Technical guide
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Functional agrobiodiversity

Perennial flower strips – a tool for improving pest control in fruit orchards

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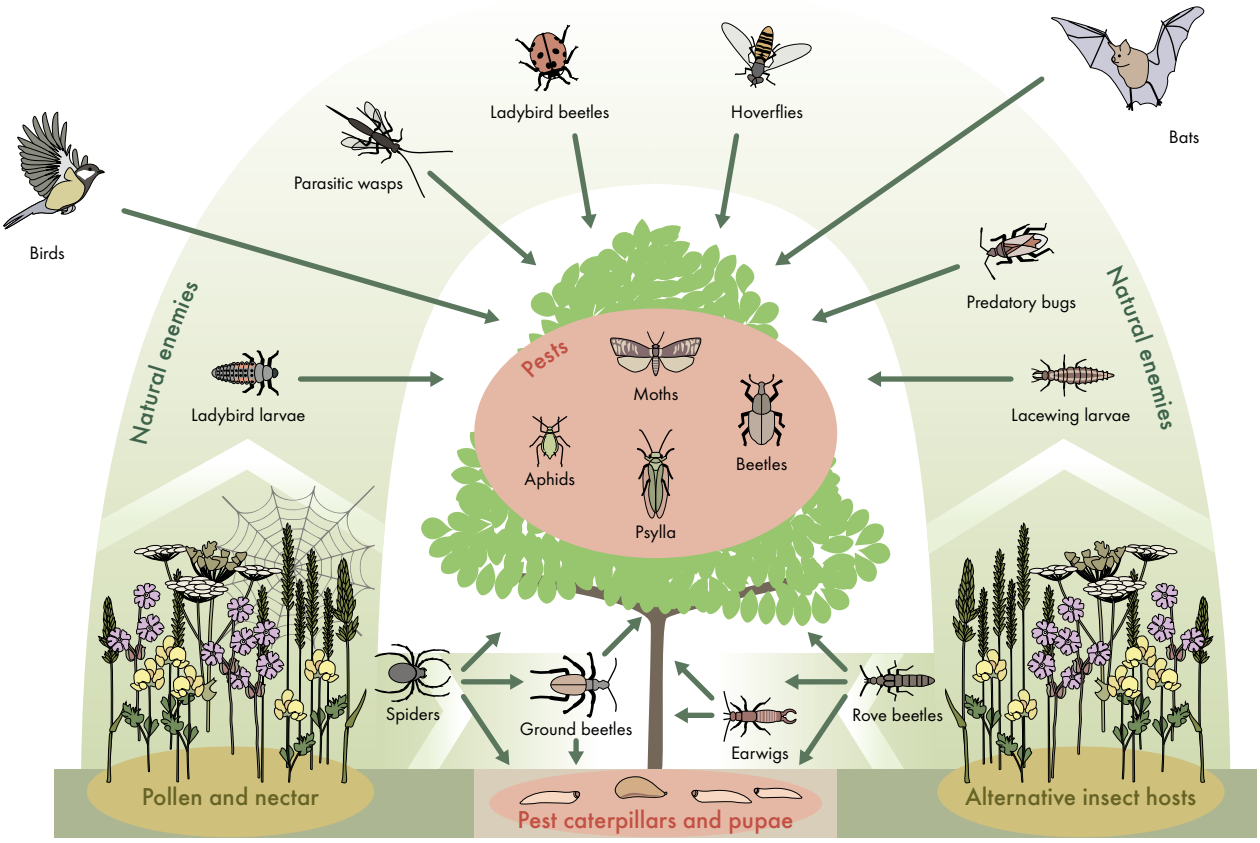
Why sowing flower strips in orchards?

Orchards are interesting habitats for biodiversity due to their perennial character and their diversified structure. They are potentially attractive for both pollinators and pests' natural enemies. Diversifying orchards with non-crop vegetation such as flower strips can provide additional opportunities to maintain and develop these populations and thus optimize ecosystem services.

Advantages of sown flower strips:

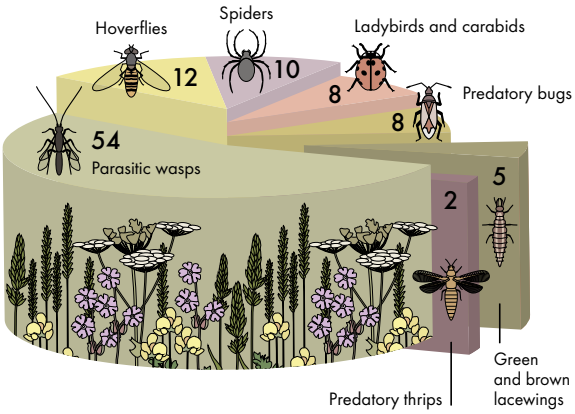
- Flower strips in drive alleys enhance the complexity of the orchard ecosystem, which is attractive to many species of predators, parasitoids and pollinators. A diversified and complex ecosystem **provides better biological pest control**.
- They **provide natural enemies with shelter and food** (pollen, nectar, alternative preys) that allow them to maintain their populations within the orchard and to produce more offspring.
- The flower strips' proximity to the crop **makes it easier for the predators and parasitoids to reach the pests and thus increase biological pest control**, especially for little, mobile species.
- Undisturbed ground zones in flower strips **promote beneficial arthropods** that live on the soil surface such as ground beetles and spiders that feed on pest larvae.

Interaction between natural enemies promoted by flower strips and phytophagous pests



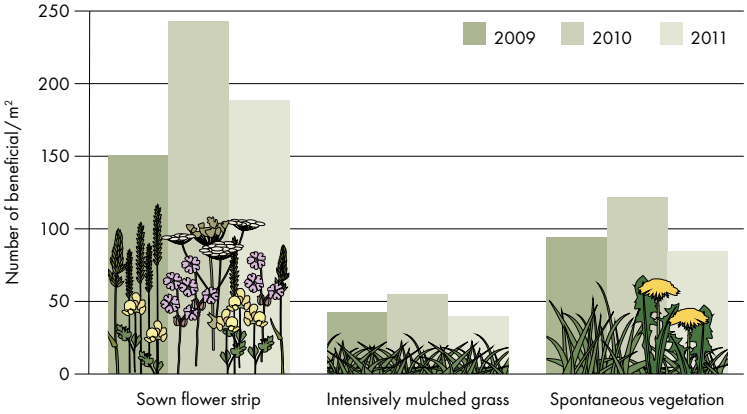
Throughout the year, sown flower strips maintain a diverse population of natural enemies close to the fruit trees. In this way, they manage to rapidly control pest populations in a natural way.

Proportion (%) of different natural enemies found in flower strips



Flower strips are habitat for a large variety of beneficial organisms. Parasitic wasps account for about half of the biodiversity (mean of six assessments by year in three years in two orchards; source: Interreg TransBioFruit project 2008–2014).

Attractiveness of flower strips compared to intensively mulched grass and spontaneous vegetation



Sown flower strips composed of 20 species were more attractive to natural enemies than intensively mulched grass, and spontaneous plant zones with a two-time-a-year mulching regime (mean of six sampling periods a year during three growing seasons in orchards in Belgium and the North of France; source: Interreg TransBioFruit project 2008–2014).

What are predators?

Predators are animals that feed on other animals. In orchards, we can find two predator types:

- Generalists: They feed on a large prey range. Generalist predators are for example green and brown lacewings, earwigs, spiders, ground beetles and predatory bugs.
- Specialists: They feed on specific preys or a narrow range of closely related preys. Specialist predators are ladybirds, some mite species and hoverflies, for example.

What are parasitoids?

Parasitic insects develop as larvae in or on host insects, which are killed as a result. Adult parasitoids are free-living and feed predatory or on nectar and pollen. Most parasitic insects are found in the order *Hymenoptera*. About 10% of all insect species described are parasitoids.

Predatory larvae of ladybird in an aphid colony.

Parasitic wasp on a wild carrot.

Potential effectiveness of natural enemies present in perennial flower strips for main apple and pear pests (situation in Central Europe)

Natural enemies / Pests	Earwigs	Predatory mites	Predatory bugs	Lacewing larvae	Hoverfly larvae	Ladybirds (adults and larvae)	Predatory midge larvae	Ground beetles	Spiders	Parasitic wasps or flies	Entomopathogenic fungi	Entomopathogenic nematodes	Birds and bats
Apple blossom weevil								●	●	•			
Rosy apple aphid	•		●	•	●	●	•		⬤	•	●		
Apple sawfly	●		•					•	●	•		●	
Winter moth	●		●	●				●	●	•	•	●	•
Woolly apple aphid	●		•	•	•	●	•		●	⬤	●		
Codling moth	●		●	●				●	●	●	•	●	●
Apple seed moth	●		●	●				●	●	●	●		•
Summer fruit tortrix moth	●		●	●				●	●	●	•	●	●
Fruit tree red spider mite	●	⬤	•	●		●	•	●	●				
Pear psylla	●		⬤			•			●	●			
Pear midge	•	●	•	●				•	●	⬤			
Hawthorn jewel beetle	●					●			●	●			
Pearleaf blister mite	●	⬤	•	●		●	•	●	●				
Forest bug			●						●		●		
Scale insects	●		•			•			●	•			

⬤ key natural enemy ● important natural enemy • minor natural enemy

Positive experiences of perennial flower strips in orchards

- In Swiss apple orchards, with sown flower strips including 30 species of biannual and perennial flowers, the impact of rosy apple aphid damage was significantly decreased below an economic threshold during several years, without the use of insecticides. (*source: FiBL*)
- In Belgium, in apple orchards with sown flower strips including 20 species of annual, biannual and perennial flowers, the number of aphid predators was increased and damage by the rosy apple aphid was below the economical threshold during several years, without the use of insecticides. (*source: CRA-W*)
- In France, the presence of flowering *Anthemis arvensis, Centaurea cyanus* and *Chrysanthemum segetum* in proximity to young pear trees infested with psylla significantly suppressed infection rate within two weeks. (*source: GIS Fruits / INRA*)
- In France, perennial sown flower strips grown in the drive alley of a cider apple orchard increased the number of ladybird and hoverfly larvae in aphid colonies by about 60 %. (*source: GIS Fruits / INRA*)

Moreover, many studies show a positive correlation between the predators' abundance and the reduction of phytophagous pests. They also conclude that a complex habitat structure promotes the persistence of predators and reduces predation between predators.

Improving attractiveness for the public and local wildlife

Promoting local plant diversity within and around orchards not only significantly improves the visual quality of the landscape. It can also favour local wildlife and biodiversity.

A high biodiversity can furthermore provide an additional source of income for the farm through the receipt of subsidies, and increase its attractiveness for ecotourism and direct marketing. A biodiversity that can be perceived across farms increases the attractiveness of the landscape for visitors.

It has been shown that a better understanding of the issues and practices of biodiversity development increases farmer's interest in the introduction of flower strips, natural enemies and their interactions in agro-ecosystems.

Natural diversity in an orchard and its surroundings also makes the landscape more attractive for customers and tourists.

Complementary measures conducive to natural enemies

Flower strips' efficiency is enhanced by the presence of additional natural elements in or near the orchard such as hedges rich in species and structures, extensively used meadows, individual bushes and flowering fallow land.

An orchard whose plant diversity has been carefully selected within and around the crop may lead to an increase in predator numbers and may put pests at a disadvantage.

Flower strip in the tree row

Bat box

Hedgerow

Flower strip at the edge of the orchard

Extensive grassland

Wild bees nesting box

Benefits of generalist natural enemies

Generalist natural enemies like spiders, earwigs and others have advantages that specialized natural enemies do not have:

- Their abundance is maintained also in absence of orchard pests as they consume alternative prey. Their **presence** in the orchard or nearby is therefore **less fluctuating**.
- They also feed on the first developmental stages of pests, thus **providing early protection** before an increase in pest populations. Examples are predatory bugs, spiders and ground beetles.

To ensure the efficiency of generalist predators when first pests appear, their populations must be sufficiently large and diverse. This can be achieved by promoting alternative prey by flower strips. Predators also must have the possibility to quickly recolonize the site after a perturbation from ground tillage or plant protection treatments. This is enabled by nearby natural elements like flower strips and hedges.

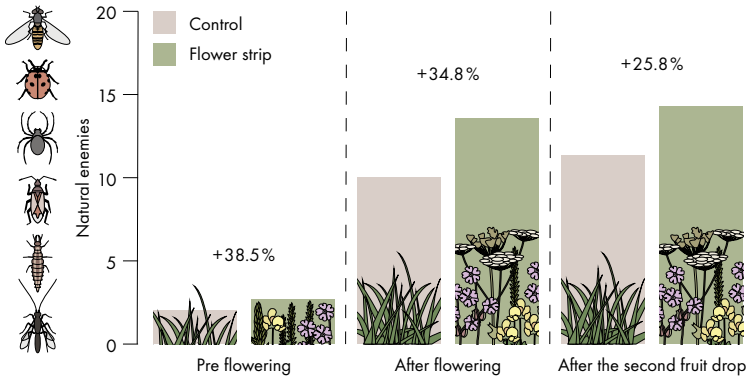
At the start of the year, flowering strips already offer a suitable habitat for many beneficial insects and spiders.

Flower strips also provide shelter to generalist natural enemies.

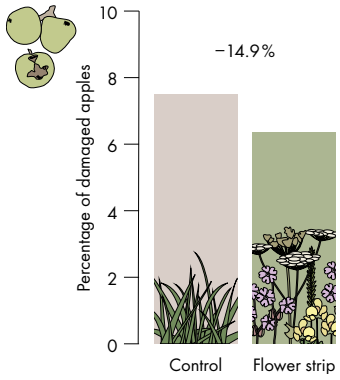
Temporal occurrence of key-pests (P) and main natural enemies (E) found in orchards with flower strips during the year

Key-pests		
P1	**Apple blossom weevil**	*Anthonomus pomorum*
P2	**Rosy apple aphids**	*Dysaphis plantaginea*
P3	**Apple sawfly**	*Hoplocampa testudina*
P4	**Winter moth**	*Operophtera brumata*
P5	**Woolly apple aphid**	*Eriosoma lanigerum*
P6	**Codling moth**	*Cydia pomonella*
P7	**Appleseed moth**	*Grapholita lobarzewskii*
P8	**European red mite**	*Panonychus ulmi*
P9	**Pear psylla**	*Cacopsylla pyri*
P10	**Pear midge**	*Contarinia pyrivora*
P11	**Hawthorn jewel beetle**	*Agrilus sinuatus*
P12	**Pearleaf blister mite**	*Eriophyes pyri*
P13	**Forest bug**	*Pentatoma rufipes*
Main natural enemies		
E1	**Ladybug**	*Coccinellidae*
E2	**Hoverflies**	*Episyrphus* sp., *Syrphus* sp.
E3	**Brown lacewings**	*Hemerobius* sp.
E4	**Green lacewing**	*Chrysoperla carnea*
E5	**Common flower bug**	*Anthocoris nemorum*
E6	**Anthocorid bugs**	*A. nemoralis, Orius* sp., ...
E7	**Miridae bug**	*Heterotoma pl., Deraeocoris r.*, ...
E8	**Soldier beetles**	*Cantharis livida / rustica*
E9	**European earwig**	*Forficula auricularia*
E10	**Parasitic wasps**	*Aphidius* sp., *Aphelinus mali*
E11	**Aphid midge**	*Aphidoletes aphidimysa*
E12	**Ground beetles**	*Poecilus cupreus* and others
E13	**Rove beetles**	*Staphilininae, Aleocharinae*
E14	**Predatory mites**	*Phytoseiidae (Gamasidae)*
E15	**Spiders**	*Araneidae* and other families

Promotion of aphid natural enemies during the season



Reduction of fruit damages caused by aphids



Up to 38 % more natural enemies of aphids were found on flower clusters (pre flowering), fruitlet clusters (after flowering) or long shoots (after the second fruit drop) of apple trees with adjacent flower strips compared to trees without flower strips. The percentage of apples damaged by the Rosy apple aphid was 15 % lower in trees next to flower strips compared to trees in the control plots (mean 2016–2017), according to the European EcoOrchard project.

Main natural enemies	BBCH [1]
E12, E13	00-61
E1–E15	56-74
E12, E13	59-67
E2–E9	00-72
E11	51-89
E2–E9	69-85
E3–E9	71-89
E1–E15	00-89
E1–E9	00-89
E12–E15	53-71
E1, E11, E12, E15	74-89
E12–E15	00-85
E14, E15	00-89
Key-pests	
P2, P8, P9	00-89
P2, P4, P6, P7, P9	00-89
P2	54-81
P2, P4, P6–P9	60-89
P2, P4, P6–P9	54-89
P2, P4, P6–P9	54-89
P2, P4, P6–P9	74-89
P2, P4, P6, P7, P9	72-81
P2, P4, P6, P7, P9	72-89
P2, P9	72-89
P2–P7	54-81
P1–P4, P6–P8, P12	54-81
P2, P3, P10	54-81
P8, P12	00-89
P2–P13	00-89

[1] BBCH: 00 = Dormancy, 51–59 = Inflorescence emergence, 61–69 = Flowering, 71–79 = Fruit development, 81–89 = Fruit and seed maturity

The benefits of natural enemies promoted by flower strips

Ladybug larvae

Ladybirds *(Coccinellidae)*
About a dozen of the 150 ladybird species known in Europe can be found in orchards. Larvae and adults' diets are similar. About 65 % of coccinellids predate aphids. Larvae and adults can eat 30 to 60 aphids per day during their lifetime that can last up to 12 months. Some ladybirds like *Stethorus* species are specialized on mites, mealybugs or thrips. Others are major predators of moth eggs. Some species also need pollen at adult stage to reproduce, hence the importance of flower's availability in their environment.

Green and Brown lacewings *(Chrysopidae* and *Hemerobiidae)*
The adults of Green lacewings feed on nectar, honeydew, and pollen. Females produce 400 to 500 eggs over a relatively long life of up to 3 months. Larvae of the Green lacewing (called aphid lion) are generalist natural enemies of aphids, mites, thrips, mealybugs, and almost any other soft-bodied prey. They are voracious aphid predators that can eat 200 to 600 aphids during their one to two week development period. They can also be important predators of moth eggs and larvae. The smaller Brown lacewings are predatory, both as adults and larvae. They are much more tolerant to lower temperatures than the green lacewings and are useful predators early in the season.

Green lacewing larva eating an aphid

Hoverfly larva

Hoverflies
Several hoverfly species are among the most voracious natural enemies of aphids in orchards. Adults are known as hoverflies and resemble bees, except that they have only one pair of wings. Their food sources are pollen, nectar and aphid honeydew, which they need for egg production. Adults lay white eggs in the midst of aphid colonies. A single larva can eat 500 aphids during the 3 weeks of its development. There may be 5 to 7 generations per year with most species overwintering as adults or last larval stage. From Nordic countries many hoverflies migrate to overwinter in the south.

Parasitic wasps and flies (parasitoids)
There is a large number and a great diversity of parasitic wasp species. Among them, some species are natural enemies of apple and / or pear pests. They lay eggs on or inside an insect host and parasitic larvae later emerge and feed on it. The process inexorably leads to the death of the host, once all the needs of the larvae have been fulfilled. Some species are important natural regulators of their host populations. Almost all apple and pear pest species are host to one or more parasitoids. Some parasitoids are highly specialized on one pest species or one small group of closely related pest species. Others have a broader host range. Important resources which contribute to the success of parasitoids are suitable overwintering sites or shelter and / or alternative hosts or food sources like nectar.

Parasitic wasp during parasitisation of an aphid

Web-building spider

Spiders

Spiders are generalist natural enemies and together with predatory bugs the most important natural enemies in early spring. They display a variety of prey-capture tactics. Some spiders spin silk webs to ensnare prey, others actively hunt prey. Approximately 50 species can be found in apple orchards. Even though they are generalist predators, they can have major effects on the regulation of pest populations. Web-spinning spiders have been shown to significantly reduce numbers of the Rosy apple aphid returning from its summer host in autumn. Spiders are adversely affected by pesticides and the number and diversity of species present in sprayed commercial orchards is much lower than in unsprayed orchards.

Predatory bugs (anthocorids, mirids and nabids)

Predatory bugs are generalist natural enemies and feed on many pests including aphids, sucking pests, spider mites, codling and tortrix moth eggs and young caterpillars. Immature stages (nymphs) and adults can eat about 30 mites or aphids per day. They are able to subsist on pollen or plant juices when prey is not available. Predatory flower bugs (Anthocorids) and minute pirate bugs (*Orius* sp.) are often the most common predatory bug species in apple and pear orchards. They overwinter as adults and appear as soon as the weather permits and are active all season until early autumn.

Adult damsel bug (*Nabidae*) eating an aphid

Predatory ground beetles

Ground beetles and rove beetles

Many species live in or on the soil surface in orchards. Larvae and adults feed their own weight each day on a wide range of soil-dwelling insects, mites, molluscs. Different ground beetle *(Carabidae)* species have diverse spectra of prey. Several key pest species spend part of their life cycle in the soil, usually the pre-pupal and pupal stages. Important examples are apple and pear sawfly, pear midge and various moth species. Predatory ground and rove beetles (*Staphylinidae*) can reduce these soil-dwelling pests. Populations of predatory ground beetles can be enhanced by the provision of ground vegetation and non-disturbed soil.

Earwigs

Earwigs are very widely distributed and abundant on apple and pear trees. Most trees have a resident earwig population. They mate in late autumn and the female then digs an underground nest in which the pair overwinters. In late spring, earwigs leave the ground. They hunt at night and shelter by day, so populations in orchards are often underestimated. Earwigs are important natural enemies of numerous pests of apple and pear. They feed on aphids (especially also woolly aphid), apple and pear suckers, various species of caterpillars, codling and tortrix moth eggs, scale insects and spider mites. Earwigs are omnivorous and may feed on plant material but it is assumed that they mainly cause only secondary damages by excavating pre-existing damage on fruit. Overall, the benefits of earwigs outweigh their disadvantages as pests in top fruit orchards.

Common European earwig

Predatory mites

Many species are numerously found in unsprayed orchards. The species *Typhlodromus pyri* is omnivorous and at the same time the most reliable and effective mite predator in European orchards. It is the key natural enemy of the Fruit tree red spider mite, Apple rust mite and Pear leaf blister mite. The species is very active and moves rapidly, consuming up to 350 mites in a lifespan of about 75 days. Females may lay up to 70 eggs and have several generations per season. Therefore, populations can build rapidly in response to pest mite populations.

Typhlodromus pyri (right) attacking a Fruit tree red spidermite (left)

Selection of effective plants

The specialisation of beneficial insects on certain plant species requires a selection of the appropriate plants to meet the conservation and plant protection targets.

Requirements for the seed mixture composition

- **Attractive and valuable to natural enemies** with accessible nectar and pollen (short corolla blossoms) for unspecific mouth parts of natural enemies.
- **Early first flowering** in the cropping season to support early natural enemies and limit infestation by aphids in spring.
- **Continuous flowering throughout the season**. Natural enemies must be able to find food sources in every development stage. In this way they are active as soon as pests emerge, at different times during the season and at various apple trees' growth stages.
- **No enhancement of pest insects.** Pest insects and hyperparasitoids may also profit from certain plant species in flower strips. Thus, food plants that are mainly used by natural enemies should be used.
- **Short growth** (low height of plants) and thus tolerant to repeated mulching (3–4 times a year).
- **Bi-annual and perennial** are preferred. In contrast to annual plants, bi-annual and perennial plant species do not need to be resown annually.
- **Grass species** are included to stabilize the plant community of the flower strip, but may not become too dominant. They should be limited to 75 to 80 % weight of total seed mixture.

Species used in the EcoOrchard project
Sown flower species: *Achillea millefolium*, Ajuga reptans, Bellis perennis, Campanula rotundifolia, Carum carvi*, Cardamine pratensis*, Centaurea jacea*, Crepis capillaris, Daucus carota*, Galium mollugo, Geranium pyrenaicum, Hieracium aurantiacum, Hieracium lactucella, Hieracium pilosella, Hypochaeris radicata, Lathyrus pratensis, Leontodon autumnalis, Leontodon hispidus, Leontodon saxatilis, Leucanthemum vulgare*, Lotus corniculatus*, Medicago lupulina*, Myosotis scorpioides, Primula elatior, Prunella vulgaris, Silene dioica, Silene flos-cuculi, Trifolium pratense*, Veronica chamaedrys, Vicia sepium**
Sown grass-species: *Anthoxanthum odoratum, Cynosurus cristatus, Festuca guestfalica, Festuca rubra rubra, Poa nemoralis, Poa pratensis, Poa trivialis*

* particularly beneficial for natural enemies and pollinators

Hoverflies feed on various flowers such as *Daucus carota*, *Hieracium pilosella*, *Centaurea jacea* or *Geranium pyrenaicum* (from top to bottom).

- **Adapted to orchard soils** that often are quite rich in nutrients and compacted.
- **Adapted to the soil type, shade and dry and wet periods.** The use of native and mainly ecotypes of plants is recommended.

Beneficial insects with short tongues need open nectar plants. Pollinators with long tongues, such as some wild bee species, forage on concealed nectar plants.

Open nectar plants for natural enemies
Apiaceae such as Wild carrot (*Daucus carota*), cumin (*Carum carvi*)
Vetches such as Bush vetch (*Vicia sepium*) with extrafloral nectaries

Concealed nectar plants for pollinators
Legumes such as Bird's-foot trefoil (*Lotus corniculatus*), Red clover (*Trifolium pratense*)

Flower strips composed of perennial plants providing a wide variety of food resources.

Soil preparation and sowing of flower strips

Sowing periods

Two sowing periods are possible:
In regions with short winters
(i) from April to May or
(ii) from early September to mid-October.

In regions with long winters
(i) in May or
(ii) in August to early September (after harvest).

Climatic conditions immediately after sowing have a major influence on the result. Sowing between April and early June enables germination of a part of the seeds before summer drought. Further seeds will germinate in the following years.

In regions with frequent dry periods in spring, sowing can be postponed or be done in autumn, in order to increase the chance to benefit from a wet period inducing a good germination rate. Late sowing also allows soil cultivation during summer, which reduces perennial weeds and regrowth of grasses. Moreover, lower weed developments can occur during autumn.

Soil preparation

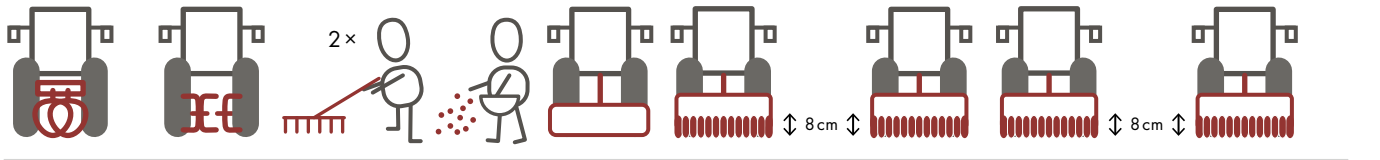
A carefully prepared seedbed promotes good germination and early development of the sown plants and reduces later maintenance measures. The goal is to prepare a seedbed reducing the grass competition, so that it will stay vegetation-free at least for four weeks.

The recommended width for flower strips is equal to the inner distance between the tractor wheels plus 10 cm, resulting in a 5 to 10 cm overlap into the tractor track at each wheel. Flower strip width also depends on the available machinery for soil preparation and mulching.

How to proceed

- Only work the soil after it has dried well.
- Prepare a relatively fine grain size of the soil using a rotary tiller / cultivator. Avoid too fine soil, as it will silt when it rains and thus hinder emergence of the sown plants.
- Ensure good settling of the soil for four to six weeks to enable a good contact between seeds and soil.
- Before sowing, encourage germination of weed seeds through repeated (two times) superficial (max. 3 cm deep) mechanical harrowing or manual raking. This will reduce weed pressure after germination of the seed mixture.

Sowing and management of flower strips in the first year (spring sowing option)



Soil preparation in autumn: ploughing or spading in heavy soils or repeated use of the rotary tiller / cultivator

Weed control: repeated raking

Seedbed preparation in March with the rotary tiller / cultivator

Sowing: onto the soil surface

Rolling

1–2 mulchings when plants are 30–40 cm tall

1 mulching after summer drought, before harvest

1 mulching before winter

Sowing

- Sowing density of seed mixtures is very low. Depending on the proportion of flower and grass species, sowing density varies between 2 to 5 g / m^2. For pure flower mixtures, 2 g / m^2 are needed. For grass-flower mixtures 5 g / m^2 are needed with 20 to 25 % weight of flowers and about 75 to 80 % weight of grasses. For a good distribution of the seeds on the soil surface, flower seed mixtures are ideally mixed with river sand or vermiculite.
- Distribute the seeds on the soil surface (do not drill).
- After sowing, roll the soil with a Cambridge roll to ensure a good contact of seeds with the soil and reduce germination of undesired weeds. Irrigate if needed.
- Fertilisation of flower strips is neither necessary nor recommended.
- In case of expected high slug pressure (e. g. under rainy / humid conditions), one application of a molluscide is recommended to protect the sown plants.

Management of flower strips

Management in the first year

A proper management in the first year is decisive to enable the flower species to settle in.

- **1st mulching / cut:** Weeds germinate after 2 to 3 weeks, whereas the sown flowers need 4 to 8 weeks to germinate. A first maintenance cut at a plant height of 30 to 40 cm will provide light to the sown flower plants. The cutting height should be at least 8 cm. Cutting the flower strips then removing the material from the drive alleys is better than mulching, because the mulch cover may hinder germination of remaining flowers.
- **2nd mulching / cut:** A second maintenance cut is necessary 6 to 8 weeks later, if the flower strip is not dense enough. Cutting down the vegetation will bring more light to the soil surface and encourage the germination of the remaining flower seeds. If the biomass of mulched plants covers the flower strip too much, it should be removed from the drive alleys and put into the tree lines.
- **3rd mulching:** A third mulching after summer drought before harvest can be useful.
- **4th mulching:** Last mulching should be done in September / October before winter to reduce the risk of frost damage.

Most plant species composing the seed mixtures blossom after an overwintering period. Thus, in the first year, the flower strips often look more like grass strips than flower strips. Floral diversity increases in the following years. The photo shows a flower strip in the third year.

Management from the second year onwards

The mulching regime greatly depends on the mixture used. The mulching height should be at least 8 to 10 cm to ensure the survival of flowers and that rosette-plants are spared.

Alternate mulching (50 : 50 of area) with a delay of about 3 weeks can be performed to enlarge the availability period for pollen and nectar. The remaining half will provide shelter to insects during winter.

Perennial, highly diverse mixtures need about 3 to 4 cuttings or mulching per year:

- **1st mulching:** First mulching when pruning with great care to avoid damaging the sown strips. The first mulching can be carried out 2 to 3 weeks before the flowering of trees at the latest, so the flower strips will blossom again simultaneously with fruit trees and attract natural enemies during this critical period. In northern countries it may be necessary to omit the first cutting to ensure the presence of flowers around fruit tree bloom.

- **2nd mulching:** Second mulching in spring 1–6 weeks after main flowering of the key-plants and the fruit crop to increase light penetration and to limit the development of grasses. However, it should not take place later than end of June to early July in order to allow a proper new growth and flowering of the flower strips. If possible, cutting should be avoided when the key natural enemies of the key pests are the most active. If cutting is done after grass seed production, the new growth may be too slow. In heavy soils, high cutting intensity could stimulate the growth of grasses in the mixture and weaken flowers.
- **3rd mulching:** Third mulching is recommended in September after summer drought during pre-harvest. The mulching schedules are based on the phenology and growth stages of the plant species. A long flowering period is targeted.
- **4th mulching:** Last mulching at the end of October, if the vegetation is tall and if the risk of vole damage is high.

Mulched material from flower strips should be removed in order to reduce progressively the soil fertility. Indeed, plant diversity is reduced to few species on nutrient-rich soil, such as nitrogen loving species like nettles and fireweed. Instead, on middle-rich or poor soils a high diversity of flowers is privileged in balance with lightweight grass species.

Mulching device in action (model "Humus OMB®"). A proper management of the ground cover (tree-row, drive alley) and flower strip is crucial and must be realised in relation to specific site conditions.

Mulching device (model "Aedes®") for larger flower strip-width.

Mowing regime versus protection of arthropods

Mowing is necessary to prevent homogenization in the flower strip and minimize weed problems. But mowing frequency and schedules affect arthropod communities by harming them and their habitats. Thus, a compromise must be found between promoting plant diversity and protecting arthropods. This can be achieved by monitoring the presence of key natural enemies in the orchard over the years.

Flower strips in the second year.

Costs of installation and management of flower strips

The costs of sowing flower strips vary depending on the seed used and the costs calculated for tractor, implements and work. The costs of the seed depend on the species composition, the ratio between herbs and grasses and the origin of the seed. Ecotypes from local ecotypes are more expensive than commercial varieties, but are more durable.

Depending on the biopesticides used, costs of insecticide treatments in organic orchards range from 250 to 500 € per hectare and per treatment. Some field trials have shown that at least one or two insecticide treatments may be omitted in orchards with perennial flower strips, which means a return on costs after one year.

Based on a standard calculation incorporating decreased pesticide residues and improved environmental quality, it is shown that the additional annual costs associated with the installation and management of flower strips are lower than those of treatments used to achieve the same pest control effect.

In addition, a system including flower strips with reduced mowing saves time and fuel for the maintenance of the drive alleys compared to a system without flower strips.

The European farmers are encouraged through European subsidies given by the Common Agricultural Policy to implement agro-environmental schemes such as the planting of hedgerows, extensive management of grass buffer strips or sowing of flower strips (European Commission, 2005). Both annual and perennial strips exist. The type of strips, management rules and subsidies vary considerably between countries, depending on national policies.

Exchange of experience between farmers and researchers on cultivation techniques, effects and costs of flower strips.

Possible costs for installation and annual management of flower strips in the alley rows of an orchard [1]

		Unit price	Quantity per ha	Costs per ha	€ per ha a. year (5 years)
Installation cost	Seed: ecotype mixture (30 flower species 20 % + 8 grass species 80 %)	60 € / kg	2000 m^2 / ha (5 g / m^2)	600 €	120 €
	Seed bed preparation (6 passages, fuel)	25 € / ha	6 passages	150 €	30 €
	Biocides (molluscicide) in 1st year	5 € / kg	40 kg	200 €	40 €
	Human labour	22 € / h	18 h / ha	396 €	79 €
Management	Equipment: mulching machinery for flower strips	9.500 €	1	950 € (10 ha)	190 €
	Mulchings (including human labour)	47 € / ha	3 mulchings	141 €	141 €
	Total				**600 €**

[1] Cost base of Belgium

Potential draw backs to growing flower strips in orchards

As is the case for other orchard management practices, growing flower strips within orchards can bring both advantages and disavantages. A farmer may decide that the potential disadvantages are insignificant or are acceptable in order to reduce pesticide applications, residues on fruits or costs by pesticide treatments.

The potential drawbacks of growing flower strips may be:

- **Attraction of rodent pests**, even if the flower strips may also attract rodent predators like weasel and ermine. A compromise between the promotion of biodiversity and rodent risk management needs to be found. Experiences with vole control measures (such as trapping or fencing) in combination with the mulching regime especially in midsummer and late autumn have shown positive results.
- **Potential competition between trees and flower strips** for access to water and nutrients, depending on flower species, water availability, and the distance to the trees. However, 50 to 60 cm wide flower strips situated in the centre of drive alleys should not compete with trees.
- **Spreading of weeds:** a weed control plan is needed if not any cutting is done, or if the flower strips are grown from spontaneous vegetation. In sown flower strips, the species are able to prevent weeds from settling in the strip, except in case of long-lasting dry periods in the first year. Weeds must be controlled by removing their roots and cutting the flower strips. It will improve establishment and growth of the latter.
- **Frost damage in risky areas:** higher vegetation could be involved in retaining humidity and increasing risk of frost damage. Strips should be cut in winter in case of regular risks and after the start of flower bud development of trees in case of late spring frost.
- **Restrictions to insecticide applications** during flowering of the flower strip periods (see box).

Strategies to mitigate those disadvantages may include species selection, adjustment of the mowing regime, and sowing the flower strips every second drive alley.

Implementing flower strips inside orchards requires an adaptation of pest protection management, since they are very attractive for pollinators and natural enemies during flowering periods.

Considerations to be taken when applying pesticides

Legislation

- During flowering, EU regulation (EC No 1107/2009) prohibits the applications of plant protection products that are harmful to bees.

Pesticide selection

- Whenever possible, only selective pesticides that are harmless to beneficial insects and other non-target organisms should be used.
- Only volatile and photo-susceptible products with quick degradation properties and no retentive compounds should be used.

Time and way of application

- If a treatment with a harmful biopesticide is necessary, the flower strips should be cut before applying it.
- Spraying of pesticides should be done when pollinators are absent, for example in the evening or at night.

Providers of seed flower mixtures in Europe	
Country	**Website**
Belgium	www.ecosem.be
Denmark	www.nykilde.dk
France	www.nova-flore.com, www.pinault-bio.com, www.nungesser-semences.fr, phytosem.com
Germany	www.rieger-hofmann.de, www.appelswilde.de
Spain	www.semillassilvestres.com
Switzerland	www.hauenstein.ch, www.ufasamen.ch

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