Perennial flower strips for pest control in fruit 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 optimise ecosystem services.

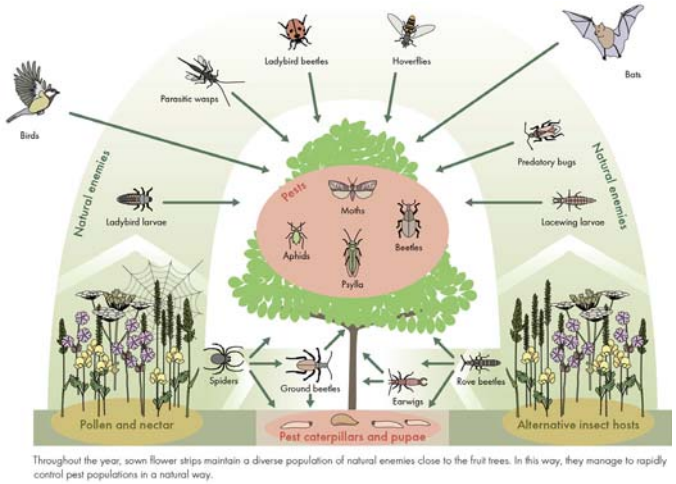
Advantages of sown flower strips:

- Flower strips in 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.

Positive experiences of perennial flower strips in orchards

- In Swiss apple orchards, with sown flower strips including 30 species of biennial and perennial flowers, the impact of rosy apple aphid damage was significantly decreased below an economic threshold in several years, without the use of insecticides. (source: FiBL)
- In Belgium, in apple orchards with sown flower strips including 20 species of annual, biennial and perennial flowers, the number of aphid predators was increased and damage by the rosy apple aphid was below the economic threshold in 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 flower strips grown in the alley of a cider orchard increased numbers 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.



Interaction between natural enemies promoted by flower strips and phytophagous pests

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

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

The recommended width for flower strips is equal to the inner distance between the tractor wheels plus 10cm, resulting in a 5 to 10 cm overlap into the tractor track at each wheel.

Photos: EcoOrchard

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).
- Early first flowering in the cropping season to support early natural enemies and limit infestation by aphids in spring.
- Continuous flowering throughout the season.
- No enhancement of pest insects. Pest insects and hyperparasitoids may also profit from certain plant species in flower strips.
- Short growth (low height of plants) and thus tolerant to repeated mulching (3–4 times a year).
- Biennial and perennial are preferred.
- Grass species are included to stabilise the plant community of the flower strip, but should be limited to 75 to 80 % weight of total seed mixture.
- 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.

Species used in the EcoOrchard project

Sown flower species: *Achillea millefolium** (yarrow), *Ajuga reptans* (bugle), *Bellis perennis* (daisy), *Campanula rotundifolia* (harebell), *Carum carvi** (caraway), *Cardamine pratensis** (cuckoo flower/Lady's smock), *Centaurea jacea** (brown knapweed), *Crepis capillaris* (smooth hawksbeard), *Daucus carota** (wild carrot), *Galium mollugo* (hedge bedstraw), *Geranium pyrenaicum* (mountain cranesbill), *Hieracium aurantiacum* (orange hawkweed), *Hieracium lactucella* (European hawkweed), *Hieracium pilosella* (mouse-ear hawkweed), *Hypochaeris radicata* (Catsear), *Lathyrus pratensis* (meadow vetchling), *Leontodon autumnalis* (autumn hawkbit), *Leontodon hispidus* (rough hawkbit), *Leontodon saxatilis* (lesser hawkbit), *Leucanthemum vulgare* (oxeye daisy)*, *Lotus corniculatus** (birdsfoot trefoil), *Medicago lupulina** (black medick), *Myosotis scorpioides* (forget me not), *Primula elatior* (oxlip), *Prunella vulgaris* (selfheal), *Silene dioica* (red campion), *Silene floscuculi (ragged robin)*, *Trifolium pratense** (red clover), *Veronica chamaedrys* (germander speedwell), *Vicia sepium** (Bush vetch).

Sown grass species: *Anthoxanthum odoratum* (sweet vernal grass), *Cynosurus cristatus* (crested dogstail), *Festuca guestfalica, Festuca rubra rubra* (creeping red fescue), *Poa nemoralis* (wood meadow grass), *Poa pratensis* (smooth-stalked meadow grass), *Poa trivialis* (rough-stalked meadow grass)

* particularly beneficial for natural enemies and pollinators

Soil preparation and sowing

Sow in May or in August to early September (after harvest). Spring sowing enables germination of part of the seeds before summer drought. Further seeds will germinate in the following years. In regions with frequent dry periods in spring, sowing in autumn can increase the chance to benefit from a wet period inducing good germination. 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 for at least four weeks.

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 sand or vermiculite and broadcast rather than drilled, rolled and irrigated if needed.

Management in the first year

- **First cut and mulch.** Weeds germinate after two to three weeks, whereas the sown flowers need four to eight weeks to germinate. A first maintenance cut at a plant height of 30 to 40 cm will provide light to the sown flowers. The cutting height should be at least 8 cm. Cutting the flower strips then removing the material from the alleys is better than mulching, because the mulch cover may hinder germination of remaining flowers.
- Second cut and mulch. A second maintenance cut is necessary six to eight 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 seeds. If the mulch covers the flower strip too much, it should be removed from the alleys and put into the tree lines.
- **Third cut and mulch**. A third mulching after a summer drought before harvest can be useful.
- **Fourth cut and mulch.** Last mulching should be in September / October before winter to reduce the risk of frost damage.

Management in the second year on

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 three weeks can enlarge the availability period for pollen and nectar. The remaining half will provide shelter to insects during winter.

Photos: EcoOrchard

Mulching device in action (Humus OMB®).

Perennial, highly diverse mixtures need about three to four cuttings or mulching per year.

- **First mulching.** In spring, one to six weeks after main flowering of the key-plants and the fruit trees to increase light penetration and to limit the development of grasses. However, it should not take place later than the end of June / early July in order to allow new growth and flowering of the flower strips. If possible, avoid cutting when the key natural enemies of the key pests are 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.
- **Second mulching.** Mulching is recommended in September before harvest.
- **Third mulching.** Last mulching at the end of October, if the vegetation is tall and if the risk of vole damage is high.

Mulch from the flower strips should be removed in order to progressively reduce soil fertility. Indeed, plant diversity is reduced to a few species on nutrient-rich soils, such as nitrogen loving species like nettles and rosebay willowherb.

Mowing frequency can harm arthropod communities 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.

Potential drawbacks

- Attraction of rodents, particularly voles, though the strips may also attract rodent predators. 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 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 alleys should not compete with trees.
- **Weeds.** A weed control plan is needed if no cutting is done, or if the flower strips are grown from spontaneously regenerated 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.

Costs of establishment

- The costs of establishing flower strips varies depending on the seed used and the costs calculated for tractor, implements and work. The costs 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 £215 to £430 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 alleys compared to a system without flower strips.

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. The type of strips, management rules and subsidies vary considerably between countries, depending on national policies.

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Installation/management	Unit price	Quantity	Costs per ha	£ per ha/yr (5 years)
Installation				
Seed: (30 flower species 20% + 8 grass species 80%)	£52/kg	2000m²/ha (5g/m²)	£516	£103
Seed bed preparation (fuel)	£21.50/ha	6 passes	£129	£26
Biocides (molluscicides)	£4.3/kg	40 kg	£172	£34
Labour	£19/hr	18 hrs/ha	£340	£68
Management				
Equipment: mulching machinery for flower strips	£8177	1	£818 (10ha)	£164
Mulching (including labour)	£40	3	£121	£121
Total				£516

Possible costs for installation and annual management of flower strips in the alley rows of an orchard (Based on costs in Belgium)

The benefits of natural enemies promoted by flower strips

Ladybirds (*Coccinellidae)*

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 specialised 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 availability in their environment.

Green and brown lacewings (*Chrysopidae/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 three 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.

Hoverflies

Several hoverfly species are among the most voracious natural enemies of aphids in orchards. The food sources of adult hoverflies 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 three weeks of its development. There may be five to seven generations per year with most species overwintering as adults or last larval stage.

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 specialised on one pest species or one small group of closely related pest species. Others have a broader host range. They need suitable overwintering sites or shelter and / or alternative hosts or food sources like nectar for success.

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.

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

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.

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