Competitiveness of Thirty-Eight Ecotype Species in Sown Perennial Flower Strip Within Apple Orchards in Belgium

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ABSTRACT

Flower strips in orchards using native plants and local adapted ecotype has shown to be a promising approach to boost natural enemies of fruit pests and pollinators, providing shelter, nectar, alternative prey and pollen. Flower strips within the grass alleys, between fruit tree rows, allow to enhance natural enemies without spend additional area for fruit production. However, the key issue in habitat manipulation such flower strips so set within between tractor wheels in the orchard alley ways, concern adaptation to orchard design and practices. The aim of the study is to assess, during three growing seasons, the development of thirty eight selected ecotype species, including dicotyledons and grasses species, in sown perennial flower strip planted in intensive apple orchards in temperate European climatic area. The study shows that species with the highest overall mean recovery are Cynosorus cristatus L. (12.61%), Geranium pyrenaicum Burm.f. (11.06%), Leucanthenum vulgare Lam. (9.72%), Lotus corniculatus L. (6.15%) and Trifolium pretense L. (5.32%). Results indicate an exceptional installation of the flower mixture, with a covering dominance of sown dicotyledons without excessive concurrency of grasses. The nine functional agro-biodiversity (FAB) species, particularly interesting for biocontrol in orchards, have been able to develop themselves without being dominated, offering a great functional diversity. The average recovery of FAB species increased throughout the study period to reach 44.4% in autumn 2017.

INTRODUCTION

Natural enemies and pollinators are crucial to maintain or enhance fruit production and quality in orchards. Well-nourished natural enemies live longer, reproduce more off-springs and thus have a greater impact on pest control. Perennial flower strips using native plants and local adapted ecotype has shown to be a promising approach to boost natural enemies and therefore can help to reduce some pests complementary to direct control with biopesticides [1-6]. Natural enemies and pollinators are increased by flower strips, providing shelter, nectar, alternative prey and pollen [7-9].

The boosting effect can be achieved by adding elements such as single bushes, hedges or flower strips adjacent to the orchards. However, flower strips within the grass alleys, between fruit tree rows, provide the additional benefits to enhance natural enemies, which move only short distances, such as small parasitoids, to reach fruit tree canopies [10-12].

Key issue in habitat manipulation such flower strips within the grass alleys concern adaptation to orchard design and practices. Flower species have to be adapted to orchard compacted soil, micro-climatic conditions, competition with trees, shadow and stress by machinery, weed competition, etc [8,13]. In addition, plant species in such flower strip have to be attractive to key natural enemies, flowering during the entire cropping season, tolerant to repeated mulching, target for an at least mid-term life period of 8-10 years.

The EcoOrchard project, untitled “innovative design and management to boost functional biodiversity of organic orchards”, has collected, experimented and provided methodology to improve functional agrobiodiversity in organic apple production. Within EcoOrchard, methods for creating but also assessing flower strip in the orchards were tested in seven European countries, including in Belgium. The Belgium case study is presented in this study.

Based on the above, the aim of the present study was to characterize the development of thirty eight selected ecotype species in sown perennial flower strip planted in two experimental orchards at Gembloux in Belgium, over three growing seasons, from 2015 to 2017, under intensive orchard management regime. As an outcome of this study is to provide technical information how to create and keep functional agrobiodiversity in apple production.

MATERIALS AND METHODS

Orchards and Flower Strips Design

The study was conducted from 2015 to 2017 in two well-maintained experimental apple orchards (3.5 m × 1.5 m), extended on one hectare each, planted in 2002 at Gembloux Belgium [14]. The tree's height reached an average of 3.5 m. For weed control under the tree rows, a cover crop machine was successfully used three times a year. The trees were grown according to organic production standards. In both orchards, six individual flower strips were set in the drive-alleys, establishing the so-called between tractor wheels flowering strip in the orchard alley ways. Each flower strip was sown according 1 m width × 36 m long, into six randomized blocks including six rows (plots) of 24 dwarf trees. The width for cultivation corresponds to the inner distance between the tractor wheels plus 10 cm, resulting in a 5-10 cm overlap into the tractor track at each wheel. Grass alleys beside flower strips and between the trees rows were kept short.

Selection Criteria of Plant Species for Flower Strips

The selection criteria for plant species were as follow: (i) highly attractive to key natural enemies, thus species with short corolla blossoms and well accessible nectar and pollen sources, (ii) flowering during the entire cropping season, (iii) not attractive to pest insects, (iv) short growing and thus tolerant to repeated mulching, (v) bi-annual and perennial, excluding annuals, as annuals have no chance to survive over years under such a mulching regime, (vi) with some grass species that do not become too dominant, (vii) adapted to orchard soils that often are quite rich in nutrients and compacted and (viii) adapted to shadow and stress by machinery. The competitive and perennial flowering strip in the orchard alley ways was established to be compatible with regular mulching and to target for an at least mid-term flowering period of 8-10 years. The mixture contains many ecotypes or wild form species, avoiding breeding types, as these show usually much less competitiveness within the community than ecotype wild plants. Accessibility of nectar and pollen is a function of floral architecture and the morphological structure of insect mouthparts. Beneficial insects with their short-tongue need open nectar plants and pollinators with long-tongue as wild bees forage on concealed nectar plants.

Flower Strip Establishment

Seed flower mixture was provided by Ecosem Belgium Company, specialized for seed production of native plants and local adapted ecotypes flower species. Flower strips were sown in springtime, early June 2015, after careful seed bed preparation. Before sowing, germination of weed seeds was encouraged through repeated superficial mechanical harrowing of the soil with a rake in order to reduce weed pressure after germination of the seed mixture. The sowing density of the seed mixtures was 4 g/m^2, including 20% weight of flower mixed with 80% weight of grass.

Flower Strip Management

Flower strip didn't receive any organic fertilizers. Considering that there is an effective movement of natural enemies between the flower strip and the tree canopies, and that we need efficient flower strips with flowers during the critical period around the fruit tree flowering, three mulchings were done in 2016 and 2017: (i) three weeks before tree flowering, (ii) seven weeks after tree flowering around June-drops and (iii) in autumn after harvest for limiting vole development. Hay mulched yield from flower strip were kept away in order to reduce soil fertility progressively and therefore reduce nitrophilous species. A high diversity of herb flowers in balance with lightweight grass species on middle rich or poor soil was desired.

Botanical Assessment

Flower strips were characterized three times a year (April, June and August), in 2016 and 2017, by assessing the ground cover (in %) of each plant species occurring at the site (sown and spontaneous plants), also indicating the flowering stage. The sampling area is a rectangular of 6 × 0.8 m^2 for each repetition in each orchard. Sampling areas were moved from year to year in order to get more realistic insight of the plant variability. The mean recovery rate and his variability were calculated for each species and each sampling period to follow the flower strip evolution in time. A general mean was also calculated to determine the most covering species during the study period.

RESULTS AND DISCUSSION

A total of thirty eight species were sown including thirty dicotyledons and eight grasses species. Among the dicotyledons, nine species are considered particularly interesting for the biodiversity and fauna of orchards and are called FAB (Functional Agro-Biodiversity) species, *Achillea millefolium* L., *Carum carvi* L., *Cardamine pratensis* L., *Centaurea jacea* L., *Leucanthenum vulgare* Lam., *Lotus corniculatus* L., *Medicago lupulina* L., *Trifolium pretense* L. and *Vicia sepium* L. **(Table 1)**. These nine FAB species showed a high development, since about 30% the recovery rate of flowering strips averaged 83%.

In the spring of 2016, it can be observed that nine (24%) sown species did not germinate. They were only five at the end of 2016 and two had never been observed after two years of assessment. These are *Ajuga reptans* L. and *Festuca guestfalica* Boenn. This germination rate could be in some case lower. This suggest the need for periodic flower strip mulching in order to allow new slow seed germinations [15].

Twenty other species, didn't include in the initial sown seed mixture, appeared spontaneously and were observed within the flowering strips. There were five at the first survey and during the rest of 2016. Among them, two species were no longer observed in 2017, *Geranium dissectum* L. and *Veronica persica* Poir. Four of these spontaneous species did not appear until the last survey of 2017, *Agropyron repens* (L.) P. Beauv., *Agrostis stolonifera* L., *Origanum vulgare* L. and a species of the genus Carduus.

The total recovery rate of flowering strips averaged 83% in the spring of 2016, reflecting a good installation of these and a good colonization of the space by the sown species. In autumn 2017, this rate averaged 143%, which means that the bare soil has disappeared and even there is a stratification of different layers of foliage superimposed in the strip. Species with the highest overall mean recovery are *Cynosorus cristatus* L. (12.61%), *Geranium pyrenaicum* Burm.f. (11.06%), *Leucanthenum vulgare* Lam. (9.72%), *Lotus corniculatus* L. (6.15%) and *Trifolium pretense* L. (5.32%) **(Table 1)**.

The average recovery of FAB species increased throughout the study period to reach 44.4% in autumn 2017 with a global average of nearly 30%. Globally three of these species are in the top 5 of species with the greatest recovery rate (*Leucanthenum vulgare*, *Lotus corniculatus* and *Trifolium pretense*). Nevertheless, three others have an average recovery rate lower than 1% (*Vicia sepium*, *Carum carvi* and *Cardamine pratensis*). The low presence or near absence of these species can lead to a loss of functional traits sought within the band.

The other sown dicotyledonous plants also have a growing recovery rate throughout the duration of the study, with an overall average of 41.1%. It is interesting to note that the recovery of FABs tends to equal or even exceed this one in autumn 2017.

Grass cover, meanwhile, increased in 2016, returning to its original level in spring 2017, and increasing again until autumn 2017, without however reaching the level of autumn 2016. Overall average of grass cover is 29.2%, i.e. the same as for FABs.

Recovery of spontaneous species decreased between spring and summer of 2016 and remained stable until autumn. It rose sharply in the spring and summer of 2017 to slightly decrease in the fall when it reached 21.9%.

Results seem to indicate an excellent installation of the flowered mixture, with a dominance of the covering of sown dicotyledons without excessive concurrency of grasses. The FAB species have been able to develop without being dominated, allowing a greater functional biodiversity to settle and stay in the orchards. Since beneficial insects have specific requirements, the selection of appropriate flowering plants is key to meet conservation targets and to realize benefits to ecosystem services. Additionally, the abundance of beneficial insects is influenced by the temporal availability of food resources. Therefore, it is important to ensure that managed areas provide these resources during the entire growing season. In the same way, the composition of the flower strip should ensure flowering during the entire cropping season, starting as soon as possible to limit aphids spring infestation as also showed by Wyss, Landis and Albert et al [6-8].

Table 1. Mean recovery rate for each species and respective flowering periods.

Species		2016						2017			
		Flowering period (month)**	Sown quantity (kg/ha)	%	Springer (%)	Summer (%)	Autumn (%)	Springer (%)	Summer (%)	Autumn (%)	Geneal mean (%)
Sown FAB species	*Achillea millefolium*	6-11	0.024	0.10%	1.5 (0.3)*	1.7 (0.3)	1.4 (0.3)	1.9 (0.3)	2.3 (0.3)	2 (0.4)	1.8 (0.3)
	Carum carvi	5-6	0.682	2.73%	0.8 (0.2)	0.5 (0.2)	0.9 (0.2)	0 (0)	0 (0)	0 (0)	0.4 (0.2)
	Cardamine pratensis	3-6	0.088	0.35%	0.2 (0.1)	0 (0)	0 (0)	0.3 (0.1)	0 (0)	0 (0)	0.1 (0.1)
	Centaurea jacea	6-10	0.13	0.52%	0.3 (0.1)	0.7 (0.4)	0.8 (0.3)	4.2 (0.5)	6.5 (1.1)	10.1 (1.3)	3.7 (1.3)
	Leucanthemum vulgare	5-8	0.062	0.25%	8.8 (1.9)	8.8 (1.2)	5.2 (0.4)	9.3 (0.4)	11.9 (0.9)	14.3 (0.8)	9.7 (1.3)
	Lotus corniculatus	5-9	0.258	1.03%	1.1 (0.3)	1.8 (0.4)	2.1 (0.4)	8.1 (0.9)	11 (1.8)	12.8 (0.7)	6.1 (1.6)
	Medicago lupulina	4-10	0.427	1.71%	1.8 (0.4)	2.7 (1.3)	2.6 (0.9)	1.2 (0.4)	1.1 (0.4)	0.6 (0.2)	1.7 (0.8)
	Trifolium pratense	5-10	0.258	1.03%	4.4 (0.8)	7.3 (0.9)	7.4 (0.6)	4.2 (0.7)	5.1 (1.1)	3.5 (0.3)	5.3 (0.9)
	Vicia sepium	5-8	0.342	1.37%	0.1 (0.1)	0 (0)	0 (0)	0.6 (0.2)	0.7 (0.3)	1.1 (0.2)	0.4 (0.2)

Other sown dicotyledonous species	*Ajuga reptans*	5-6	0.088	0.35%	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Bellis perennis	1-12	0.02	0.08%	1.2 (0.3)	0.5 (0.2)	0.8 (0.2)	1 (0.2)	0.5 (0.1)	0 (0)	0.7 (0.2)
	Campanula rotundifolia	6-10	0.012	0.05%	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
	Crepis capillaris	6-10	0.029	0.12%	0.1 (0.1)	0.8 (0.5)	0.5 (0.3)	0.2 (0.1)	0.2 (0.2)	0.3 (0.2)	0.3 (0.3)
	Galium mollugo	5-8	0.071	0.28%	1.2 (0.2)	3.2 (0.5)	3.4 (0.5)	4.5 (0.3)	5.7 (0.5)	10.7 (1.4)	4.8 (1.1)
	Geranium pyrenaicum	5-9	0.258	1.03%	13 (1.5)	14.4 (1.1)	14.7 (1.1)	8.6 (0.4)	10 (0.7)	5.8 (0.5)	11.1 (1.3)
	Hieracium aurantiacum	6-8	0.054	0.22%	0 (0)	1 (0.5)	0.8 (0.4)	6.3 (0.4)	7.8 (0.5)	4.9 (0.8)	3.5 (1)
	Hieracium lactucella	5-8	0.021	0.08%	0 (0)	2.7 (0.7)	2.5 (0.6)	0 (0)	0.3 (0.3)	0 (0)	0.9 (0.5)
	Hieracium pilosella	5-9	0.079	0.32%	1.2 (0.4)	1.9 (0.4)	2 (0.3)	1.7 (0.4)	1.6 (0.4)	0 (0)	1.4 (0.4)
	Hypochaeris radicata	5-9	0.113	0.45%	1.4 (0.5)	2.5 (0.8)	2.5 (0.8)	3 (0.5)	2.8 (0.7)	0.3 (0.2)	2.1 (0.7)
	Lathyrus pratensis	6-8	0.512	2.05%	0.1 (0.1)	0 (0)	0 (0)	1.5 (0.3)	2.2 (0.5)	9.2 (1.8)	2.2 (1.2)
	Leontodon autumnalis	6-10	0.113	0.45%	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
	Leontodon hispidus	6-10	0.241	0.96%	3.9 (1.5)	2 (0.7)	1.7 (0.4)	1.8 (0.6)	2.1 (0.8)	2.9 (1)	2.4 (0.9)
	Myosotis scorpioides	5-9	0.054	0.22%	0.2 (0.1)	1 (0.4)	0.7 (0.1)	0.3 (0.1)	0 (0)	0 (0)	0.4 (0.2)
	Plantago lanceolata	5-9	0.173	0.69%	3.3 (0.5)	4.8 (0.9)	4 (0.3)	4.8 (0.3)	5 (0.3)	3.5 (0.2)	4.2 (0.5)
	Plantago major	5-9	0.029	0.12%	0.1 (0.1)	0 (0)	0 (0)	0.4 (0.1)	0.3 (0.1)	0.1 (0.1)	0.2 (0.1)
	Primula elatior	3-5	0.012	0.05%	0.3 (0.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)
	Prunella vulgaris	7-9	0.105	0.42%	4.5 (1.3)	5.5 (0.4)	4.6 (0.1)	3.8 (0.4)	4.8 (0.8)	2.9 (0.3)	4.3 (0.7)
	Silene dioica	5-7	0.173	0.69%	0.2 (0.1)	0 (0)	0 (0)	0.5 (0.1)	0.5 (0.1)	0 (0)	0.2 (0.1)
	Silene flos-cuculi	5-8	0.046	0.18%	0.2 (0.1)	0.5 (0.2)	0.9 (0.2)	0.7 (0.2)	0.8 (0.2)	0 (0)	0.5 (0.2)
	Veronica chamaedrys	4-6	0.046	0.18%	1.5 (0.6)	0.2 (0.1)	0.2 (0.1)	2.8 (0.4)	4.1 (0.4)	2.8 (0.3)	1.9 (0.6)
Sown grasses	*Anthoxanthum odoratum*	4-6	0.995	3.98%	3.5 (0.5)	4.6 (0.2)	5 (0)	4.8 (0.9)	5.2 (1)	5.1 (0.9)	4.7 (0.7)
	Cynosurus cristatus	6-7	3.977	15.91%	13.6 (2.7)	20.3 (1.7)	19.5 (1.8)	5.8 (0.8)	6.1 (0.7)	10.4 (0.7)	12.6 (2.3)
	Festuca guestfalica	5-6	3.977	15.91%	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Festuca rubra rubra Mit.	6-7	3.977	15.91%	0 (0)	0 (0)	0 (0)	0.8 (0.1)	0.9 (0.1)	0.6 (0.1)	0.4 (0.1)
	Lolium perenne	5-10	4.971	19.88%	0 (0)	1.5 (0.3)	1.9 (0.4)	6.4 (1)	7.7 (1.2)	10.7 (1)	4.7 (1.4)
	Poa nemoralis	6-9	0.596	2.38%	1.8 (1)	5.7 (2.3)	6 (2.2)	0.4 (0.2)	0.5 (0.2)	0.1 (0.1)	2.4 (1.5)
	Poa pratensis	5-7	1.591	6.36%	3.1 (0.8)	2.4 (0.5)	3 (0.6)	0.1 (0.1)	0.7 (0.4)	0.8 (0.4)	1.7 (0.6)
	Poa trivialis	5-7	0.398	1.59%	0 (0)	0 (0)	0 (0)	5.7 (1.9)	5.4 (1.9)	5 (0.8)	2.7 (1.4)

Spontaneous species	*Agropyron repens*	6-8			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1.9 (1.3)	0.3 (0.6)
	Agrostis stolonifera	6-7			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)
	Bromus hordeaceus/ mollis	5-6			0 (0)	0 (0)	0 (0)	1.5 (0.7)	1.8 (0.8)	1.8 (0.8)	0.9 (0.6)
	Carduus sp	6-9			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)
	Dactylis glomerata	5-7			0 (0)	0 (0)	0 (0)	0.9 (0.2)	0.8 (0.2)	0.6 (0.2)	0.4 (0.2)
	Festuca pratensis	6-8			0 (0)	0 (0)	0 (0)	0 (0)	4 (1.2)	2.4 (0.5)	1.1 (0.7)
	Geranium dissectum	5-9			0.3 (0.1)	0.4 (0.3)	0.8 (0.3)	0 (0)	0 (0)	0 (0)	0.2 (0.2)
	Holcus mollis	6-9			0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
	Hypericum perforatum	7-9			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Leontodon saxatilis	6-10			0 (0)	0 (0)	0 (0)	0 (0)	0.2 (0.2)	0 (0)	0 (0.1)
	Malva moschata	7-9			0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
	Origanum vulgare	7-9			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.1 (0.1)	0 (0)
	Phleum pratense	6-7			0 (0)	0 (0)	0 (0)	2.1 (0.5)	1.9 (0.4)	3 (0.8)	1.2 (0.6)
	Ranunculus repens	5-7			0.1 (0.1)	0 (0)	0 (0)	1.1 (0.3)	1.4 (0.5)	2.3 (1.6)	0.8 (0.7)
	Rumex obtusifolius	6-9			0.5 (0.3)	2.9 (1.7)	1.8 (0.9)	4 (1.3)	6.4 (2.5)	4.7 (1.3)	3.4 (1.6)
	Sonchus asper	6-11			0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.3 (0.1)	0 (0.1)
	Taraxacum officinale	4-5			8.5 (1.7)	4.4 (0.3)	4 (0.3)	4.7 (0.5)	4.4 (0.5)	2.4 (0.4)	4.7 (1)
	Trifolium repens	5-11			0 (0)	0 (0)	0.9 (0.2)	3.8 (0.7)	3.9 (0.8)	1.2 (0.3)	1.6 (0.6)
	Urtica dioïca	6-10			0 (0)	0 (0)	0 (0)	0 (0)	0.9 (0.3)	0.9 (0.3)	0.3 (0.2)
	Veronica persica	3-10			0.3 (0.1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0.1)

* Values in bracket indicate the standard error of the mean (*n*=12)
** Labinon et al., 2004

The flower strip was sown in late spring in this study. However, two sowing periods are possible: In regions with short winters: (i) from April to May and (ii) from early September to mid-October. In regions with long winters: (i) in May and (ii) in August to early September (after harvest). Climatic conditions immediately after sowing have a major influence on the result. In regions with frequent dry periods in spring, sowing can be postponed or done in autumn, in order to have more chance to quickly 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 [16].

In our experiment, three mulching a year were achieved. To enable the sown flower species to germinate and establish, proper mulching management in the first year is decisive. As weeds germinate after two to three weeks and the sown flowers need four to eight weeks to germinate, a first maintenance should be done at a plant height of 30-40 cm ('weed cur'). The cutting height should be not lower than 8 cm to 10 cm to ensure that herbs are conserved and rosette-plants are spared. Cutting and removal of the material from the drive alleys is preferable to mulching, because the mulch cover may hinder germination of remaining flowers. A Second mulching or cut is necessary about six to eight weeks later, if the flower strip has not grown densely. Cutting down the vegetation will bring more light to the soil surface and encourage germination of new flower seeds [2]. If the biomass of mulched plants covers the flower strip densely, the biomass should be removed from the drive alleys and deposited into the tree lines.

The evolution of the composition of the bands will however have to be followed in order to make sure that grasses and other spontaneous species such as Rumex and thistles do not have a development which would disturb the balance of these by taking the space of more interesting species. Species abundance and diversity, indeed, tend to change years after the flower strip installation [17-19]. For example, Leps observed a decrease in species diversity from 3rd after sowing.

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CONCLUSION

Results of the present study showed that it's possible to install diversified and functional flower strips, within the grass alleys, between fruit tree rows, of intensive commercial orchards and to maintain it with appropriate cutting regime and management. The present field results, achieved in Belgium, will be further compared and validated with experimental field studies succeeded during the same period in other European countries, using various species mixtures. Further studies are needed to clarify (i) the efficacy of flower strips to be attractive for natural enemies, (ii) the impact of flower strips on pest control in orchards. These topics will be the purpose of further papers.

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