# Flower Strips

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Wildflower strips, a semi-natural manmade habitat comprising mixtures of native herbaceous species, can be sown on arable field margins to provide multiple ecological, agricultural and conservation benefits. The main aim of creating flower strips is to enrich the fauna of farmland with the species that are beneficial in terms of the agricultural economy: animals that limit the population density of pests (e.g., parasitic insects, including parasitoids, predatory insects and spiders and birds) and pollinators (insects that feed on pollen or nectar), including those with economic significance. For this reason, flower strips should be included in agri-environmental programs to enhance sustainable plant production and the biodiversity of pollinators on farmland or natural aphid enemies. Flower strips are thus increasingly frequently promoted in environmental programmes, and financial support is being implemented as an additional business incentive.

beneficial macro-organisms | biodiversity | Flower Strips

## 1. Species Composition

Detailed guidelines as to seed mixtures, sowing time and proper flower strip management must be carefully adjusted to habitat conditions (soil, weeds and neighboring habitats) and specific aims. Pfiffner and Wyss [1] indicate that flower strips should be established on sites free of problem weeds (such as *Rumex obtusifolius* L., *Agropyron repens* L., *Cirsium arvense* L. and *Convolvulus arvensis* L.) that provide proper soil conditions (water availability). After careful soil preparation, flower strips are usually sown in spring in mineral soils and in autumn in organic soils to avoid weeds that sprout in spring (e.g., *Galinsoga* sp., *Setaria* sp.). In Polish conditions, however, the soil requirements for the plants sown in flower strips are not of much importance, as farmland is usually located on soils formed in oak-hornbeam forest habitats, appropriate for the development of a large number of plant species that are significant in terms of flower strips [2].

The composition of seed mixture for flower strips should particularly take into consideration the requirements of desired insect species; provide food for insects that feed on nectar and pollen (e.g., hoverflies and green lacewings) and whose larvae are predators; and include seeds of long-blooming plants to ensure continuity of blooming and food for herbivorous insects, thanks to which they will feed within the strip and not on cultivated plants. For instance, the plants of the Poaceae family may become a feeding place for crop pests. The selected plants should be particularly advantageous for the species that control pest populations and the plants whose pollen or nectar is often eaten by pests should be excluded. At the same time, it is important to differentiate the blooming times of particular species in the flower strip as much as possible [2][3] (**Figure 1**).

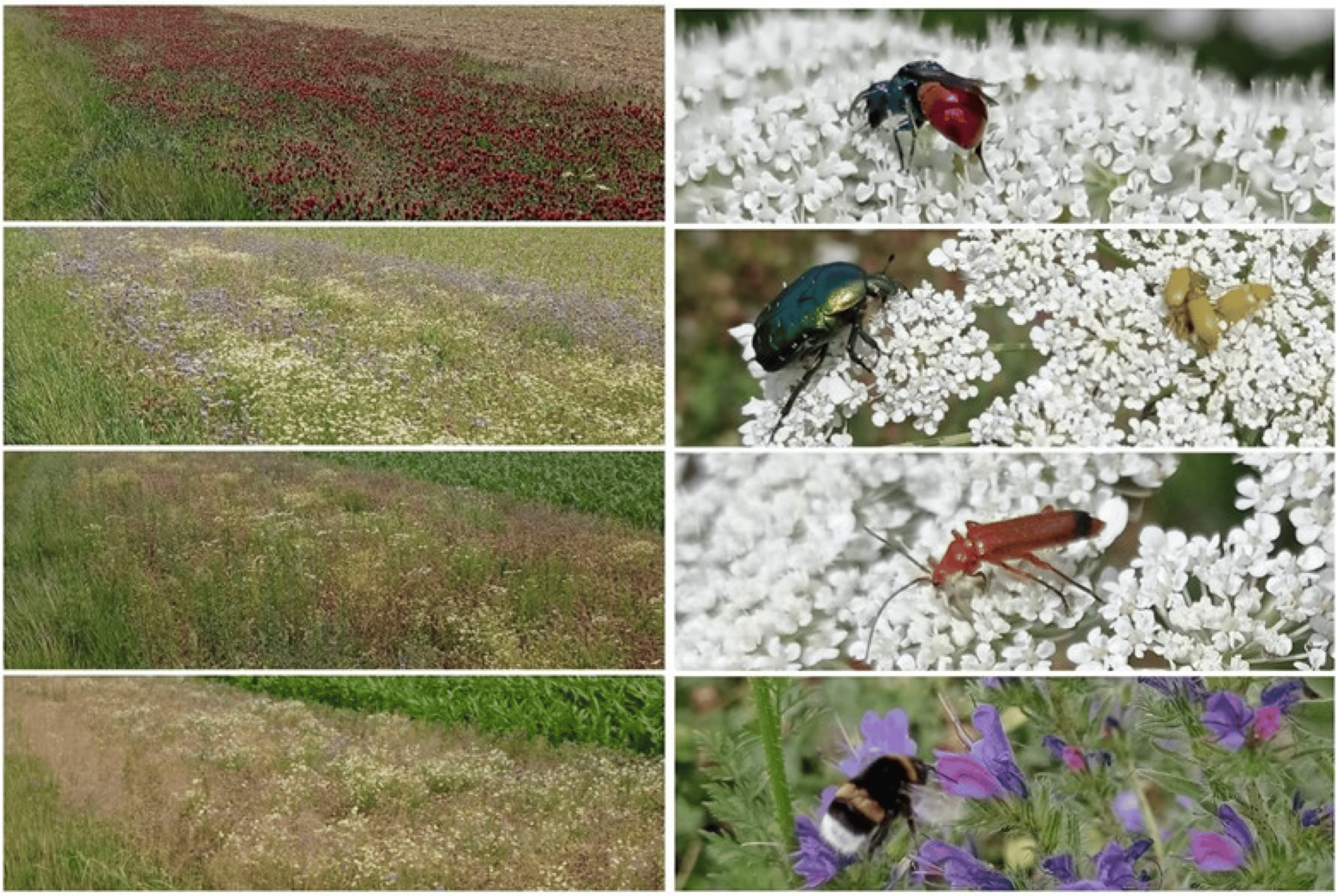


**Figure 1.** Differentiation of blooming plants and insects in a flower strip in the National Park of Greater Poland: (**A**) blooming plants of the flower strip from the beginning of May to the end of June, every two weeks. (**B**) Diversity of insects in the flower strips; species from the top: *Chrisis ignita* L.—parasitic wasp, *Protaoetia cuprea metallica* Herbst, *Rhagonycha fulva* Scopoli—predatory beetles, *Bombus lucorum* L.—pollinator (authors' observations, 2022).

The species of plants for flower strips should offer vast resources, both of a flower and non-flower character (e.g., shelter as well as living and breeding places), and be favourable for natural enemies of cultivated plants pests. Flower strips rich in species may be attractive for beneficial fauna and bring higher tangible benefits than strips poor in species or composed of one species. The application of flower mixtures differentiates the resources, which leads to a higher diversity of pollinators and natural enemies due to insects' selective feeding. In research by Pontin et al. [4], clear differences in the attractiveness of flower species for bumblebees, honey bees and, to a lesser extent, hoverflies were observed. Bumblebees and honey bees almost exclusively visited phacelia, even when other flower species were available, while hoverflies visited all available plant species without clear preference, which confirms that it is possible to adjust the species composition of flower strips to maximise biological control and pollination. It is worth noting that bumblebees are active even in early spring, when air and ground temperatures are still low, so their presence is essential for the multiplication of the plants that bloom in that season [2]. In research by Haaland and Gyllin [5], two-thirds of all flower visits by butterflies were observed to

*Knautia arvensis* L. (44%) and *Centaurea* spp. (*C. jacea* L. and *C. scabiosa* L. 20%). *Cirsium arvense* L., *Senecio* spp. and *Trifolium* spp. were other commonly visited plants. For bumblebees, visits to *Centaurea* spp. were totally dominant (72%), while 14% of all visits were recorded to *K. arvensis*, 5% to *Trifolium* ssp. and 4% to *C. arvense* L. Along with the accumulation of knowledge on particular insects' preferences for plant speciesm it will be easier to predict which flower species are appropriate for particular schemes of protection and pest control and minimize the risk of accidentally supporting harmful agrophages.

Pollinators are most attracted to the species with the highest numbers of flowers. The species best for flowers strips in Spain turned out to be *Coriandrum sativum* L., *Diplotaxis virgata* L., *B. officinalis* L. and *Calendula officinalis* L. They had the largest flower cover and were the highest in the mixture (50 to 100 cm), which probably made it easier for pollinators to find them (they also have open or partly hidden nectar). It is observed (2022) that bumblebees very frequently visited the high (up to 100 cm) *Echium vulgare* L., which had a large number of flowers in inflorescence. Baden-Bohm et al. [6] found that the composition of the flower mixture and, consequently, flower structure affects the subsequent occurrence of honey bees. Flower strips of good quality, rich in pollen and nectar and spread evenly, attract more bees, unlike flower strips of poor quality, which are less satisfying for bees. In research by Tschumi et al. [3][7], flower strips greatly encouraged the diversity of hoverflies. The flower mixture was composed of native flowers of Switzerland and herbs grown in the region: *Anethum graveolens* L. (Apiaceae), *Anthemis arvensis* L. (Asteraceae), *Anthriscus cerefolium* Hoffm. (Apiaceae), *Bellis perennis* L. (Asteraceae), *Calendula arvensis* L. (Asteraceae), *Camelina sativa* (L.) Crantz (Brassicaceae), *Centaurea cyanus* L., (Asteraceae), *Coriandrum sa-tivum* L. (Apiaceae), *Fagopyrum esculentum* Moench (Polygonaceae), *Papaver rhoeas* L. (Papaveraceae) and *Sinapis arvensis* L. (Brassicaceae). Research by Amy et al. [8] did not show significant differences in terms of abundance and diversity of pollinators in single-species and multi-species strips. Only hoverflies were more numerous in the multi-species mixture.

Pontin et al. [9] note a situation in which a flower strip is more attractive for target insects than the cultivation itself; then, ecosystem services—i.e., biological pest control and pollination—can be at risk in the cultivation. This is why the blooming seasons of flower strips (affected by the selection of species and the cultivation itself) must be considered in order to ensure only minimal overlap in time. Describing melon cultivation as an example, Azpiazu et al. [10] confirm that a flower strip may act as a competitor if it blooms at the same time as the main cultivation; this is why *Calendula officinalis* L. should be avoided in melon cultivations. Flower strips may also compete with native plants. In research by Montero-Castaño et al. [11], strips of *Hedysarum coronarium* L. decreased the abundance of pollinators in the adjacent shrubberies by monopolising honey bee visits and attracting wild bees. Considering the above, further research is necessary to prepare guidelines on the flower mixtures that are definitely more advantageous for pollinators than neighbouring plants and semi-natural habitats.

## 2. Types of Flower Strips

### 2.1. Annual Flower Strips

Annual flower strips may be easily created from year to year in various places; they do not require particular care. They may also constitute a first step in introducing perennial flower strips in areas where they have not been used before. They quickly become local shelter for arthropods, including pest enemies that can help control the pests in neighbouring cultivations [12]. Research by Tschumi et al. [13] showed high effectiveness for annual flower strips that lower the abundance of pests below economic threshold, thus offering a real alternative for insecticides or providing a chance to limit insecticides in conventional winter wheat production. Annual flower strips positively influence the number of hoverfly larvae. Adult Syrphidae probably travel longer distances to lay eggs in a flower strip to avoid competition with other individuals using locally available flowers. Moreover, Syrphidae probably need less energy due to the better availability of nectar, thanks to which they can fly further [14][15]. Klatt et al. [16] recorded a rise in bumblebee colonies and their activity near annual flower strips; however, the effects decreased as the distance from the strips grew. The results of research by Kujawa et al. [12] confirm that, within only three months of their creation, annual flower strips became a habitat, with the species richness of carabids, spiders, butterflies and other pollinators, as well as predatory insects living on plants, being significantly higher than in the neighbouring rye field. Similar results were obtained by Boetzl et al. [17]. The neighbouring of annual flower strips increased the share of predatory insects and, at the same time, decreased the share of pests in an adjacent oilseed rape field.

On the one hand, annual flower strips may start blooming too late to ensure resources during the activity period of, e.g., solitary bees and wasps, but, on the other, they can be advantageous for ground predators (e.g., spiders, beetles), probably by providing more diversified shelter and a favourable microclimate directly after sowing [15][18][19]. Annual flower strips liquidated at the end of cultivation or after harvest are, however, poor wintering habitats for arthropods, as they can become ecological traps (e.g., the insects wintering in the ground will not survive ploughing) [20]. Raderschall et al. [19] estimated additional placement of beehives in fields with annual flower strips and broad bean cultivation. There was no adverse effect on the bumblebees visiting the broad beans, which suggests that competition was not strong enough to drive bumblebees from cultivations, while, in research by Bommarco et al. [21], adding beehives decreased the abundance of bumblebee males, thus eliminating the positive effect of flower strips. Herein, it should be borne in mind that the honey bee is neither wild nor an endangered species.

## 2.2. Perennial Flower Strips

A flower strip may cause positive population reactions in pollinators, such as decreased abundance and fecundity, which may lead to increased pollination. Perennial herbaceous plants and the connected fauna help common species remain common and ecologically important components of cultivations, and the insects that live on perennial plants are more diverse and specialised. They can also provide neighbouring fields with natural enemies and pollinators [22][23]. Species richness and the total abundance of insects are on average lower in wild flower strips in their first year than in older strips. Species richness of insects reflects the age and wild flower cover in the strips. The proportions of oligo- and monophagous species with only one generation a year and the species that winter in the form of eggs increase with strip succession, both in terms of species numbers and individual numbers [24].

Buhk et al. [25], in their research, estimated the general species richness of bees and butterflies; the abundance of bees clearly rose in the areas with perennial flower strips (after more than 2 years, a three- to fivefold increase in species richness was found). Perennial flower strips ensure diverse, rich plant cover and the related food resources for pollinators. Furthermore, it is worth noting that a high variety of spontaneously appearing plant species, which may colonise any gaps in a flower strip and provide pollen and nectar during the months of their scarcity, were observed [26]. Albrecht et al. [27] found that pollination increased by 27% in 2 year flower strips in comparison to the youngest ones, which may be explained by a higher number of breeding places and the possibility of wintering in older plantings. Perennial flower strips are a valuable wintering habitat for many arthropod taxa. In research by Ganser et al. [20], the age of perennial flower strips positively affected the wintering of spiders and the number of wintering pollinating flies and rove beetles did not change significantly with the age of the strip. Moreover, the number of beetles tended to decrease in the four-year-old flower strip in comparison with younger plantings. Research by Albrecht et al. [27] did not confirm increased pest control in the cultivations next to flower strips in subsequent years of the flower strip.

In order to achieve a maximum insect diversity, wild flower strips should be characterised by a high diversity of species and structure [24]. Wix et al. [28] recorded more butterflies and individuals in total in flower strips than in control plots, with the number of plant species as the key factor.

Flower strips must include plants that bloom even for several years, which requires careful planning and management, as the ability of plants to bloom decreases with time [26][28]. With environmental awareness continuously rising, the assumption in creating flower strips is to do so in the fields where plant protection chemicals are not used. Depending on the quality of the perennial flower strips (plant diversity, dominant species), they may need some treatment. Mowing or slight care treatments (every two or three years) may turn out to be necessary to minimise problems with weeds [1]. However, it must be borne in mind that rare mowing is beneficial for pollinators, particularly butterflies, which need constant access to nectar [5].

## 3. Width of Flower Strips

Apart from an appropriate species mixture, the width of the strip to seed the plants is also important. Tschumi et al. [3] showed that a 3 metre strip adjacent to a potato field was a place where the abundance of net-winged insects, hoverflies and ladybirds increased significantly, thus making it possible to limit the number of aphids. Although the research on flower strips covers strips of various widths (mainly 3 to 8 m) [29][30], one advantage of minimum 6 metre flower strips is undoubtedly the fact that they can act as a buffer zone protecting green cultivations from pollution by plant protection chemicals coming from neighbouring non-green cultivations. Moreover, if flower strips (e.g., perennial ones) include high plants, they may also become a mechanical barrier stopping pathogenic fungal spores carried by winds. It is worth noting that the plants in the strip are also often food for birds, which are a natural farmers' ally in biological protection [31] (**Figure 2**). A strip that is too narrow may then expose them to predators more easily, while a wider one can provide shelter and even a safe nesting place.

**Figure 2.** A 6 m flower strip with high plants surrounded by sweet corn cultivation, luring beneficial insects (mid-July 2022, authors' observations in the National Park of Greater Poland).

## 4. Weeds on Flower Strips

Some farmers fear that flower strips may become a reservoir of weeds that can then spread into the surrounding fields. Although there is such a risk, properly created and tended strips will not create problems [31]. Moreover, some weeds can be maintained on arable land, pathways, the lines of fences and non-cultivated areas at an acceptable level of density. Accompanying plants, the so-called weeds, strengthen landscape diversity, mainly playing a functional role in agricultural ecosystems and their biodiversity; they constitute a basis for the agricultural food web, providing food to many organisms [9][32][33][34]. For example, their presence increases regulatory services, as they ensure the survival of the Apidae [33][35]. The interactions between a weed and the pollinating insect are regulated by flower features, such as its colour, shape and smell, but also depend on the quality of available pollen and nectar. Rollin et al. [34] suggest three groups of pollinators as potential bioindicators for biological evaluation of balance within a farming land management strategy in a moderate climate: the species Geometridae and Bombyliidae visiting Caryophyllaceae and Papilionidae feeding on Apiaceae and Syrphidae, which visit Asteraceae. Molthan [36] also indicated preferences of insect groups visiting particular plant families. Syrphidae were indicated to prefer the plants of the Apiaceae (*Pastinaca satica* L., *Daucus carota* L.) and Asteraceae (*Matricaria chamomilla* L., *M. maritima* L., *Sonchus arvensis* L.).

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