Effects of measures to enhance biodiversity in organic apple orchards in Germany

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Abstract

*In context of a project funded by the German Federal Agency for Nature Conservation and six federal states, measures to enhance the biodiversity in organic orchards are tested in six German regions. In twenty farm plots and orchards fitted with a standard set of measures, e.g. flowering strips in the alley and at the borders and shrubs at the top of each second row are compared with control plots without these measures. Additionally, practical experience with such measures is gained in on farm tests without control plots. The number of flowering species differed greatly between the plots with flowering strips and the control. After three years experience, a seed mixture with 32 species for flowering strips in the alleys proved feasible and ecologically reasonable and is thus recommended yet. Already in the 2nd test year, 2.8 times more butterflies were observed in the plots with flowering strips as in the control areas. The locust population increased slowly and not in all plots. In the upgraded plots, the visits of blossoms by wild bees are 10 to 40 times higher than in the control, depending on the plant species. The effect of these measures on the green apple aphid (*Aphis pomi *De Geer) is mainly an earlier decrease of the population. The relation of aphid predators to aphid colonies was considerably increased in the plots with biodiversity measures, especially at the beginning of the development of the aphid population. Until now, no fruit damage occurred that could be correlated with the biodiversity measures.*

Keywords: biodiversity, flowering strips, wild bees, aphids

Introduction

The project funded within the framework of the Federal Programme for Biological Diversity by the German Federal Agency for Nature Conservation with resources from the Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety started in July 2016 consisting of two different complementary subprojects: One for IPM-farmers and one for organic farmers. It is focused on measures to enhance biodiversity in orchards. The organic subproject aims towards the evaluation and improvement of these measures in a participatory process with the organic fruit growers organized in FOEKO in the main fruit growing regions of Germany, and in close cooperation with scientists experienced in different scientific disciplines. At the end of the evaluation, a catalogue with evaluated measures, which can be integrated in the organic fruit growing system to enhance biodiversity, will be published.

Material and Methods

The on-farm studies are conducted mainly in six fruit growing areas in Germany: southern region with the areas Lake Constance, Neckar Valley and Baden, western regions Rhineland and Rhinehesse, as well as Northern Germany and Saxony.

In each region, five farms participate in the standard evaluation with two comparable orchards with a minimum size of 1 ha each or with two plots of the same orchard with a

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distance between the plots of at least 100 m. In one orchard/plot a standard combination of measures to enhance biodiversity is tested, the other plot serves as “untreated control”.

The combination of measures includes:

- Flowering strips in the alleys
- Flowering strips at the border
- Shrubs at the end of each second row (*Euonymus europaeus, Viburnum opulus, Ligustrum vulgare*)
- Nest boxes for different species of wild bees and birds

In the following, first results of the evaluation of the measures are presented.

The **flowering strips** of ca. 0.5 m width were sown as a mixture of certified autochthonous seed of 28 species in the middle of the alleys in autumn 2016 and spring 2017. Flowering strips at the border of the orchards were sown with a mixture of 52 species (Kienzle et al., 2018). *Centaurea cyanus, Matricaria recutita, Papaver rhoeas, Sinapis arvensis (wild species), Fagopyrum esculentum* (cultivated species) *and Lepidium sativum* (cultivated species) were added in both kinds of strips to provide a flowering aspect in the first year and to protect the sprouting of the seedlings.

The strips in the alleys were mulched 2-3 times a year depending of the height of the vegetation. The rest of the vegetation in the alley was mulched more often. For this purpose, a special mulching machine that can exclude the strip was used (Manufacturer HUMUS OMB). The border strips were mulched only once in late autumn or in spring.

In the first year, the **success of the flowering strips** was determined by counting the halms in a 3 x 50 x 50 cm test frame in the alleys. The position of the frame was based on typical sections of the strips. From species not listed in field determination keys, the seedlings were photographed as an aid for later determination.

During the second vegetation period, a vegetation survey was carried out once on three 1 m² plots using the Schmidt scale, which was supplemented by Londo (1976), for documentation purposes.

The **flowering phenology** was recorded annually on 5 to 6 transects following the transect method based on the methodology for the determination of "species-rich grassland" in Baden-Württemberg (“FAKT”). The flowering phenology is traversed by the alleys, tree strips and tall shrub borders. In addition, all species in the alleys were qualitatively recorded with transects. To test how the two seed mixtures perform on different kinds of soil, a germination experiment was conducted additionally in May 2019 in the Lower Elbe / Altes Land Region, Northern Germany. Therefore, the seed mixtures for flowering strips in the alleys and for flowering strips at the border were sown each on a plot filled with marsh soil, marsh soil/sand mixture (1:1 mixture), lawn soil and mother soil, resulting in eight plots in the size of 1 m^2. After eight weeks, germination success was controlled.

In the orchards, the usual plant protection management in organic apple growing was applied. To monitor the effect on agronomic parameters, the **occurrence of aphids and their predators** on 500 randomly selected shoots per plot was assessed twice during the main infestation period of the green apple aphid (*Aphis pomi* De Geer) in June and July. The aphid colonies on the shoots were distinguished into 5 classes based on the estimation of aphid numbers: class A = 0-6 aphids, B = 6-10, C = 11-25, D = 26-50, E = more than 50 aphids per colony. The degree of infestation (DI) was calculated considering the number and size of the colonies as follows: DI = ((0,1 x A) + (0.25 x B) + (0.5 x C) + (0.75 x D) + E) / number of shoots assessed). The DI was also used for the calculation of the predator/prey relation.

Furthermore, in June before fruit thinning and in autumn before harvest, 1,000 randomly selected **fruits** per orchard were **controlled for damage by insects**. All skin injuries that could not be attributed without a doubt to fungal diseases or to russetting, hail, etc. were recorded. Rare or unclear skin defects were documented photographically. This should allow to identify the possible incidence of uncommon insect damage in the plots with weed strips.

The **general biodiversity** is recorded by means of several arthropod catches with a main focus on butterflies, wild bees, grasshoppers, birds and bats. Malaise traps, sweep nets and beating trap samples are completely evaluated, first as field species within 40 orders. Beneficial insects and pests are determined down to species level, as well as spiders, leafhoppers, bugs, and mostly ground beetles.

Results

1. Botanical composition of the flowering strips

The assessment of the germation rate showed a good to very good germination of the sown 28 autochthonous wild herb species. On average, 53 % of the species germinated already in the first vegetation period (Fig. 1). The seedling density varied between 64 and 534 seedlings / m². There was a great difference between the plots with flowering strips and the control regarding the number o flowering species (Fig 2).

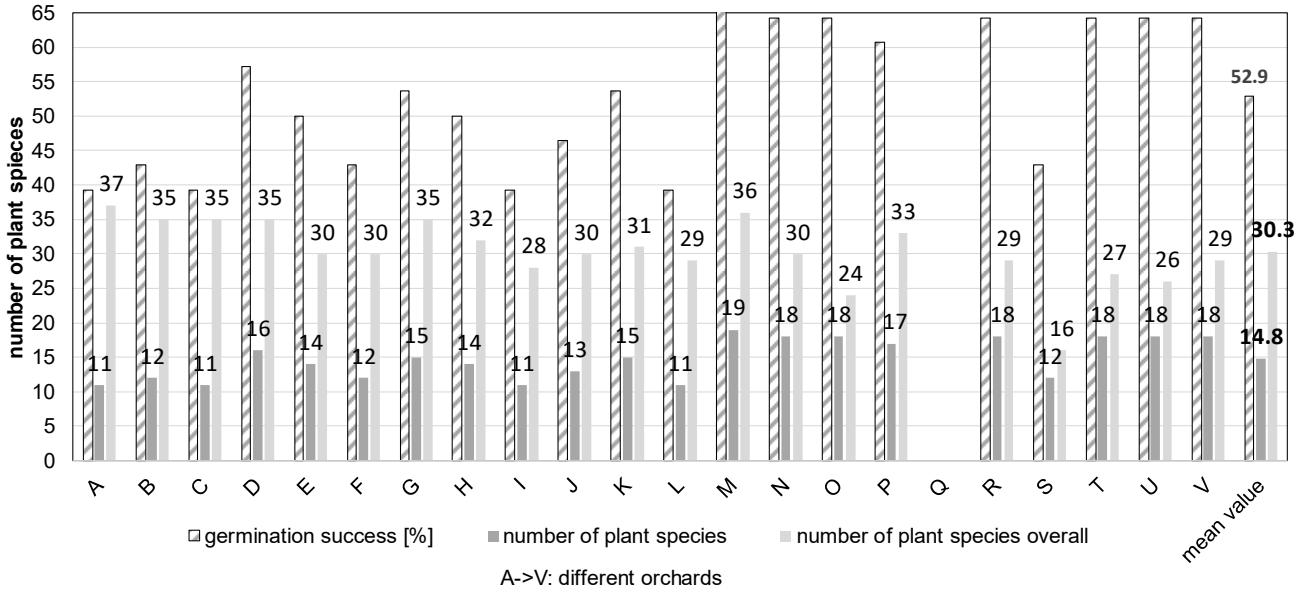

Fig. 1: Overrun seed germination success for the strips in the alleys (N = 21) 2017.

Based on these evaluations, at the end of 2019 a first recommendation for a seed mixture for the strips in the alley was given (Table 1). The mixture is marketed under the name “FOEKO-Mischung Bluehstreifen Fahrgasse” and is recommended with 2.5 g/m² of the herbal mix combined with 2.0 g/m² of the fast germination mix.

In the additional germination experiment, the seed mixture for flowering strips in the alleys showed the highest germination success on marsh soil with 27.3 % and marsh soil/sand mixture with 24.2 % followed by lawn soil with 15.2 % and top soil with 12.1 %. By contrast, the seed mixture for flowering strips at the border germinated best in lawn soil and top soil, with a germination rate of 13.8 % and 12.1 %, respectively. A relatively low germination rate was observed on marsh soil with 10.3 % and marsh soil-sand mixture with 3.4 %.

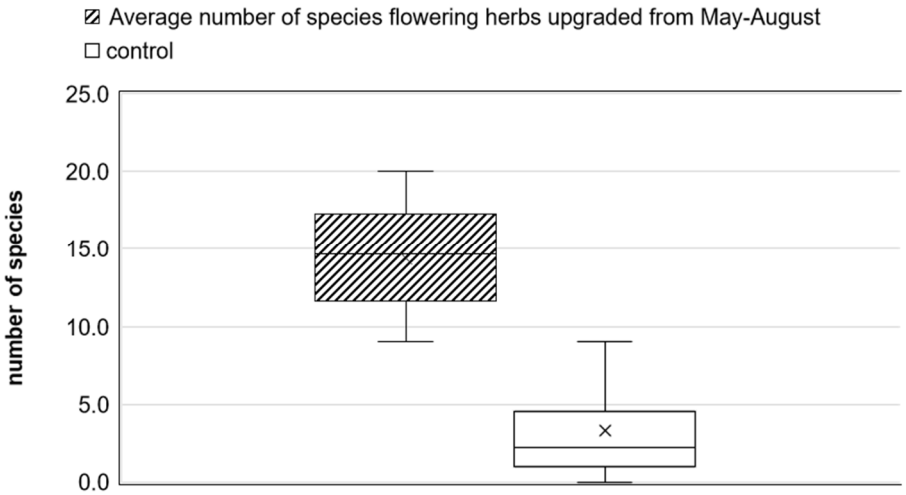

Fig. 2: Comparison of biodiversity area and control: flowering phenology (N = 21, 2018).

Table 1: “FOEKO-Mischung-Blühstreifen Fahrgasse” – Final herb mixture (for insemination of a strip in the middle of the alleys).

Plant species	Weight percent	Plant species	Weight percent
Achillea millefolium	1.5%	*Malva moschata*	3.0%
Anthemis tinctoria	0.5%	*Medicago lupolina*	6.0%
Centaurea jacea	2.5%	*Medicago sativa*	10.0%
Cichorium intybus	2.0 %	*Picris hieracioides*	4.0 %
Crepis biennis	4.0%	*Prunella vulgaris*	4.0%
Crepis capillaris	2.0%	*Silene vulgaris*	8.0%
Daucus carota	5.0%	*Trifolium dubium*	2.0%
Echium vulgare	3.0%	*Trifolium pratense*	4.0%
Galium album	5.0%		
Galium verum	1.0%	**Fast germination mixture**	
Geranium pyrenaicum	6.0%	*Centaurea cyanus*	20.0%
Hypochoeris radicata	5.0 %	*Fagopyrum esculentum*	35.0%
Knautia arvensis	5.0%	*Papaver rhoeas*	10.0 %
Leontodon hispidus	2.5%	*Sinapis arvensis*	20.0%
Leucanthemum ircutianum	4.0%	*Lepidium sativum*	1.0%
Lotus corniculatus	7.0%	*Coriandrum sativum*	13.8%
Malva alcea	3.0%	*Matricaria recutita*	0.2%

2. Results of faunistic analyses

The first results show a significantly higher arthropod density and diversity in the upgraded plots. Already in the 2nd year 2.8 times as many butterflies were observed as in the control areas (Fig. 3).

The locusts apparently needed more time to establish in the flowering strips. It was only in the third year that 2.5 times more individuals could be detected as in the control (in the first year only 67% more).

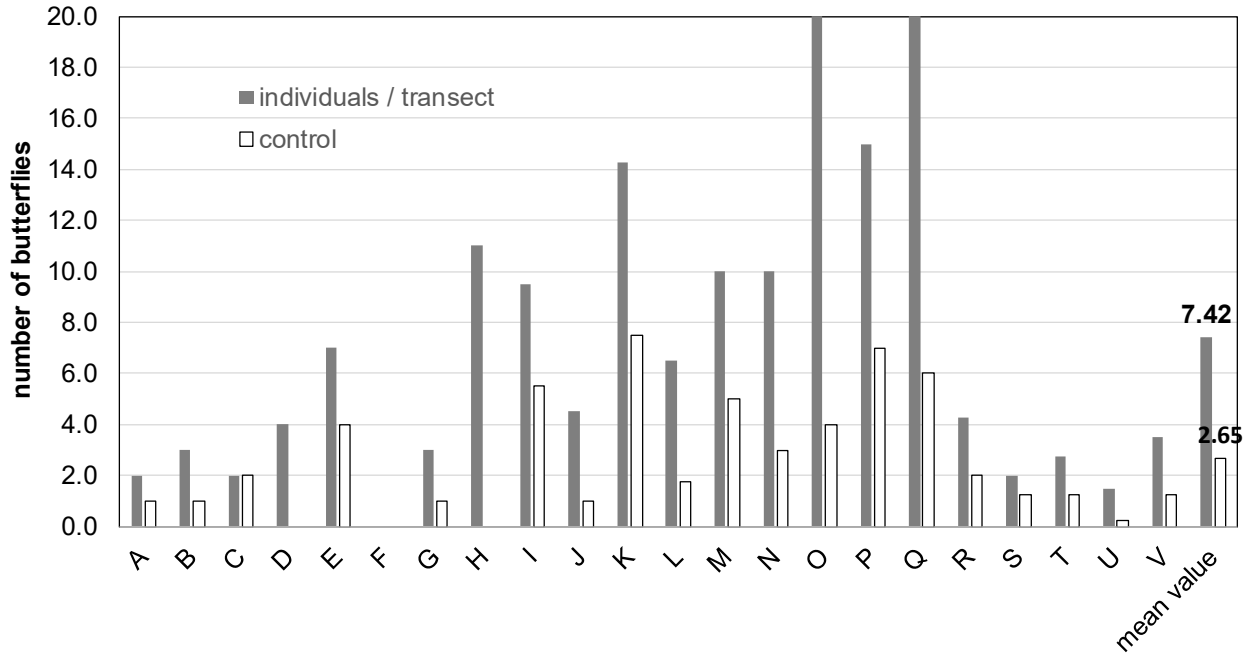

Fig. 3: Effect on butterflies per transect (N = 19, 2018) for the plots with flowering strips and the control.

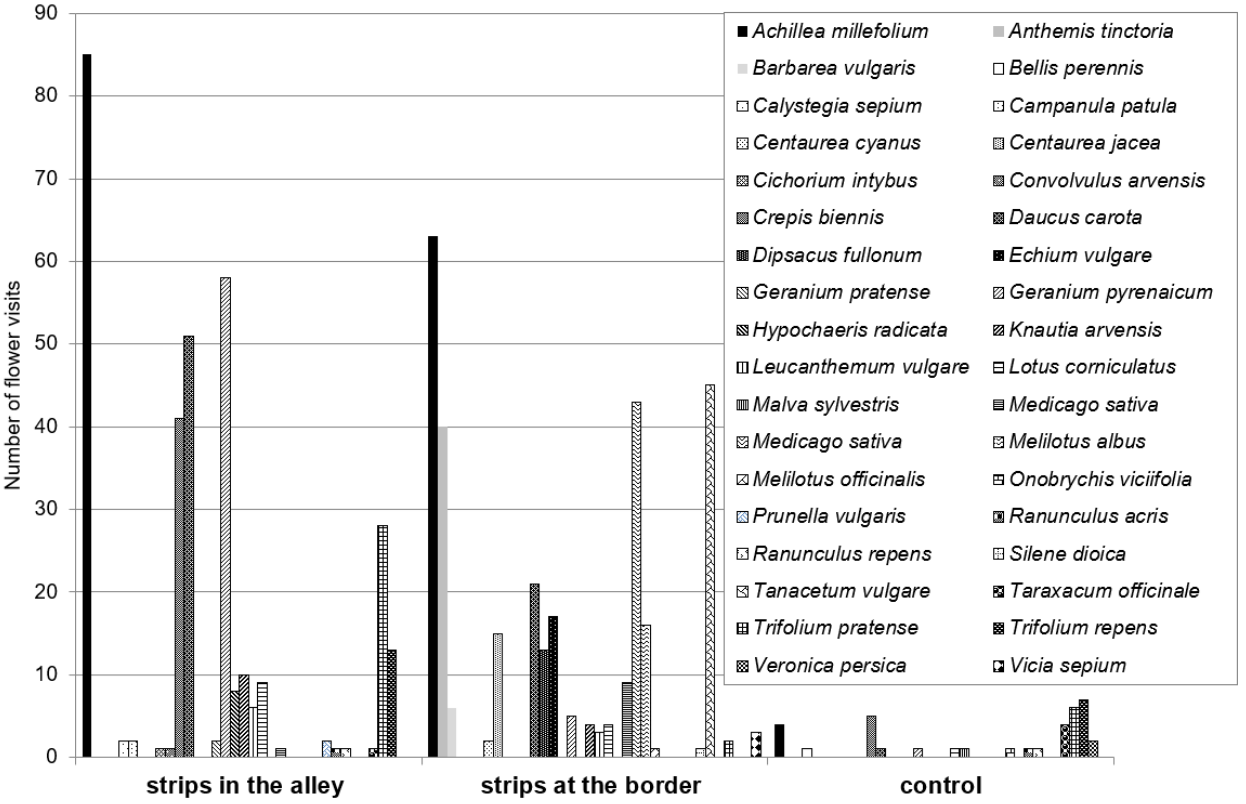

Fig. 4: Comparison of flower visits of wild bees for areas sown with wild herbs and control areas in the years 2018 and 2019.

The bird nesting boxes in upgraded areas were 24 % more occupied, but this correlates with environmental factors. The occupancy of wild bee nesting boxes in upgraded areas is only a few percent higher than in the control. This is due to a high *Osmia* dominance, which occupies all larger holes in the second year at the latest. In contrast, the number of species

is significantly higher in the upgraded areas (species determinations have not yet been completed). The difference in the observed flowering visits of wild bees in the wild herb alleys, but also in the border strips, is particularly striking compared to the control areas (see Fig. 3.) In the upgraded plots the flowering visits of wild bees are 10 to 40 times higher than in the control, depending on the plant species. The number of actually flying wild bees was 6-10x as high as in the control.

3. Effects on the production system

Summarizing the years 2017, 2018, and 2019 and the regions Neckar valley, Lake Constance, Western Germany, and Saxony with 16 comparisons of plots with and without measures for enhancement of biodiversity, the effect on the development of green apple aphid populations is observed mainly in the second assessment.
Whether at the beginning of the population development, the degree of infestation is almost similar in the control and the upgraded plot, at the second assessment the degree of infestation is reduced in average about 20 % in the upgraded plot compared to control.
In the first assessment, the number of antagonists in the upgraded plots was in average ca. 30 % higher than in the control. In the second assessment, this difference declined to 12 %. The predator/prey relation in the first assessment was in average 1.16 in the control and 1.7 in the upgraded plot. In the second assessment it was 3.7 in the control and 5.2 in the plots with biodiversity measures. The effect of these measures is mainly an earlier decrease of the aphid population. In many years, the green apple aphid is not an important pest so that this effect could be of minor interest. However, if weather conditions are unfavourable or if the plant vigour is high due to reduced fruit setting the natural control of this aphid becomes important.
In the last three years, there were no relevant differences in fruit damage between the control and the upgraded plot. Even in the additional on farm tests without control plots, no damage that could be attributed to the flowering strips has been reported. Until now, no damage occurred that could be attributed with certainty to *Ametastegia glabrata* Fall. Particular attention is paid to possible damages by mirids or other bugs but until now no differences between the orchards amended with flowering strips and the control have been observed.
However, it is well known that insect populations need time to increase so it is still too early to conclude that there is no risk for fruit damages by pests that could be attracted by the flowering strips.

4. Implementation in practice

For the implementation in practice, in each region on the pilot farms demonstration meetings in collaboration with the extension service take place. Until now, more than 100 organic fruitgrowers with a farm area of 2.300 ha participate in the project.

Conclusions

The establishment of flowering strips in the middle of the alleys of commercial organic fruit orchards as well as at the borders of the orchard in the form of hem strips has been successfully tested and is currently introduced into broad practice. For these flowering strips, a commercially established seed mixture is now available based on three years results in the project. The marsh soil in region Niederelbe differs significantly from the soils in other fruit growing regions. The germination test showed a germination rate in the alley mixture that was about 20 percentage points worse than in the practical tests in the other regions. The mix for the border strips germinated particularly badly. A regional mixture will have to be developed here.

After three years, clear to very clear positive effects could be determined for all investigated animal and plant groups in the ecologically upgraded areas.

So far, no negative economic effects could be determined in the farms. In relation to the promotion of beneficial organisms, positive effects are visible. Vole management is monitored and work is done to integrate the flowering strips in a vole management concept. The cost of the measures, however, particularly of the seed, has to be considered.

Acknowledgement

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