

Managing Semi-natural Habitats of Pollinators within Agro-ecosystems

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Abstract

Although wild pollinators are better conserved within protected areas and natural parks, where floral diversity and shelters are available, for agricultural production it is more convenient to conserve pollinators within agricultural fields. Recently, implementation of floral margins in agricultural landscapes has been shown to increase the abundance of pollinators in agro-ecosystems and positively affects production of neighbouring crops. However, special attention should be focused on the selection of beneficial insectary plants and their management in the agro-ecosystems. Therefore, this short review highlights the importance of choosing appropriate plants to attract beneficial insects and to consider their attractiveness to pollinators, ecology, physiology, floral phenology, and potential weediness prior introducing them in agro-ecosystems.

Introduction

Since agricultural practices can damage biodiversity through various pathways, agriculture is frequently considered anathema to conservation. However, appropriate management can ameliorate many of the negative impacts of agriculture, while largely maintaining provisioning ecosystem services [1,2]. Although honey bee has high economic importance in honey production and it is the most abundant cosmopolitan pollinator, it has been discovered that there are various crops for which honey bees are poor pollinators compared to wild bees [3,4]. For that reason, national and international organizations are publicizing the need to conserve native pollinators [3]. Moreover, honeybees are insufficient to supply the demands of crop pollination in Europe [5].

Although wild pollinators are better conserved within protected areas and natural parks, where floral diversity and shelters are available, for agricultural production it is more convenient to conserve pollinators within agricultural fields. Conventional farmers routinely manage their fields for greater provisioning services by using inputs and practices to increase yields, but management practices can also enhance other ecosystem services, such as pollination, biological control, soil fertility and structure, and support biodiversity [1]. Therefore, if introduced properly, habitat management within agro-ecosystem can provide resources needed for conservation of pollinators and natural enemies [6].

Large monocultures of bee-pollinated crops such as almond, melon, oilseed rape, alfalfa, coriander or canola [7,8], normally provide abundant food sources for pollinators, but only for a few weeks period. Therefore, lack of within field or adjacent wild plants, blooming before and after the main crops bloom, can result in a decline of healthy pollinators abundance and diversity [9]. Recently, implementation of floral margins in agricultural landscapes has been shown to increase the abundance of pollinators in agro-ecosystems [10,11]. Naturally regenerated uncropped margins were primarily designed to conserve rare local arable flora and their associated fauna [11]. However, sowing an uncropped margin with wildflower seed mixture can offer better food sources to pollinators and improve their conservation [12].

Therefore, in order to maintain native plant species in each region for pollinator conservation, there is a need for pollination biologists to integrate their findings with those of plant restoration ecologists and to ensure sustainable restoration of pollinator habitats within agro-ecosystems by using native plants [13]. For that reason, special

attention should be focused on the selection of beneficial insectary plants and their management in the agro-ecosystems [14].

Beneficial Insectary Plants

Beneficial insectary plants attract beneficial insects (pollinators and natural enemies of pests) by producing nectar and pollen which are their main food sources [15]. Although many pollinators are generalist, e.g., honey bee and the majority of hoverfly species [16,17], some pollinators have preferences when choosing the plants to visit [17].

Pigmentation in flowers seems to play a major role in pollination success [18] and can significantly influence the insects' preference [19]. In addition, colour can help beneficial insects with plant species selection, flower location and ripeness, and nectar and pollen location within the flower. Besides, shape and size of the flower [20,21], nectar availability and chemical composition of the plant species [22,23] also contribute to the preferences of pollinators.

Some plant families have been widely known as highly attractive to beneficial insects, for instance Boraginaceae, Brassicaceae and Apiaceae, and many plant species from those families have been introduced within agricultural fields worldwide. Plants as buckwheat (*Fagopyrum esculentum* Moench (fam. Polygonaceae)) (Figure 1a), phacelia (*Phacelia tanacetifolia* Benth. (fam. Boraginaceae)) (Figure 1b), alyssum (*Lobularia maritima* L. Desv. (fam. Brassicaceae)) (Figure 1c) and coriander (*Coriandrum sativum* L. (fam. Apiaceae)) (Figure 1d), have been used in beneficial insect conservation practices in the last 10 years [24,25], where their attractiveness to beneficial insects have been highly ranked on the basis of feeding visit frequencies [26].

While it is important to consider all the factors mentioned above when choosing plants to attract beneficial insects, it is also necessary to consider the ecology, physiology, floral phenology, and potential

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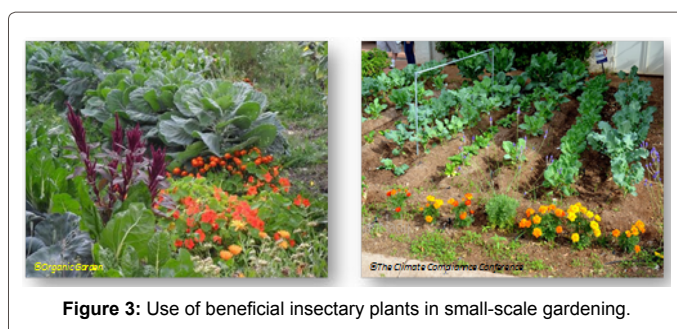
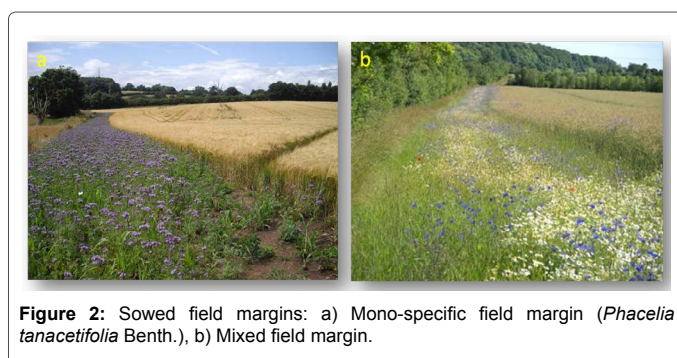
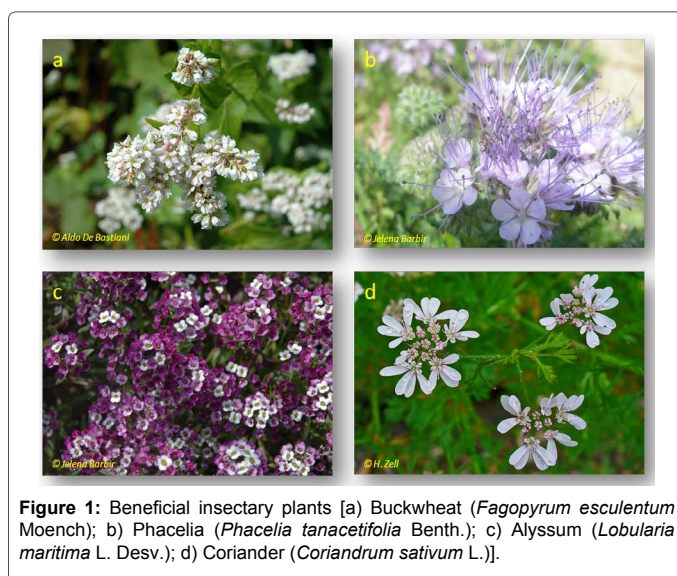
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weediness of the plants prior introducing them in agro-ecosystems [14], with the final aim to apply the most appropriate and sustainable habitat management for conservation of pollinators.

Management of Beneficial Insectary Plants within Agro-ecosystems

Although some plants can be widely attractive to cosmopolitan pollinators, other plants have flowers that are more attractive to specific groups of pollinators, e.g., open flowers are attractive to hoverflies and plants from Boraginaceae family are very attractive to bumblebees [27]. Therefore, it is important to have fundamental knowledge about the abundance and diversity of groups of pollinators in the region before choosing plant species for efficient management of pollinator habitats within the landscapes.



In addition, to manage beneficial insectary plants within agro-ecosystems it is essential to consider the climate conditions of the region [28]. In the Mediterranean region, where precipitation and irrigation water are scarce, usage of plant species that can cope with water stress are preferred, while in other regions, i.e., tropical, Central and Northern Europe, irrigation is not a limiting factor. Under different environmental conditions, beneficial insectary plants easily managed in one region can show weediness or invasiveness in another region. Therefore, it is recommendable to test under field conditions the agricultural behaviour and the attractiveness to pollinators of introduced or native beneficial plants [29,30] before recommending its usage in specific agro-ecosystems.

Furthermore, beneficial insectary plants can be managed in different ways within agro-ecosystems depending on the scale of the field, climate and agricultural practices of specific region [31]. One of the most common approaches to implement beneficial plants within large agricultural fields is to sow field margins. However, some plant species are more efficient if sown as mono-specific margins (Figure 2a), while others are more efficient if mixed with other plant species (Figure 2b) [32,33]. Mixed margins could combine the advantages of all species in terms of a longer flowering period and offering complementary resources relative to single species. However, mixed margins are less visited by pollinators than some highly attractive mono specific margins, which might be due to the lower floral density in mixed margins.

In addition, sustainable and organic agriculture have recently received a lot of attention as strategies that will stop or at least reduce the damage to ecosystems [34,35] and improve conservation of beneficial insects [36,37]. In organic farming, beneficial insectary plants are widely used for their positive impact in conservation of natural enemies of pests and pollinators [36]. Since the commercialization of organic products is becoming increasingly widespread, this implies an unquestionable opportunity for organic production on a small-scale, where the use of beneficial insectary plants should be a key part of the production system (Figure 3) [38].

Conclusions

To manage beneficial insectary plants within agro-ecosystems it is essential to consider their attractiveness to pollinators, ecology, physiology, floral phenology, and potential weediness prior introducing them in agro-ecosystems. In addition, under different environmental conditions, beneficial insectary plants easily managed in one region can show weediness or invasiveness in another region. Therefore, it is recommendable to test under field conditions the agricultural behaviour and the attractiveness to pollinators of introduced or native beneficial plants. Finally, this short review highlights the importance of choosing the most appropriate implementation of the beneficial plants in the agro-ecosystems, as mono-specific or mixed margins.

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