1997). Lutte biologique sous abri: les plantes relais contre *Aphis gossypii* (*PHA* Revue Horticole* 384, 44–45.

Vieira Marques, R., Almeida Sarmento, R., Alves Ferreira, V., Venzon, M., Lemos, F., Pedro-Neto, M. et al. (2014). Alternative food sources to predatory mites (*Acari*) in a *Jatropha curcas* (*Euphorbiaceae*) crop. *Rev. Colomb. Entomol.* 40, 74–79.
Vila, E. (2004). Refugis vegetals en la conservació de mirids depredadors [Ph.D. Thesis]. Universitat de Lleida, Lleida, Spain.

Vila, E., del Mar Morales, M., and Parra, A. (2017). Prey mites as an in-crop food: an innovative strategy to enhance biocontrol on chrysanthemums. IOBC/WPRS Bull. 124, 178–182.

Villanueva, R. T., and Childers, C. C. (2004). Phytoseiidae increase with pollen deposition on citrus leaves. Fla. Entomol. 87, 609–611. doi: 10.1653/0015-4040(2004)087[609:PIATCF]2.0.CO;2

Wäckers, F. L. (1999). Gustatory response by the hymenopteran parasitoid Cotesia glomerata to a range of nectar and honeydew sugars. J. Insect Physiol. 47, 1077–1084. doi: 10.1006/jisr.2000.00088-9

Wäckers, F. L. (2000). Do oligosaccarides reduce the suitability of honeydew for predators and parasitoids? A further facet to the function of insect-synthesized honeydew sugars. Oikos 90, 197–201. doi: 10.1034/j.1600-0706.2000.900124.x

Wäckers, F. L. (2005). “Suitability of (extra-) floral nectar, pollen, and honeydew as insect food. Plant-provided food for carnivorous insects: a protective mutualism and its applications,” in Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications, eds Jan Bruin, P. C. J. van Rijn, and F. L. Wäckers (Cambridge: Cambridge University Press), 17–76.

Wäckers, F. L., and Bonfay, C. (2004). How to be sweet? Extraloral nectar allocation by Gossypium hirsutum fits optimal defense theory predictions. Ecology 85, 1512–1518. doi: 10.1890/03-0422

Wäckers, F. L., Romeis, J., and van Rijn, P. (2007). Nectar and pollen feeding by insect herbivores and implications for multitrophic interactions. Annu. Rev. Entomol. 52, 301–323. doi: 10.1146/annurev.ento.52.110405.091352

Wäckers, F. L., and Steppuhn, A. (2003). Characterizing nutritional state and food source use of parasitoids collected in fields with high and low nectar availability. IOBC/WPRS Bull. 26, 203–208.

Wäckers, F. L., and van Rijn, P. C. (2005). “Food for protection: an introduction,” in Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications, eds Jan Bruin, P. C. J. van Rijn, and F. L. Wäckers (Cambridge: Cambridge University Press), 1–14.

Wäckers, F. L., van Rijn, P. C., and Heimpel, G. E. (2008). Honeydew as a food source for natural enemies: making the best of a bad meal? IOBC/WPRS Bull. 37, 101–114. doi: 10.1016/j.biocoweb.2008.07.002

Wäckers, F. L., and van Rijn, P. C. (2012). Predators and Parasitoids-in-First (eds G. M. Murphy, G. ed D. V. Alford) (Oxford: Blackwell Science), 1–18.

Wojciechowicz-Zytko, E., and Wnuk, A. (2007). Effect of intercropping of broad bean (Vicia faba L.) with tansy phacelia (Phacelia tanacetifolia Benth.) on the occurrence of Apis fabe Scop. and predatory syrphidae. Aphids Other Hemipterous Insects 13, 211–217.

Wojciechowicz-Zytko, E., and Jankowska, B. (2016). Sambucus nigra L. as a reservoir of beneficial insects (Diptera, Syrphidae). Folia Hortic. 28, 209–216. doi: 10.1515/fohrt-2016-0025

Wong, S. K., and Frank, S. D. (2012). Influence of banker plants and spiders on biological control of Orius insidiosus (Heteroptera: Anthocoridae). Biol. control 63, 181–187. doi: 10.1016/j.biocontrol.2012.07.001

Wong, S. K., and Frank, S. D. (2013). Pollen increases fitness and abundance of Orius sauteri (Heteroptera: Anthocoridae) in greenhouse tomato production. Biol. Control 64, 45–50. doi: 10.1016/j.biocontrol.2012.09.015

Xia, B., Zou, Z., Li, P., and Lin, P. (2012). Effect of temperature on development and reproduction of Neoseiulus barkeri (Acari: Phytoseiidae) fed on Aleuroglus ovatus. Exp. Appl. Acarol. 56, 33–41. doi: 10.1007/s10493-011-9481-1

Yang, S., Duan, Y., Jiang, Y., Shen, X., Liu, S., et al. (2009). Influence of prey species on growth, development and reproduction of Orius sauteri. Sci. Agricult. Sin. 42, 900–905.
Yano, E. (2006). Ecological considerations for biological control of aphids in protected culture. *Popul. Ecol.* 48:333. doi: 10.1007/s10144-006-0008-2

Yano, E., Nishikawa, S., Yamane, M., and Abe, J. (2009). Development of the use of the banker plant system to control aphids in protected culture in Japan. *IOBC/WPRS Bull.* 49, 259–262

Yano, E., Toyonishi, H., Inai, K., and Abe, J. (2011). Development of a new banker plant system to control aphids in protected culture. *IOBC/WPRS Bull.* 68, 195–198.

Yasukawa, H., Matsumura, M., Nakano, T., and Kurose, M. (2011). Effect of soil fumigation using chloropicrin and dazomet to reduce damage by *Tyrophagus similis* Volgin and fusarium wilt of spinach. *Bull. Nara Prefectural Agricult.* Exp. Station 1–6.

Ying, X. F., Run, M. Q., Shen, G., and Osborne, L. S. (2012). Banker plant system: a new approach for biological control of arthropod pests. *Chin. J. Biol. Control* 28, 1–8.

Yokoyama, V. Y. (1978). Relation of seasonal changes in extracellular nectar and foliar protein and arthropod populations in cotton. *Environ. Entomol.* 7, 799–802. doi: 10.1093/ee/7.6.799

You, J., Zhu, F., Zhao, W., Zhao, X. E., Suo, Y., and Liu, S. (2007). Analysis of saturated free fatty acids from pollen by HPLC with fluorescence detection. *Eur. J. Lipid Sci. Technol.* 109, 225–236. doi: 10.1002/ ejlt.200600224

Yue, B., Childers, C. C., and Foully, A. H. (1994). A comparison of selected plant pollens for rearing *Euseius mesembrinus* (Acari: *Phytoseiidae*). *Int. J. Acarol.* 20, 103–108. doi: 10.1080/016747959408684008

Yue, B., and Tsai, J. H. (1996). Development, survivorship, and reproduction of *Amblyseius lagenensis* (Acari: *Phytoseiidae*) on selected plant pollens and temperatures. *Environ. Entomol.* 25, 488–494. doi: 10.1093/ee/25.2.488

Zemek, R., and Prenerová, E. (1997). Powdery mildew (Ascomycotina: *Erysipheales* - an alternative food for the predatory mite *Typhlodromus pyri* Scheuten (Acari: *Phytoseiidae*). *Exp. Appl. Acarol.* 21, 405–414. doi: 10.1023/A:1018427812075

Zhang, G., Zimmermann, O., and Hassan, S. A. (2004). Pollen as a source of food for egg parasitoids of the genus *Trichogramma* (Hymenoptera: *Trichogrammatidae*). *Biocontrol Sci. Technol.* 14, 201–209. doi: 10.1080/09583150310001655648

Zhang, N. X., Messeinka, G. J., Alba, J. M., Schuurink, R. C., Kant, M. R., and Janssen, A. (2018). Phytophagy of omnivorous predator *Macrolopthus pygmaeus* affects performance of herbivores through induced plant defences. *Oecologia* 186, 101–113. doi: 10.1007/s00442-017-4000-7

Zhao, J., Guo, X., Tan, X., Desneux, N., Zappala, L., Zhang, F., et al. (2017). Using *Calendula officinalis* as a floral resource to enhance aphid and thrips suppression by the flower bug *Orius sauteri* (Hemiptera: *Anthocoridae*). *Pest Manag. Sci.* 73, 515–520. doi: 10.1002/ps.4474

Zheng, Y., Daane, K. M., Hagen, K. S., and Mittler, T. E. (1993). Influence of larval food consumption on the fecundity of the lacewing *Chrysoperla carnea*. *Entomol. Exp. Appl.* 67, 9–14. doi: 10.1111/j.1570-7458.1993.tb01645.x

Zhou, W., and Wang, R. (1989). Rearing of *Orius sauteri* (Hem.: *Anthocoridae*) with natural and artificial diets. *Chin. J. Biol. Control* 5, 9–12.

**Conflict of Interest:** All authors were employed by company Biobest Group NV.

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