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KEY GENERAL ASPECTS TO BE CONSIDERED IN HABITAT MANAGEMENT: A REVIEW

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ABSTRACT

The aim of this work is to analyse the most important components that involve habitat management considerations to understand how it could be an alternative to reduce pest pressure in crops to avoid the use of pesticides in agricultural ecosystems. To accomplish this objective, a literature review of several research papers related to the topic was done. It was found that a high percentage of studies showed favourable results for natural enemy populations and pest pressure. However, these practices show more positive results for natural enemy populations than for pest suppression. The success of habitat management practices to reduce pest pressure depends mainly on the selection of non-crop plant species at crop field scale, landscape complexity and the targeted natural enemy species. Nevertheless, among these factors, the landscape complexity in the surrounding semi natural habitat is the most important aspect, since it could determine the abundance of natural enemies in the crop. Understanding the complexity of semi natural habitats could help farmers to take better coordinated decisions to manage semi natural areas and improve the biological control service in their farms. Finally, the adoption of habitat management measures is not broadly accepted by farmers and more research is needed to show them the benefits of these practices.

Keywords: Non-crop plants, landscape and crop field complexities, natural enemies, pest suppression.

1. INTRODUCTION

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Human activities like urbanization (Isaacs et al., 2009), agriculture expansion, up-scaling of field sizes and intensive farming management practices (Maas et al, 2021), have led to simplification of agricultural landscapes and decrease of biodiversity. As a consequence, the ecological function of natural pest control and pollination services have been decreased (Bianchi et al., 2006; Isaacs et al., 2009; Parolin et al., 2012; Balmer et al., 2013; Balzan et al., 2014).

Monocultures impoverish the amount of non-crop plants in the landscape, which provide habitat or food for natural enemies (predators and parasitoids). In conventional agricultural systems, the presence of non-crop plants is minimized to avoid competition with the crop and maximize yields. Therefore, herbivore populations grow without any natural control and herbivores become pests, decreasing the productivity of the crops (Isaacs et al., 2009; Balmer et al., 2013). On the other hand, pollinators also play an important role in agricultural systems. According to Balzan et al., (2014), pollination services maintain the productivity of 75% of the main global food crops, which represent 35% of the global production volumes. Besides, low crop productivity and yield have also been associated with loss of pollination services, that have been compensated with agriculture expansion (Isaacs et al., 2009; Balzan et al., 2014). In other words, beneficial arthropod populations and the health of plant communities are highly linked (De Pedro et al., 2020). For example, a comparison of insect population made in Europe before and after 1980 showed that the abundance of bees and syrphid flies has declined with a simultaneous loss of abundance of plant species dependent on specialist bee species. This illustrates a negative effect of monoculture systems on beneficial arthropod populations and plant species (Isaacs et al., 2009).

The use of pesticides has become an alternative to counteract crop pests. However, its use has a detrimental effect on biodiversity and consequently on non-target species which can be a potential biological control agent of pests (Isaacs et al., 2009; Parolin et al., 2012; Mateos et al., 2021) or pollinators (Balzan et al., 2014). Furthermore, the use of pesticides develops pest resistance (Parolin et al., 2012; Balzan et al., 2014); thereby higher amounts of pesticides might be required to control herbivore populations. Additionally, plant breeding programs have given priority to develop high yield crop varieties, leaving aside pest resistance characteristics of wild ancestors and land races, and indirectly promoting the use of pesticides (Balmer et al., 2013). Moreover, the use of pesticides has multiple effects on the environment (chemical run-off and leaching into water bodies) and human health (Parolin et al., 2012; Balmer et al., 2013 Ochieng et al., 2022).

On the other hand, the loss of biological control and pollination services provided by the ecosystem have also an economical importance. According to Balzan et al. (2014), replacing the

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global biocontrol services would cost society between 40 to 74 billion euros per year, while the economic value of pollination would cost 153 billion euros per year.

With these antecedents, it is important to promote alternatives to prevent the simplification of agricultural landscapes, the decrease of biodiversity, and pest resistance to pesticides (Parolin et al., 2012). In this context, habitat management, gives the opportunity to manipulate local habitats at landscape or farm level with the aim to provide natural enemies with several resources such as alternative hosts or prey, nectar, pollen, shelter from crop disturbances, refuge to overwinter, among the principal ones, thus optimizing natural enemy performance (Woltz et al., 2012; Madden, Widick & Blubaugh, 2021). There could be many possibilities to achieve this goal, for example, a common way to provide a suitable environment to natural enemy populations is to sow strips of flowering plants inside or in the borders of the crop field (Jonsson et al., 2010;Woltz et al., 2012). It has been registered that the use of flowering buckwheat (*Fagopyrum esculentum*) and alyssum (*Lobularia maritima*) helps to increase the parasitism rate of *Dolichogenidea tasmanica* in the apple moth (*Epiphyas post vittana*) and decrease the densities of the same pest. Additionally, it has been shown that these plants increase the fecundity, longevity and female proportion of the parasitoid. In the same way, Mateos et al. (2021) found that wildflower strips lead to an increase in pest regulation services under polytunnel systems in sweet cherry orchards by enhancing natural enemies.

Another habitat management practice is the use of beetle banks, which consists of grass covered with earth in the middle of the field. This practice provides spiders and predatory beetles of the families Carabidae and Staphylinidae with overwintering sites. In addition, this practice can increase the density of these predators (Jonsson et al., 2010). Another example of habitat management could be the use of banker plants. This system consists of a non-crop plant which is infested by a non-pest herbivore that works as an alternative host or prey, depending on the targeted beneficial insect required to protect the crop. The most common banker plant system consists of cereal plants infested with *Rhopalosiphum padi* as a host for the parasitoid *Aphidius colemani* (Huang et al., 2011). On the other hand, habitat management practices can be carried on with the objective to enhance the performance of existing natural enemies (conservation biological control) or to enhance released natural enemies (augmentative biological control) (Balmer et al., 2013).

Finally, besides supporting biocontrol ecosystem services, the adoption of habitat management practices may provide other benefits such as increased farmer profits by increased pollination services (Isaacs et al., 2009; Balzan et al., 2014), reduced dependence on chemical pesticides (Bianchi et al., 2006; Isaacs et al., 2009; Woltz et al., 2012; Balmer et al., 2013), higher yield quality (Bianchi et al., 2006), on farm educational services and sell of native flowers (Isaacs et al., 2009); environmental benefits such as erosion control (Isaacs et al., 2009), nutrient cycling, water regulation (Woltz et al., 2012), and conservation of higher general biodiversity (Bianchi et al., 2006; Isaacs et al., 2009; Balmer et al., 2013).

The aim of this work is to analyse the most important considerations related to habitat management focused on biological control services, in order to understand how it could be an alternative to reduce pest pressure in crops and to avoid the use of pesticides in agricultural ecosystems. In this context, we cover the following topics: a) non-crop plants, b) landscape and field scales, and c) natural enemies.

2. NON-CROP PLANTS

2.1 Functionality of non-crop plants

The functionality of non-crop plants for habitat management activities is diverse. Non-crop plants can provide natural enemies with extra food (plant derivatives and alternative hosts or preys), refuge to overwinter or even a place to hide from agricultural disturbance (Chen et al. 2021). Nevertheless, the beneficial effects on natural enemies may depend on the phenotypical traits of the plant in use and the spatial distribution of the flowers within the agroecosystem (Lu et al., 2014; Tortosa et al. 2022).

Non-crop plants can provide nectar, pollen (Bianchi et al., 2006; Isaacs et al., 2009; Parolin et al., 2012; Balzan et al., 2014; Lu et al., 2014; Mátray & Herz, 2022), and extra floral nectar (Lu et al., 2014) as source of food for beneficial insects. However, the nutritional value of these sources of food depends on the type of plant and the growing environment (Lu et al., 2014). Nectar provides natural enemies with sucrose and its derivates (glucose and fructose), essential amino acids for insect growth and development, lipids, vitamin C and minerals. Almost all beneficial arthropods require this source of food to maintain high levels of reproduction and optimal survival (Isaacs et al., 2009).

In parasitic wasps, the lack of food sources can cause the reabsorption of mature eggs to compensate nutritional imbalances, thereby reducing their fertility. Besides, carbohydrates are the main source of energy to fly. Number of flights and flight distance have been related to monosaccharides and oligosaccharides within a parasitoid's diet. Furthermore, nectar can also be consumed by spiders. Extra floral nectar is another source of carbohydrates such as oligosaccharides, fructose, glucose, and sucrose. Besides, it can have adverse compounds for insects such as lectins, proteins, enzyme inhibitors, cardiac steroids, alkaloids, polyphenols, and flavonoids. However, for natural enemies, this can be an important source of carbohydrates before flowering time. It has been observed that extra floral nectar in peach trees enhances the level of parasitism of *Grapholita molesta* by hymenopteran parasitoids and reduces pest fruit

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damage in 90%. On the other hand, it has been shown that insect longevity and fecundity can be improved with pollen (Hinds & Barbercheck, 2020). For example, bell pepper pollen augments the longevity and fecundity of *Amblyseius fallacis* and *Orius minutus;* and corn pollen increases the longevity of *Macrocentrus linearis* and *Anagrus nilaparvatae*. Besides, pollen has also been adduced to promote flight initiation for many insects (Lu et al., 2014). Pollen can also be an important protein source for predators such as coccinellids when insect preys are scarce (Woltz et al., 2012).

Besides, non-crop plants can provide natural enemies with alternative hosts or preys when they are not available (Isaacs et al., 2009; Woltz et al., 2012; Parolin et al., 2012; Laurenz & Meyhöfer, 2021). Buckwheat (*Fagopyrum esculentum* cv. Mancan) strips serve as a source of alternative prey, like non-pest aphids and the eggs and larvae of lepidopterans and herbivorous beetles (Woltz et al., 2012). Wood avens *(Geumurbanum*), wild strawberry (*Fragaria vesca*), European columbine (*Aquilegia vulgaris*) and peach-leaved bellflower (*Campanula persicifolia*) were non-crop plants that provided *Aleyrodeslonicerae* (non-pest whitefly), with a place to overwinter. This fact ensured *Encarsia tricolor* (parasitoid) an alternative host to maintain higher populations when *Aleyrodes proletella* (pest in cabbage crops) is not present. Wood avens was the best option to provide *Encarsia tricolor* with a suitable host to maintain higher populations (Laurenz & Meyhöfer, 2021).

Additionally, it is important to consider that there could be competition for parasitism between targeted and alternative pest, meaning that parasitoids could prefer to parasitize alternative species instead of the targeted one (Balmer et al., 2013). Similarly, there could be the possibility that generalist predators get satisfied with alternative preys (Jonsson et al., 2010).

Furthermore, non-crop plants may serve natural enemies as a physical refuge to overwinter and reproduce (Parolin et al., 2012; Lu et al., 2014). For example, the lady beetles require undisturbed habitat for overwintering and specifically *Harmonia axyridis* is known to overwinter in wooded areas (Woltz et al., 2012). However, habitats like meadows, and riparian habitats around the crop could provide natural enemies with a place to overwinter (Jonsson et al., 2010).

2.2 Considerations to select non-crop plants for habitat management strategies

It is important to take some considerations when choosing non-crop plant species to be included in habitat management practices. For instance, the anatomic traits of the targeted natural enemy are important factors to consider when selecting non-crop species. For some natural enemies, the access to nectar and pollen is determined by their mouth structures (Lu et al., 2014). Generally, Apiaceae plant species, which have exposed floral nectaries, are used to conserve and increase biological control. For example, several hymonepteran parasitoids and generalist predators with short mouthparts are attracted to flowers of Apiaceae (Balzan et al., 2014).

In addition, floral area has been related to greater natural enemy abundance. In this way, plants with large floral display within their corresponding bloom period should be analysed for habitat management activities (Isaacs et al., 2009). Moreover, the phenology of the plants needs to be considered to provide natural enemies with a continuous source of food resources like nectar, pollen or even hosts or preys. For example, alfalfa sprouts provide ladybird beetles with aphids during early spring before soya is planted in the summer (Woltz & Landis, 2014). To enhance the abundance of ground-dwelling arthropods is not necessary to take into account the floral composition of the non-crop plants due to the fact that the presence is mainly influenced by the vegetation cover (Balzan et al., 2014).

On the other hand, native plant species are not frequently considered to support beneficial arthropods, and more importance has been given to foreign plants with annual or biennial cycles. In addition, some of these foreign plant species such as fennel (*Foeniculum vulgare*), Queen Anne's lace (*Daucus carota*), and white clover (*Trifolium repens*) have been considered as invasive. The use of native plants in habitat management strategies could be an option to solve this problem. It could have some advantages like local adaptation, habitat permanency (native perennial plants), conservation of plant diversity and minimized recurring cost (plants persist in the field and usually re-seed naturally). It has been observed that the abundance of beneficial arthropods is greater with native plants than with non-native ones. Nevertheless, for the use of native perennial plants, it is important to consider that the establishment period of could be longer than the needed by annual plants (Isaacs et al., 2009).

According to Jonsson et al., (2010), it is also important to measure the attractiveness of food plants by assessing the rate of natural enemy visits to the plants in the field. However, the suitability of the food plant should be confirmed in laboratory to check how it affects the efficacy parameters of the natural enemy such as: longevity, fecundity, sex ratio, dispersal ability, and parasitism (Mátray & Herz 2022). For example, *Amblyseius cucumeris* prefers the pollen from plants of the genus *Salix* than pollen from plants of the genus *Eucalyptus*. Nevertheless, the number of laid eggs was higher with the latter (Lu et al., 2014). Mátray & Herz (2022) found that the longevity of *Ascogaster quadridentate*, a parasitoid of codling moth (*Cydia pomonella*), was more than double when inflorescences of buckwheat (*Fagopyrum esculentum*), coriander (*Coriandrum sativum*), wild carrot (*Daucus carota*) and parsnip (*Pastinaca sativa*) were offered individually, instead of just water. In this laboratory experiment, similar longevities were found for both: sex and plant species. The same authors found that parasitism (parasitized larvae/female) did not change among plant diets. However, these results were higher than the observed for starving females (water diet).

Likewise, it is important to keep in mind that adding secondary plants to a crop system may influence multitrophic interactions between pests, beneficial organisms and crop plants by causing positive or negative effects, via direct or indirect interactions (Bianchi et al., 2006; Parolin et al., 2012). For example, secondary plants can provide pest with shelter or food, therefore enhancing pest fitness and reproduction (Parolin et al., 2012). The lepidoptera *Tuta absoluta* is able to use nectar from a wide range of flowers. In that way, flower strips could give a negative effect on the crop (Balzan et al., 2014). Moreover, it can be the case that omnivore species like predatory mites, ladybeetles and brown lacewings could satisfy their necessities only with plant provided resources (Jonsson et al., 2010). Finally, it is also important to take into account that non-crop plants may compete for light, water and nutrients with the crop and in some cases, non-crop plants can become invasive. Hence, identifying the way in which particular plant characteristics influence arthropods, crops, and their interactions, is important to understand how these mechanisms operate and integrate to develop an efficient and safe strategy to use secondary plants (Parolin et al., 2012).

3. LANDSCAPE AND CROP FIELD COMPLEXITIES

According to Isaacs et al. (2009); Woltz & Landis (2014), the structure and composition of the landscape influences the richness of insect communities (natural enemies and pollinators) and their abundance. In that way, the success of pest control depends on the capacity of the surrounding landscape to provide crop fields with natural enemies. The abundance, species richness and fecundity of natural enemies have been related to the amount of semi natural habitats (or perennial crops) in the landscape (Woltz & Landis, 2014). Besides, biodiversity in general is more stable in non-crop habitats (Bianchi et al., 2006).

Semi natural habitats and perennial crops can provide natural enemies with food and shelter when annual or biannual crops are suffering disturbances caused by agricultural activities. Furthermore, landscapes with higher proportions of semi natural habitats and perennial crops have usually been related to higher pest control and lower pest population establishment (Bianchi et al., 2006; Woltz & Landis, 2014). Nevertheless, it is not a general rule, and it can vary during time even in the same field (Woltz et al., 2012). It can be that an increase in the abundance of a natural enemy, as consequence of a high proportion of semi natural habitats, is not correlated with a higher pest control (Le Gal, et al., 2020). For example, the biological control of aphids was high in soya fields surrounded by high or low proportion of semi natural habitats, even though the proportion of semi natural habitats and the abundance of coccinellids in the soya field were positively correlated with high proportion of semi natural habitats. Contrastingly, previous

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experiments in the same fields showed that coccinellid abundance in the field and aphid control were correlated with a higher proportion of semi natural habitats (Woltz et al., 2012).

Landscape configuration also influences the arrival of natural enemies into the crop, thereby affecting the efficacy of natural enemies. Through modelling it has been suggested that an even distribution of semi natural habitats with small crop fields could favour the abundance of natural enemies in the crop fields (Woltz & Landis, 2014).

Similar to the proportion of semi natural habitats in relation to crop field, natural enemy diversity and abundance, and pest suppression have also been related to land cover diversity (Balzan et al., 2014, Woltz & Landis, 2014), which can be increased by sowing non-crop plants at field scale, for example in field margins (Bianchi et al., 2006) or in intercropping configurations such as strip or pixel cropping (Juventia et al., 2021).

Regarding to natural enemy diversity, De Pedro et al. (2020) found that cover crops like *Borago officinalis*, *Coriandrum sativum*, *Calendula arvensis*, *Calendula officinalis*, *Diplotaxis erucoides*, *Echium vulgare*, *Hordeum vulgare*, *Phacelia tanacetifolia* and *Vicia faba*, sown in strips increased the biodiversity of spiders, which are linked to pest control in pear orchards. On the other hand, Woltz et al. (2012) found that the abundance of coccinellids was higher in buckwheat (*Fagopyrum esculentum* cv. Mancan) strips than in field edges containing grasses and weedy herbs. However, the increase of coccinellid abundance in the buckwheat strips was not mirrored with a higher abundance of coccinellids in the adjacent soybean fields. As mentioned before, the abundance of coccinellids in the soybean fields was related to the semi natural habitats. Many studies have shown that a higher abundance of natural enemies (parasitoids and predators) in floral resource strips does not guarantee a higher abundance of natural enemies in the crop field (Woltz et al., 2012). In that way, the same authors suggest that actions at landscape scale should be taken in order to manage biological control services. Nevertheless, to accomplish with this aim, the identification of specific traits of landscape structure are necessary to establish strategies able to increase the abundance of natural enemy populations in the crop fields (Woltz & Landis, 2014).

According to Woltz & Landis (2014), additional land covers could provide natural enemies with multiple services at different times depending on the phenology of plant species. In fact, the rate of egg predation of *Mamestra brassicae* by *Trichogramma brassicae*, egg parasitism by *Trichogramma* spp. and larvae parasitism by *Microplitis mediator* were higher when having cornflowers as non-crop plants than without them in *Brassica oleracea* fields (Balmer et al., 2013). Besides, a high ratio between the perimeter and the area of a small crop field increases the interface between crop and non-crop plants. It could facilitate fast crop field colonization and avoid a fast pest population growth (Bianchi et al., 2006; Woltz & Landis, 2014). Additionally,

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the distance between the crop and the non-crop could influence parasitism rates for some species. For instance, in the previous example, the parasitism rate of *Mamestra brassicae* by *Trichogramma* spp. was less effective when the distance between the crop and non-crop was longer, while the parasitism rate of *Mamestra brassicae* by *Microplitis mediator* was not influenced by the distance between crop and non-crop (Balmer et al., 2013).

4. NATURAL ENEMIES

In order to implement habitat management strategies, it is necessary to consider important aspects related to the behavior and the biology of targeted species for biological control. In that way, it could be useful to identify whether the effectiveness of biological control of pests is higher with a simple or a diverse community of natural enemies. The identification of effective natural enemies for a targeted pest should help to plan or modify landscape structures more suitable for the growth and distribution of important natural enemies.

In many cases a simple community of natural enemies has been shown to produce better biological pest control than a diverse community. It is suggested to identify which species are more effective to control a targeted pest and then incorporate them in the fields as a habitat management measure (Jonsson et al., 2010; Tortosa, et al., 2022). This identification could be done by using molecular tools. For example, *Anotylus rugosus*, a predator of *Plutella xylostella*, was found to be an interesting target species to enhance pest suppression in cabbage fields by detecting pest herbivore DNA in their guts with high frequency (Balmer et al., 2013). Similar studies carried out by molecular gut content analysis, detected predators that had fed on *Drosophila suzukii* in hedges that provide few host fruit resources (Siffert et al., 2021). However, it is important to consider that high diversity of natural enemies may enhance the biological control of pests (Alvarez-Baca et al.,2022) by increasing the chance to have specific species which perform better at different conditions (Jonsson et al., 2010).

The effect of a diverse community of natural enemies in the biological pest control depends on many factors. Positive effects of a diverse community could occur when the feeding niches of the different natural enemy species complement each other by resource partitioning or facilitation. Resource partitioning occurs when natural enemy species make use of different food resources, for example, foraging in different parts of the plant, pest species or even from the same pest species but different life stages (Jonsson et al., 2010). For example, parasitism for *Mamestra brassicae* can be exerted by two species *Trichogramma* spp. and *Microplitis mediator*. The first one parasites the eggs while the second one the larvae (Balmer *et al*., 2013). On the other hand, resource facilitation occurs when the foraging activity of one natural enemy species benefits the foraging species of the other one. For example, it was observed that a foliage predator facilitated the foraging of a ground living predator when feeding from the aphid *Acyrthosiphon pisum*, which dropped off the plant when threatened by the foliar predator (Jonsson et al., 2010), however, it could be that many staphylinids and the carabid *Anchomenus dorsalis* could produce the same effect for ground living insects due to the fact that they were able to climb cabbage heads and prey on cabbage herbivores (Balmer et al., 2013). In addition, having a high diversity of natural enemies could provide the ecosystem with stability by increasing the chance to have species which could adapt to different conditions, thereby exerting biological control more continuously in the ecosystem (Bianchi et al., 2006). Contrastingly, negative effects on pest biological control can also occur when having a diverse community of natural enemies. This could be caused by intra-guild predation or inter-specific interference. In both situations, more biodiversity in the field is not reflected in lower pest populations. However, intra-guild predation in beetle banks could be avoided by providing weaker predators with a safe place (Jonsson et al., 2010).

As mentioned before, the success of pest control depends on the capacity of the surrounding landscape to provide crop fields with natural enemies. In that way, it is important to consider that the natural enemy preferences for surrounding landscapes could be different even among the same kind of insect for example, native lady beetles in U.S.A are frequently associated with herbaceous perennial habitats such as grass lands and forage crops, while some exotic species are associated with forested landscapes. *Coccinella septempunctata*, another exotic species, is not influenced by the surrounding landscape. Other coccinellids like *Coleomegilla maculate* have been positively or negatively related to forest landscapes (Woltz & Landis, 2014), and *Coccinella trifasciata* is particularly attracted by alfalfa habitats (Samaranayake & Costamagna, 2019). It has also been found that some predators and parasitoids were more attracted to flower margins adjacent to apple orchards when compared to a spontaneous margin (Rodríguez, 2019). It means that knowing the landscape preferences of the possible natural enemies would help to choose the most suitable biological control according to each surrounding landscape (in the case of augmentative biological control) or modify the surrounding landscape to impulse the population growth of an existing natural enemy (conservation biological control).

In addition, it has been shown that natural enemies may have different dispersal abilities (Jonsson et al., 2010; Parolin et al., 2012). It has been found that some species can move 100 m away from their refuges, while others can move 3 km around the crop. However, for many parasitoid species, it has been shown that parasitism rate and landscape composition are strongly correlated in a diameter of 1 km around the drop (Jonsson et al., 2010). For the lady beetle *Hippodamia convergens*, it is known that its dispersal ability is in a diameter of 2 km around soya fields (Woltz et al., 2012; Woltz & Landis, 2014). In that way, knowing the dispersal ability of natural enemies could help to implement habitat management strategies at macro levels, for example in rural areas farmers could agree in planning a landscape structure which facilitates the dispersal of important natural enemies in their fields. According to (Jonsson et al., 2010), achieving landscape management will require the coordination and adoption of habitat management techniques by a group of farmers.

5. DISCUSSION

Habitat management strategies can be an alternative to avoid the use of pesticides in agricultural ecosystems as shown by Bianchi et al. (2006); Jonsson et al. (2010); Ochieng, et al. (2022). Even though the results obtained by the application of habitat management strategies could be diverse, a great percentage of the studies showed favourable results for natural enemy populations and pest pressure. Bianchi et al. (2006) found that from a review of 24 studies, 74% were positive, 20.8 % were neutral and 5.1% were negative for natural enemy populations, while from 10 studies it was found that 45%, 40% and 15% were positive, neutral and negative, respectively, for pest pressure. Jonsson et al. (2010) found that from 22 studies, 19 had positive effects on natural enemy populations and 15 studies showed decreased pest pressure. Observing these results, it can be stated that habitat management practices are more favourable to enhance natural enemy populations than to reduce pest pressure. Besides, according to (Bianchi et al., 2006), the positive effects of habitat management practices on natural enemies could be generalized due to the fact that these effects have been observed for many kinds of natural enemies such as parasitoids, carabid beetles, syrphid larvae, damsel bugs, chrysopids, staphylinids, coccinellids and spiders. Contrastingly, the frequency of success for pest suppression is more variable when compared to the favourable results observed on natural enemy populations.

The success of habitat management practices reducing pest pressure may depend on many factors as mentioned before. Nevertheless, the complexity of semi natural habitats seems to be more important to reduce pest pressure as shown by Woltz et al. (2012) where buckwheat strips (augmenting land cover diversity at crop field scale) increased the abundance of coccinellids in the buckwheat strips but not in the crop fields. It was found that the presence of coccinellids in the crop fields was related to proportion of semi natural habitats (Woltz et al., 2012). Deconvolution of specific landscape traits influencing the presence of natural enemies in the crop is important to improve the success of habitat management strategies (Woltz & Landis, 2014). In this context, a mixture of methodologies should be used to have a better understanding on how natural enemies answer to multitrophic interaction in field experiments. Molecular techniques to check for herbivore DNA in predator guts, as used by Balmer et al., (2013), could have helped to determine if the low abundance of coccinellids in soybean crops with respect to buckwheat strips (Woltz et al., 2012) was related to a higher preference of coccinellids for alternative preys located in the surrounding semi natural habitats, which is very possible due to

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the dispersal capacity of coccinellids. Furthermore, complementary studies to know the diversity and abundance of alternative preys in semi natural habitats could have been corroborated with results obtained with molecular techniques. Studies regarding to habitat management practices do not analyse the structure and composition of semi natural habitats in that depth. In fact, some of these studies evaluate only plant diversity and proportion of its proportion when analysing semi natural habitats (Woltz et al., 2012; Woltz & Landis, 2014). Having a set of data containing more complete information of what is happening in semi natural habitats would be useful to evaluate how biological control services work in a determined environment. It could also help to isolate the effects of individual landscape characteristics on natural enemies as suggested by Woltz & Landis (2014). In addition, considering that to achieve landscape management will require the coordination and adoption of habitat management techniques by a group of farmers (Jonsson et al., 2010), knowing more about the landscape could also help farmers to take better coordinated decisions to manage semi natural areas favouring biological control in their farms.

As mentioned above, habitat management strategies can be used for augmentative biological control, however, previous studies should be done in order to test whether local native species realize a better biological control than introduced species. It could be that local native species perform better than introduced species as suggested by (Balmer et al., 2013). In fact, it was found that *Trichogramma evanescens* seemed to be more efficient parasitizing *Mamestra brassicae* than *Trichogramma brassicae*; however, it was not confirmed by molecular techniques. Complementary laboratory experiments to evaluate multitrophic interactions are also important to confirm these results (Parolin et al., 2012). On the other hand, the introduction of exotic natural enemies could fail due to a low capacity of the environment to provide the natural enemy with essential conditions to survive such as food and overwintering sites, thereby limiting the effectiveness of the biological control (Jonsson et al., 2010).

Finally, the adoption of habitat management strategies by farmers is not broadly accepted and its use has been restricted by many reasons. First, the role of biodiversity in maintaining a natural pest control is still controversial. Even though many studies have shown positive effects on pest suppression, there is still the probability to have neutral or negative effects (Bianchi et al., 2006; Jonsson et al., 2010; Woltz et al., 2012). Additionally, studies related to habitat management strategies usually do not consider variables that are important for the farmers' decision making. Information related to crop damage, crop yield, crop quality and cost-benefit impact is still limited (Bianchi et al., 2006). In that way, farmers are confronted to a difficult decision when considering habitat management strategies. Whether or not to modify the soil use by reducing crop land areas and increasing or implementing non-crop land areas to propitiate biological control and avoid the use of pesticides is still a controversy for farmers. Agreeing with Isaacs et

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al., (2009), more research is needed in order to optimize the size and distribution designated for non-crop plants and semi natural habitats without decreasing crop yield and quality.

REFERENCES

[1] Alvarez-Baca, J., Montealegre, X., Le Lan, C. and Lavandero, B. (2022). Effect of a cover crop on the aphid incidence is not explained by increased top-down regulation. PeerJ, 10:e13299. http://dx.doi.org/10.7717/peerj.13299

[2] Balmer, O., Pfiffner, L., Schied, J., Willareth, M., Leimgruber, A., Luka, H., & Traugott, M. (2013). Noncrop flowering plants restore top-down herbivore control in agricultural fields. Ecology and Evolution, 3(8): 2634–46. doi:10.1002/ece3.658

[3] Balzan, M. V., Bocci, G., & Moonen, A.-C. (2014). Augmenting flower trait diversity in wildflower strips to optimise the conservation of arthropod functional groups for multiple agro ecosystem services. Journal of Insect Conservation, 18(4): 713–728. doi:10.1007/s10841-014-9680-2

[4] Bianchi, F. J. J. a, Booij, C. J. H., & Tscharntke, T. (2006). Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. Proceedings. Biological Sciences / The Royal Society, 273(1595): 1715–27. doi:10.1098/rspb.2006.3530

[5] Chen, L., Pozsgai, G., Li, X, Li, L., Reddy, G. y You, M. (2021). Effects of cover crops on beetle assemblages in tea plantations. Crop Protection. Volume 149. 105783. https://doi.org/10.1016/j.cropro.2021.105783

[6] De Pedro, L., Perera, L., López, E., Pérez, M., and Sanchez, Juan. (2020). The Effect of Cover Crops on the Biodiversity and Abundance of Ground-Dwelling Arthropods in a Mediterranean Pear Orchard. Agronomy 10(4): 580. https://doi.org/10.3390/agronomy10040580

[7] Hinds, J. & Barbercheck, M. (2020). Diversified floral provisioning enhances performance of the generalist predator, Oriusinsidiosus (Hemiptera: Anthocoridae). Biological Control, Volume 149. 104313. https://doi.org/10.1016/j.biocontrol.2020.104313.

[8] Huang, N., Enkegaard, A., Osborne, L. S., Ramakers, P. M. J., Messelink, G. J., Pijnakker, J., & Murphy, G. (2011). The Banker Plant Method in Biological Control. Critical Reviews in Plant Sciences, 30(3): 259–278. doi:10.1080/07352689.2011.572055

[9] Isaacs, R., Tuell, J., Fiedler, A., Gardiner, M., & Landis, D. (2009). Maximizing arthropod-mediated ecosystem services in agricultural landscapes: the role of native plants. Frontiers in Ecology and the Environment, 7(4), 196–203. doi:10.1890/080035

ISSN: 2455-6939

Volume: 08, Issue: 06 "November-December 2022"

[10] Jonsson, M., Wratten, S. D., Landis, D. a., Tompkins, J.-M. L., & Cullen, R. (2010). Habitat manipulation to mitigate the impacts of invasive arthropod pests. Biological Invasions, 12(9): 2933–2945. doi:10.1007/s10530-010-9737-4

[11] Laurenz, S., & Meyhöfer, R. (2021). Conservation of Non-Pest Whiteflies and Natural Enemies of the Cabbage Whitefly Aleyrodes proletella on Perennial Plants for Use in Non-Crop Habitats. Insects, 12(9): 774. https://doi.org/10.3390/insects12090774

[12] Le Gal, A., Robert, C., Accatino, F., Claessen, D. and Lecomte, J. (2020). Modelling the interactions between landscape structure and spatio-temporal dynamics of pest natural enemies: Implications for conservation biological control. Ecological Modelling, Volume 420. 108912. https://doi.org/10.1016/j.ecolmodel.2019.108912

[13] Lu, Z.-X., Zhu, P.-Y., Gurr, G. M., Zheng, X.-S., Read, D. M. Y., Heong, K.-L., … Xu, H.-X. (2014). Mechanisms for flowering plants to benefit arthropod natural enemies of insect pests: prospects for enhanced use in agriculture. Insect Science, 21(1), 1–12. doi:10.1111/1744-7917.12000

[14] Maas, B., Brandl, M., Hussain, R., et al. (2021) Functional traits driving pollinator and predator responses to newly established grassland strips in agricultural landscapes. J Appl Ecol. 58: 1728– 1737. https://doi.org/10.1111/1365-2664.13892

[15] Madden, M., Widick, I., Blubaugh, C. (2021). Weeds Impose Unique Outcomes for Pests, Natural Enemies, and Yield in Two Vegetable Crops. Environmental Entomology. 50(2): 330–336. https://doi.org/10.1093/ee/nvaa168

[16] Mateos, Z., Fountain, M., Garratt, M., Ashbrook, K., and Westbury, D. (2021). Active management of wildflower strips in commercial sweet cherry orchards enhances natural enemies and pest regulation services. Agriculture, Ecosystems & Environment. Volume 317. 107485. https://doi.org/10.1016/j.agee.2021.107485.

[17] Mátray, S., &Herz, A. (2022). Flowering plants serve nutritional needs of Ascogaster quadridentata (Hymenoptera: Braconidae), a key parasitoid of codling moth. Biological Control. 171. 104950. https://doi.org/https://doi.org/10.1016/j.biocontrol.2022.104950

[18] Megan Woltz, J., & Landis, D. a. (2014). Coccinellid response to landscape composition and configuration. Agricultural and Forest Entomology, 16(4): 341–349. doi:10.1111/afe.12064

[19] Ochieng, L. O., Ogendo, J. O., Bett, P. K., Nyaanga, J. G., Cheruiyot, E. K., Mulwa, R. M., Arnold, S. E., Belmain, S. R., Stevenson, P. C. (2022). Field margins and botanical insecticides enhance Lablab purpureus yield by reducing aphid pests and supporting natural enemies. Journal of Applied Entomology. 146. 838– 849. https://doi.org/10.1111/jen.13023

[20] Parolin, P., Bresch, C., Poncet, C., & Desneux, N. (2012). Functional characteristics of secondary plants for increased pest management. International Journalof Pest Management, 58(4): 369–377. doi:10.1080/09670874.2012.734869

[21] Rodríguez, N., Avilla, J., Aparicio, Y., Arnó, J., Gabarra, R., Riudavets, J., Alegre, S., Lordan J. and Alins, G. The Contribution of Surrounding Margins in the Promotion of Natural Enemies in Mediterranean Apple Orchards. Insects 10(148). doi:10.3390/insects10050148

[22] Samaranayake, K. and Costamagna, A. (2019). Adjacent habitat type affects the movement of predators suppressing soybean aphids. PLoS ONE 14(6): e0218522. https://doi.org/10.1371/ journal.pone.0218522

[23] Siffert, A.; Cahenzli, F.; Kehrli, P.; Daniel, C.; Dekumbis, V.; Egger, B.; Furtwengler, J.; Minguely, C.; Stäheli, N.; Widmer, F.; et al. (2021). Predation on Drosophila suzukii within Hedges in the Agricultural Landscape. Insects. 12(305). https://doi.org/10.3390/insects 12040305

[24] Tortosa, A., Duflot, R., Rivers-Moore, J., Ladet, S., Esquerré, D. and Vialatte, A. (2022) Natural enemies emerging in cereal fields in spring may contribute to biological control. Agricultural and Forest Entomology. 24(3): 267– 278. Available from: https://doi.org/10.1111/afe.12490

[25] Woltz, J. M., Isaacs, R., & Landis, D. a. (2012). Landscape structure and habitat management differentially influence insect natural enemies in an agricultural landscape. Agriculture, Ecosystems and Environment, 152, 40–49. doi:10.1016/j.agee.2012.02.008

