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Master's thesis
Master's degree program in Agricultural Sciences

Flower strips in vineyards: promoting wild bees

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Eidgenössische Technische Hochschule Zürich
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Project description

Flower strips in vineyards: promoting wild bees

Biodiversity in vineyards has come under increasing pressure due to the extensive use of plant protection products and frequent mowing and mulching of traffic lanes. As a result, perennial, species-rich flower strips have been developed for vineyards to promote biodiversity there (Links: Beneficial insect strips, Resource Project). The native floral offerings and habitat provide an important basis for promoting beneficial insects such as wild bees, hoverflies, and beetles. However, it remains unclear what significance the sown areas have in practice for pollinators.

This master's thesis aims to investigate the impact of sown flower strips on the diversity and abundance of wild bees in vineyards, as compared to vineyards with spontaneous vegetation. Specifically, the project seeks to answer two key research questions: 1) Is the species diversity and abundance of wild bees higher in vineyards with flower strips? 2) What is the correlation between the availability of floral resources and the abundance and species diversity of wild bees? 3) How does the proportion of biodiversity promotion areas in the vicinity affect the abundance and diversity of wild bees in vineyards?

To address these questions, a multi-methodological approach will be employed. Initially, a comprehensive literature review will be undertaken to establish a theoretical foundation for the study. Following this, insect monitoring will be conducted using traps or nets in various vineyards across different cantons. Fieldwork will involve the identification and counting of floral offerings available in the vineyards, as well as insect identification to quantify and categorize the species of wild bees present. Data collected will be rigorously analyzed using the R programming language, with a focus on evaluating the relationship between floral offerings and wild bee abundance and diversity. The culmination of this research will be a written thesis, which may also be prepared for publication. Through this study, we aim to generate insights that could contribute to biodiversity conservation strategies, specifically tailored for vineyard ecosystems.

Supervisors
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Locations of work
Agroscope Reckenholz: desk work, insect sorting
10 vineyard locations in Switzerland: field work

Duration
May 2023-October 2023

Abstract

Pollinators, especially wild bees, are indispensable contributors to global food production and the maintenance of ecosystem biodiversity. However, their populations are under constant threat due to habitat loss, pesticides, climate change, and diseases. In this context, the implementation of conservation strategies in agriculture, such as the use of flower strips, has gained significant importance. Vineyards, due to intensive agricultural practices such as high application of fungicides and herbicides, frequent mowing, and mulching, are characterized by poor flower supply and a consequent decrease in biodiversity. We conducted field surveys in ten Swiss vineyards, comparing parcels with flower strips to parcels with spontaneous vegetation, over 2022 and 2023. We captured wild bees with vane traps, and we conducted botanical surveys to assess flower supply. Our analyses revealed compelling evidence of the positive impact of flower strips on flower volume and flower volume diversity. Positive impacts could also be observed for wild bees, whose abundance and diversity were greater in parcels with flower strips compared to control parcels with natural vegetation. However, conflicting results were found, as despite these positive effects of flower strips on bees, only flower volume diversity reported significant positive results on bee diversity. This significance was not observed in bee abundance, and neither did flower volume reveal significant effects on either bee abundance or diversity. The results of this study contribute to the understanding of the actual promotion of a greater and more diverse flora through flower strips in vineyards, and of wild bees in terms of abundance and diversity. To gain a clearer understanding of the effects of botanical variables, such as flower volume, we suggest implementing the research while considering the complexity of intraspecific interactions of wild bees with specific flower species. This approach could enhance comprehension of the intricate dynamics inherently involved in such an agroecosystem.

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Introduction

In the realm of agriculture, the intricate web of life is underpinned by a group of occasionally underestimated key players - pollinators. These crucial organisms, including bees, butterflies, moths, birds, and even bats, play an indispensable role in sustaining global food production (Katumo et al., 2022). The interaction between flowering plants and pollinators forms the backbone of ecosystem services, ensuring the reproduction of countless plant species and the production of fruits, vegetables, nuts, and seeds that constitute a substantial portion of human diets (Nicolson & Wright, 2017). Pollination services contribute to enhancing crop yields, improving crop quality, and bolstering the nutritional content of our diets (Van der Sluijs & Vaage, 2016; Nicolson & Wright, 2017). In addition, increased pollinator biodiversity in agro-ecosystems promotes resilience against pests and diseases and ensures a stable and diversified food supply (Senapathi et al., 2015). Beyond their economic value, pollinators are intrinsically linked to cultural and ecological dimensions, adding beauty to landscapes and connecting humans with the natural world (Lindemann-Matthies et al., 2010).

Among these invaluable pollinators, wild bees stand out as critical contributors. Their role in agricultural ecosystems is particularly notable, as they often exhibit specialized pollination behaviors that benefit specific crops (Westrich, 1989). In Switzerland, wild bees are key players in pollinating various crops, including apples, pears and berries (Sutter et al., 2021). Their importance cannot be understated, as they not only contribute to crop productivity but also play a crucial role in maintaining the diversity and stability of ecosystems. However, the existence of these vital pollinators is under threat (Lima et al., 2022). Multiple stressors, including habitat loss, pesticide exposure, climate change, and the spread of pathogens, have led to declines in pollinator populations worldwide, including those in Switzerland (Widmer et al., 2021). This alarming trend poses severe risks to global food security, ecological stability, and human well-being (Potts et al., 2010). Thus, understanding the complex dynamics of agricultural pollinators, including the pivotal role of wild bees, their conservation, and the mitigation of threats, becomes an imperative pursuit both on a global scale and within the specific context of Swiss agriculture.

Amidst the backdrop of sustainable farming practices, the use of flower strips or wildflower margins has gained widespread recognition as an efficient tool for promoting biodiversity (Kowalska et al., 2022). Switzerland, in its commitment to ecological sustainability, has actively embraced this practice (Sutter et al., 2021). Across Swiss farmlands, the deliberate integration of these floral habitats into the agricultural landscape can be observed. Since 2015, in Switzerland, the establishment of flower strips as a Biodiversity Promotion Area (BPA) has been eligible for direct payments (Sutter et al., 2021). These flower strips, typically planted alongside fields or within them, provide vital sanctuaries for native wild bees. By featuring a diverse array of native plant species, they offer abundant forage and nesting opportunities (Pfiffner & Müller, 2016). This not only aids in the conservation of wild bee species but also significantly enhances pollination services for crops (Hevia et al., 2021). Current examples of this approach in Switzerland include the establishment of flowering strips near orchards, vineyards and arable fields (Pfiffner et al., 2018; Jacot et al., 2023). However, despite their growing popularity, there remain gaps in our understanding of flower strips (Haaland et al., 2011). Current research efforts aim to address these knowledge gaps, focusing on optimal design, plant selection and management practices to maximize the benefits of these habitats (Uyttenbroeck et al., 2016).

Viticulture holds a prominent position within Switzerland, both economically and culturally, contributing significantly to the nation's agricultural sector and heritage. According to the Swiss Federal Office for Agriculture (FOAG), the total vineyard area in Switzerland in the year 2022 amounted to 146.06 km2, equivalent to nearly 20,500 soccer grounds (BLW, 2023). Before intensive agricultural practices, vineyards had a higher biodiversity of plant species, including some native geophytes (Brunner et al., 2001; Wiskemann et al., 2022). The intensive mechanical soil work and high use of herbicides and fungicides in vineyards have significant negative consequences on biodiversity and ecosystem health (Paiola et al., 2020). It is of great importance to adopt agricultural management measures that help to preserve and promote biological diversity. The habitat and availability of flowers provide an essential basis for the promotion of beneficial insects, such as important pollinators like wild bees (Griffiths-Lee et al. 2023). Vineyards are suitable places for the presence of various pollinators, offering several nesting possibilities and a potentially high supply of flowers (Wersebeckmann et al., 2023). The use of flower strips in vineyards is therefore an important biodiversity promotion measure to mitigate the negative effects of intensive agricultural practices (Kowalska et al., 2022).

Between 2018 and 2021, the project *Blühende Rebberge für Mensch und Natur* by Agroscope and FiBL (Forschungsinstitut für biologischen Landbau) conducted flower seed mixture trials on 50 vineyard farms and three research stations across different regions in

Switzerland (Bättig et al., 2022). The project aimed to develop perennial seed mixtures for vineyard inter-rows, considering factors such as soil, climate and existing vegetation. The primary goal was to increase floral diversity in low-diversity vineyards by creating mixtures of native wild plants for interrow areas. During the last year of the research project, pollinators surveys using the pan trap method were conducted. Higher plant diversity showed a positive influence on the abundance and diversity of wild bees. Five of these vineyards sown in 2020 were subsequently selected, together with five vineyards sown in 2021, to investigate the effects of pesticides on pollinators as part of Agrofutura's Ressourcenprojekt *Förderung gefährdeter Flora in Rebbergen* (2018-2027) in collaboration with Hintermann & Weber AG and Agroscope (Moser et al., 2023). In 2022, the first pollinator data were collected in the 10 vineyards with flower strips and 10 control vineyards with spontaneous vegetation.

As found by Scheper et al. (2015), biodiversity-promoting areas surrounding flower strips can show varying results, suggesting that these areas may have either an augmentative effect for some bee species present in the flower strips or a decreasing effect on others. Greater landscape diversity, as reported by Kratschmer et al. (2019), can have a positive, although possibly small effect, on the diversity of wild bees, overcoming the lack of flower resources in vineyards.

These initial findings require validation and further exploration to understand the long-term impacts of flower strips in vineyards. The focus of this master's thesis is to investigate the influence of flower strips in vineyards on wild bees as a key pollinator group. Since the type of surrounding landscape can affect wild bees on flower strips and thus the efficiency of these agricultural practices, even though it remains unclear to date in which way, the effects of surrounding biodiversity-promoting areas will also be investigated (Hellwig et al., 2022). Additionally, it is essential to assess the effectiveness of the bee trapping method in varying vegetation conditions. This is precisely the situation in vineyards, where the coexistence of low and tall vegetation presents a potential challenge for trap comparisons.

Questions and hypothesis

The primary research questions addressed in this study include:

1. Do vineyards flower strips positively influence the abundance and diversity of wild bees compared to vineyards with spontaneous vegetation?
2. Do vineyards with flower strips have a higher flower volume and diversity than vineyards without flower strips?
3. Do flower volume and flower diversity affect the abundance and diversity of wild bees in vineyards?
4. Do surrounding environmental factors, such as Biodiversity Promotion Areas (BFF), affect the abundance and species richness of wild bees in vineyards?
5. Is the vane trap method a reliable trapping technique at different vegetation heights?

The objective of this master's thesis is to deepen our knowledge regarding the enhancement of wild bee populations through the promotion of native flowers with a seed mixture. Additionally, examining the long-term impacts is pivotal because understanding the sustainability and prolonged effects of these measures can guide future conservation strategies and ensure lasting positive impacts on ecosystems. Such insights may heighten the awareness among viticulturists about their potential to foster wild bees.

Building on the findings from prior vineyard studies (Bättig et al., 2022) regarding wild bees and flower strips in Switzerland, we hypothesize that (1) vineyards with flower strips will exhibit a higher number and species richness of wild bees compared to vineyards with spontaneous vegetation, and that (2) this observed effect will be consistent with increased flower volume and flower volume diversity in the sown areas. Consequently, we expect (3) that vineyards with a higher volume and greater volume diversity of flowering plants will positively influence the abundance and species richness of wild bees. We also hypothesize that (4) Biodiversity Promotion Areas around vineyards have a positive effect on wild bee abundance and species richness. Regarding the effectiveness of the insect sampling method, namely vane traps, we hypothesize (5) that more exposed traps (lower vegetation) have higher capture rates compared to less exposed traps (higher vegetation).

Materials and methods

Study regions and sites

Vineyards suitable for pollinator surveys were selected in spring 2022 as part of the Ressourcenprojekt *Förderung gefährdeter Flora in Rebbergen* (Moser et al., 2023). Pollinators were investigated at 10 locations, each comprising a vineyard with flower strips and a vineyard with spontaneous vegetation (control). The 10 locations were spread from Lake Geneva to Schaffhausen (see Fig. 1). Five flower strips were sown in 2020 and five in 2021 with two adaptions of the *Nützlingsstreifen Reben mehrjährig* with native plants (Moser et al., 2023; BLW, 2023). Sowing was done between the rows of vines, usually in four alternate rows or for each row as decided by the winegrower (see Fig. 3). Only vineyards whose flowering strips were of acceptable quality, which were not terraced, which were at least 400 meters apart and in the vicinity of which a control parcel was available were selected as experimental parcels for the study. In contrast, the control sites should be vineyards with spontaneous vegetation and without any seeding. To ensure similar conditions between the treatment groups regarding pesticide applications and mowing and local differences, two vineyards each with and without flower strips were managed by the same wine grower or subject to a similar management. The sites were alternately mown or mulched. The individual inter-row received zero to three cuts per growing season, depending on the weather and the wine grower. Some inter-rows without seedings were partially opened annually. For an overview of vineyard parcel specifications, please refer to Table I in the Appendix.

Fig. 1. From left to right locations of Echandens/Denges (9), Auvernier (10), Twann-Tüscherz (8), Aesch (3), Spiez (2), Bözen/Hornussen (6), Schinznach (1), Volken (5, 4), Dörflingen (7). (Map by: GISGeography, last updated: August 8, 2023).

Sampling method

For the pollinator survey, the passive *vane trap* trapping method was used (Fig. 2) (Prendergast et al., 2020). This method combines funnel traps with interceptor vanes made of ultraviolet blue or yellow polypropylene to specifically attract pollinators, particularly wild bees (Hall, 2018). Since the traps were reproduced at Agroscope, they differ slightly in color and material from the traps used in other studies. A jar containing a mixture of tap water and a drop of odorless soap was screwed onto the funnel, allowing the insects to sink quickly. Through the funnel, insects attracted by the fluorescence of the vanes are collected in the bottle. It is an efficient and economical sampling method, suitable for any habitat and easy to install (Saunders & Luck, 2013). The stability and functionality of this method is well adapted to its use in vineyards, where the installation of equipment is only possible temporarily.

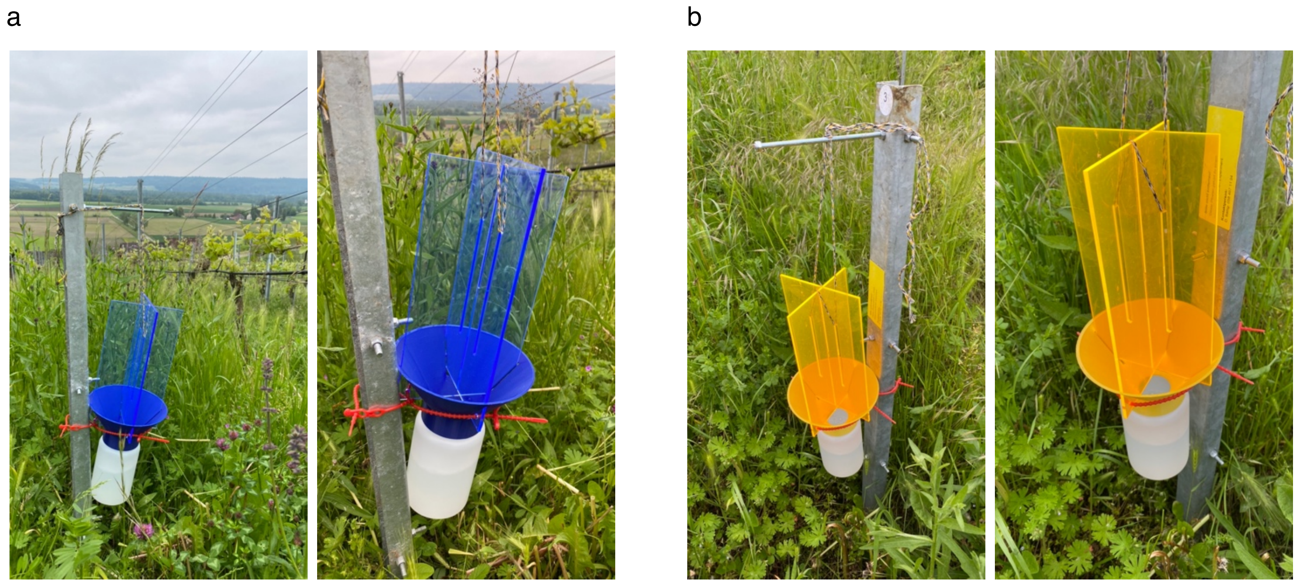

Fig. 2. Blue (a) and yellow (b) vane traps set up in a vineyard.

Experimental design

The following surveys were also conducted in 2022 within the *Ressourcenprojekt* and these data were also included in the analyses. In 2023, data were collected simultaneously for each pair of parcels from May to August and we chose the survey dates according to the following criteria: as many plants as possible should be in flowering condition in the seeding, the weather should be as sunny as possible with little precipitation and wind, and the cultivation of the vineyards had to allow a three-day blocking of the inter-rows. This required constant consultation of weather forecasts and flower strips visits to determine the most suitable period for data collection. Two surveys of a duration of 72 hours per site were carried out from May 2023 until August 2023, except for the Twann-Tüscherz site, where no plants regrew in the flower strips after mowing due to the lack of rain. As a replacement, the Echandens/Denges site was sampled three times. Furthermore, a control site had to be excluded from the analysis, as it became clear in the second year that the natural vegetation had been distorted by seedings a few years ago. This is why only nine pairs of parcels were considered for the analyses, excluding the Bözen/Hornussen site. Two types of data were collected: pollinator data and botanical data.

Insect surveys

Four vane traps, two yellow and two blue, were positioned directly in the flower strips between the rows as shown in Figure 3. To avoid edge effects, the middle inter-rows were chosen. In the control parcels, without seeding, the traps were placed in the same arrangement. Metal stakes were used as support for the traps, installed in the ground within the defined rows in a zigzag pattern, alternating between the two rows, at a distance of approximately 10 meters. The height of the traps was adjusted to the height of the surrounding flowers, aligning with the floral horizon to ensure adequate visibility while preventing direct contact with the ground. In cases where the traps came into contact with surrounding vegetation, the plants were trimmed to prevent non-flying insects from being captured. After 72 hours, the traps were removed, and the insects were stored in 70% ethanol.

Botanical surveys

Each time the traps were set, we also collected botanical data. These were collected in six plots of one-by-one meter per parcel (see Fig 4.). In both inter-rows with traps, the plots for the botanical survey were arranged above the upper trap, between the two traps and below the lower trap (see arrangement in Fig. 3). The exact location of the plots was chosen to be representative of the average flower supply within the row. The flowering plant species were identified, individual flowers were counted for each single species within the botanical plot, or if necessary, an estimation of the number of flowers was made for species with a more abundant inflorescence, e.g. for *Gallium mollugo* or *Daucus carota*.

Since flower numbers are not a direct indicator of available floral resources, we calculated the cumulative flower volume across each survey round and vineyard. Flower volume serves as a reliable proxy for the availability of nectar and pollen (Ammann et al., 2022). We approached this by representing the volume of each species as cylindrical, factoring in the flower diameter and corolla depth for our calculations. These data were derived from a study by Ammann (2022) that used own measurements and a floral trait database. Normally, volumes were calculated from individual flowers. However, with the Asteraceae family, the diameter of the entire inflorescence was used due to the challenge of discerning open flowers. If data for specific species were missing, we adopted the mean values of their genus. In scenarios where considerable variation existed within a genus, we chose the values of the most analogous species. Conclusively, we aggregated the volumes of all species frequented by wild bees to ascertain the overarching flower volume. From the 72 species documented throughout our data collection phases, we omitted 6 (or 8.33%) due to their insignificant contribution, a mere 0.038%, to the total flower volume.

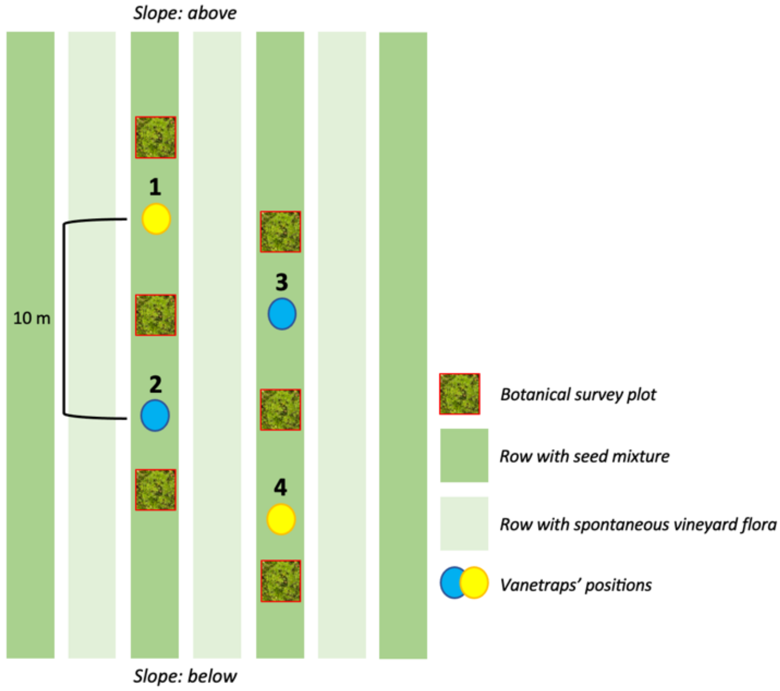

Fig. 3. Arrangement of the four traps and six botanical plots within a vineyard parcel with flower strips. In control plots, an equivalent arrangement was maintained, but all rows consisted of spontaneous vineyard flora.

Fig. 4. One of the six one-by-one meter plots per vineyard that were designated for thorough flower counting and species identification. The depicted square shows a sown plot.

Insect sorting and identification

The captured insects were sorted and counted by order and/or 'morpho-groups' in the laboratory, if necessary, by microscope (see Fig. 5). Wild bees were identified by species level by entomologist and taxonomist Dr. Andreas Müller.

The insects were categorised into the following groups: Hymenoptera (honey bees; wild bees; wasps; Formicidae), Orthoptera, Ephemeroptera, Diptera (Syrphidae; other flies), Lepidoptera, Trichoptera, Odonata, Hemiptera (Prosorryncha; Sternorryncha; *cicada*), Plecoptera, Neuroptera, Blattodea, Coleoptera (Coccinellidae; other beetles), Thysanoptera, Dermaptera, other.

a b c

Fig. 5. Catch jar after 72h exposure (a). Sorting of a sample (control) (b). Storage of sorted insects in 70% ethanol (c).

Meteorological data

The meteorological data used for the statistical analysis originate from the AgroMeteo portal. They cover the weather conditions from trap setting to trap removal, excluding the nights from 9 p.m. to 6 a.m. Data regarding temperature and precipitation were obtained from the closest weather station to the parcels (Appendix, Table II).

Environmental data

QGIS software (version 3.28.11 'Firenze') was used to obtain the data concerning the biodiversity promotion areas by following the instructions by Bauckhage (2023). Biodiversity promotion areas of quality 1 (BPA Q1) within a radius of 500 m were considered (see Fig.

6), as this distance does not extend beyond the foraging range of several bee species (Gathmann, 2002; Zurbuchen, 2010). We decided to consider BPA Q1 and not BPA Q2, because for some locations no BPA Q2 was detected and the BPA Q1 part is significantly greater than the BPA Q2 part (Appendix, Table IV).

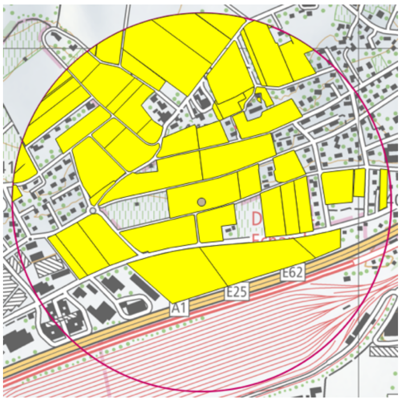

Fig. 6. GIS spatial analysis of BPA within a 500m radius for one of the study sites.

Vane trap method test

This experiment aims to investigate differences in the wild bee capture rates of vane traps with different visibility, i.e. in vineyard parcels with spontaneous vegetation at different heights. For this trial, a vineyard with typical spontaneous vegetation was chosen, similar to the control parcel of the main experiment, with rows with medium-high vegetation for less trap visibility (see Fig 8.a) and with rows with low vegetation for greater trap visibility (see Fig 8.b). The selected vineyard is located on the Au Peninsula (Wädenswil, Zurich) and presents alternate rows mown. The following plant species were observed: *Potentilla reptans*, *Medicago lupulina*, *Plantago lanceolata*, *Trifolium repens*, *Trifolium pratense*. The availability of flowers was scarce but equally balanced between the rows with vegetation of different heights. 12 traps, 6 yellow and 6 blue, were set per treatment (high or low), alternately positioned (see Fig. 7). A distance of 30 meters was set between the two different treatments, in order to prevent capture rates from being altered by the proximity of traps with different visibility (Montgomery et al., 2021). The data were collected between 16th and 19th June 2023, with an average daily temperature (from 6 a.m. to 9 p.m.) of 23.8°C (Temp.min=15.8°C, Temp.max= 30.8°C) and a total precipitation of 0.12mm/m2. Meteorological data originate from the AgroMeteo portal (weather station of Wädenswil-Au, Zurich). Similar to the main experiment, after 72 hours of exposure, the traps were removed, and the insects were sorted and stored in 70% ethanol.

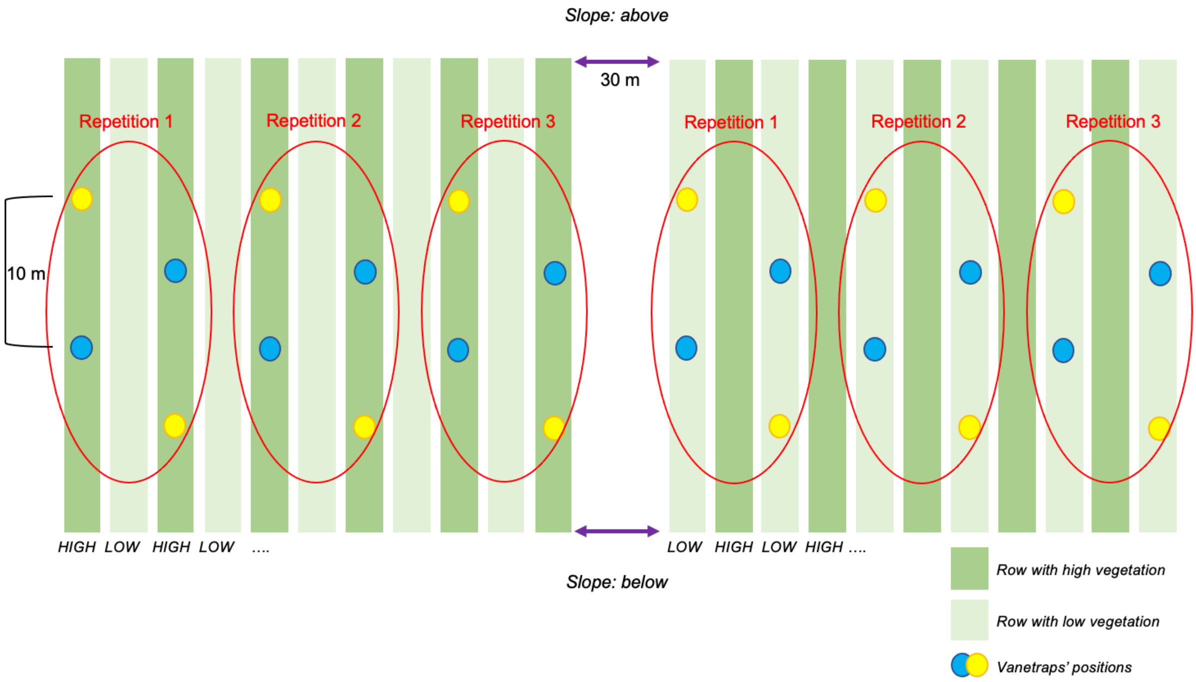

Fig. 7. Arrangement of the four traps by repetition, with three repetitions per treatment, respectively in rows with high or low vegetation.

Fig. 8. Vane traps in a row with high vegetation (a) and in a row with low vegetation (b).

Statistical analysis

Flower strips effect on wild bee abundance and diversity

To investigate the effects of flower strips and surrounding BPA Q1 area on the abundance and diversity of wild bees, Linear Mixed Effects Regressions (lmer) through R Studio software were run (version 4.3.1). The analysis incorporated consistent fixed factors, which included the treatment (sown or control), year of data collection (for 2022 and 2023), the average daily temperature during the data collection period, and the surrounding BPA Q1 within a 500-meter radius. Other non-central variables were excluded, such as total precipitation, which was mostly zero. In the preliminary stages of our analysis, we incorporated an interaction term between treatment and BPA Q1. But due to its nonsignificance and its tangential relevance to our core research question, we excluded the interaction term in subsequent analyses. This decision simplified our model and minimized the risk of overfitting. To accommodate random factors, such as different locations represented by pair number and the day of the year of the surveys, the models utilized the lmerTest::lmer() package. To examine wild bee abundance, the sum of all wild bees captured by the 4 vane traps per parcel per vineyard for each data collection was taken. To normalize the residual distribution, wild bee data were log-transformed. To assess wild bee diversity, we calculated the Shannon Diversity Index.

Botanical variables effect on wild bee abundance and diversity

Next, to examine whether vineyards with flower strips have a higher flower volume and diversity than vineyards without flower strips, the same analytical approach as above was applied. Fixed factors included treatment (sown or control), year of data collection (for 2022 and 2023), and average daily temperature. Random effects were also accounted for, including different locations represented by Pair number and the day of the year during which the botanical surveys were conducted. To represent floral diversity, the Shannon Diversity Index was calculated using flower volume to represent variable *n*.

Lastly, we assessed if flower volume and flower diversity affected the abundance and species richness of wild bees in vineyards. Fixed factors such as the year of data collection (2022 and 2023) and the average temperature during the data collection period were considered. Pair number, the day of the year and BPA Q1 were treated as random factors. To normalize the residual distribution, wild bee data were log-transformed.

Vegetation height effects on wild bee capture rate by vane traps

To investigate the differences in the wild bee capture rate between the two different treatments (high and low vegetation), due to the non-linear distribution of the data, the non-parametric Wilcox test was performed through R Studio software (version 4.3.1). The same test was performed to investigate the differences in the total insect capture rate for the two treatments.

Results

Insect survey

A total of 10'790 arthropod individuals were sampled with the vane traps in 2022 and 2023, including: Hymenoptera, Orthoptera, Ephemeroptera, Diptera, Lepidoptera, Hemiptera, Mecoptera, Neuroptera, Coleoptera, Thysanoptera, Dermaptera, and other non-flying insects. In 2022, the average wild bee abundance per vineyard was 24.22 ± 2.62 and the average site species number was 10.55 ± 0.87. In 2023, bee abundance was a mean of 23.65 ± 2.60 and mean species number was 7.83 ± 0.56. In both years, the most abundant bees were *Bombus lapidaries*, *Bombus pascuorum*, *Halictus simplex*, *Lasioglossum malachrum* and *Lasioglossum morio*.

Treatment effect on wild bee abundance and diversity

Table 1. Results of linear mixed effects model showing the differences between vineyards with and without flower strips regarding wild bee abundance, also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee abundance	estimate + SE	p.value
Treatment (control)	-0.205 ± 0.096	0.038*
Data collection year (2023)	0.491 ± 0.297	0.107
Average temperature	0.102 ± 0.046	0.032*
BPA Q1 area	-0.0001 ± 0.001	0.905

The presence of flower strips had a significant effect on the abundance of wild bees (*p*=0.038, Table 1, Figure 9.a) regardless of the data collection year. In vineyards with flower strips, there were on average 0.205 ± 0.096 more bees than in vineyards with spontaneous vegetation. In addition, the average daily temperature during the surveys had a significant positive influence on bee abundance (Table 1), the increase per degree higher temperature was 0.102 more bees. The area of BPA Q1 in the surrounding area, as well as the survey year showed no significant effect on wild bee abundance (Table 1).

Table 2. Results of linear mixed effects model showing the differences between vineyards with and without flower strips regarding wild bee diversity (Shannon Diversity Index), also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee diversity (Shannon Diversity Index)	estimate + SE	p.value
Treatment (contol)	-0.329 ± 0.082	0.0002*
Data collection year (2023)	-0.123 ± 0.152	0.424
Average temperature	-0.004 ± 0.023	0.858
BPA Q1 area	-0.0001 ± 0.0003	0.626

Wild bee diversity was positively affected by the presence of flower strips (*p*=0.0002, Table 2, Figure 9.b). Shannon diversity of wild bees in vineyards with flower strips was on average 0.329 higher than in vineyards with spontaneous vegetation. Neither survey year, nor average daily temperature, nor BPA Q1 area had a significant effect on wild bee diversity (Table 2).

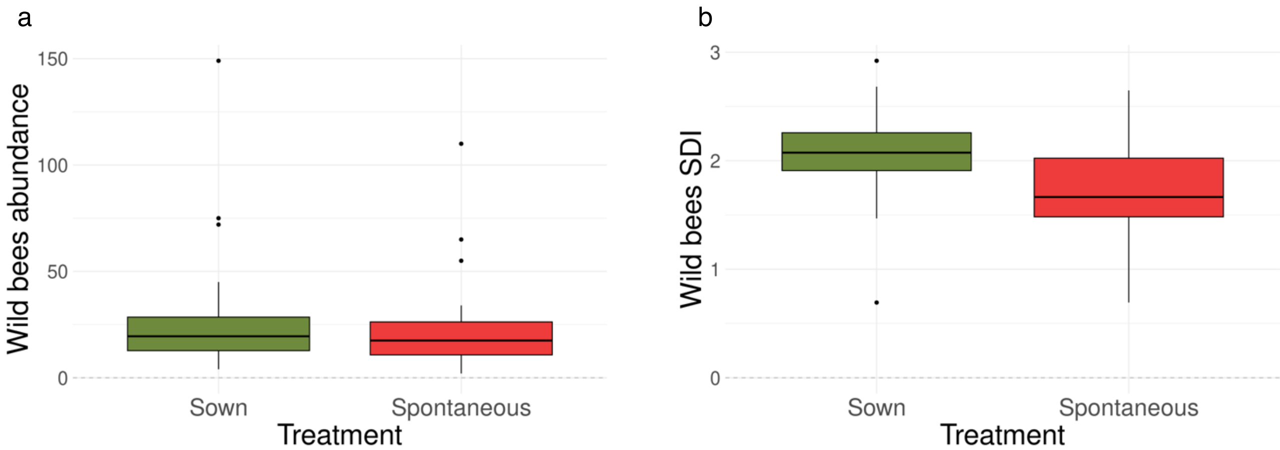

Fig. 9. Differences between (a) abundance and (b) diversity (Shannon Diversity Index) of wild bees in parcels with flower strips (Sown) and with spontaneous vegetation (Spontaneous) for the two survey years and all rounds (n=36). Abundance of bees is taken as the sum per parcel, while diversity is represented by the Shannon Diversity Index per parcel.

Botanical survey

A total of 67 flowering plant species were identified in 2022 and 2023, including the following genera: Achillea, Aegopodium, Anthemis, Anthyllis, Bellis, Borago, Capsella, Centaurea, Cichorium, Convolvulus, Crepis, Daucus, Erigeron, Erodium, Fragaria, Galium, Geranium, Glechoma, Hypericum, Hypochaeris, Knautia, Lamium, Leucanthemum, Lotus, Malva, Medicago, Melissa, Onobrychis, Papaver, Plantago, Potentilla, Prunella, Ranunculus, Rubus, Rumex, Salvia, Sanguisorba, Scabiosa, Scorzoneroides, Senecio, Silene, Sonchus, Stellaria, Taraxacum, Thymus, Trifolium, Valerianella, Verbena, Veronica and Vicia.

The following results do not consider flowering plants that are not pollinated by wild bees, which of the collected data constitute 8.33% of the total number of flower species, but only 0.04% of the total volume (Landolt et al., 2010; Westrich, 2019).

In 2022, the average number of genera per vineyard was 7.46 ± 0.45 and the average flower volume was 761.23 ± 93.99 cm^3. In 2023, the average number of genera per vineyard was 7.56 ± 0.44 and the average flower volume was 779.93 ± 93.58 cm^3 (Appendix, Table III). In both years the most present flowering plant species in terms of flower volume in the sown parcels were *Centaurea jacea*, *Daucus carota*, *Knautia arvensis*, *Lotus corniculatus*, *Ranunculus repens* and *Sanguisorba minor*, and the most present flowering plant species in terms of flower volume in the control parcels were *Bellis perennis*, *Convolvulus arvensis*, *Crepis capillaris*, *Geranium molle* and *Ranunculus repens*.

Treatment effect on flower volume and diversity

Table 3. Results of linear mixed effects model showing the differences between vineyards with and without flower strips regarding flower volume, also considering survey year and average daily temperature.

Response: flower volume	estimate + SE	p.value
Treatment (contol)	-0.396 ± 0.149	0.012*
Data collection year (2023)	0.014 ± 0.230	0.953
Average temperature	-0.074 ± 0.035	0.058

The parcels with flower strips showed a significant higher flower volume with on average 0.396 ± 0.149 m^3 more flower volume than in vineyards with spontaneous vegetation (p=0.012, Table 3, Figure 10.a). This difference is significant, regardless of the data collection year and the average daily temperature (Table 3).

Table 4. Results of linear mixed effects model showing the differences between vineyards with and without flower strips regarding flower volume diversity (SDI), also considering survey year and average daily temperature.

Response: flower volume diversity (Shannon Diversity Index)	estimate + SE	p.value
Treatment (contol)	-0.743 ± 0.099	< 0.001***
Data collection year (2023)	0.001 ± 0.138	0.994
Average temperature	-0.013 ± 0.020	0.540

The parcels with flower strips showed a significant higher flower volume diversity (p=<0.001, Table 4, Figure 10.b). Shannon diversity of flower volume in vineyards with flower strips was on average 0.743 ± 0.099 higher than in vineyards with spontaneous vegetation. Neither survey year, nor average daily temperature, had a significant effect on flower volume diversity (Table 4).

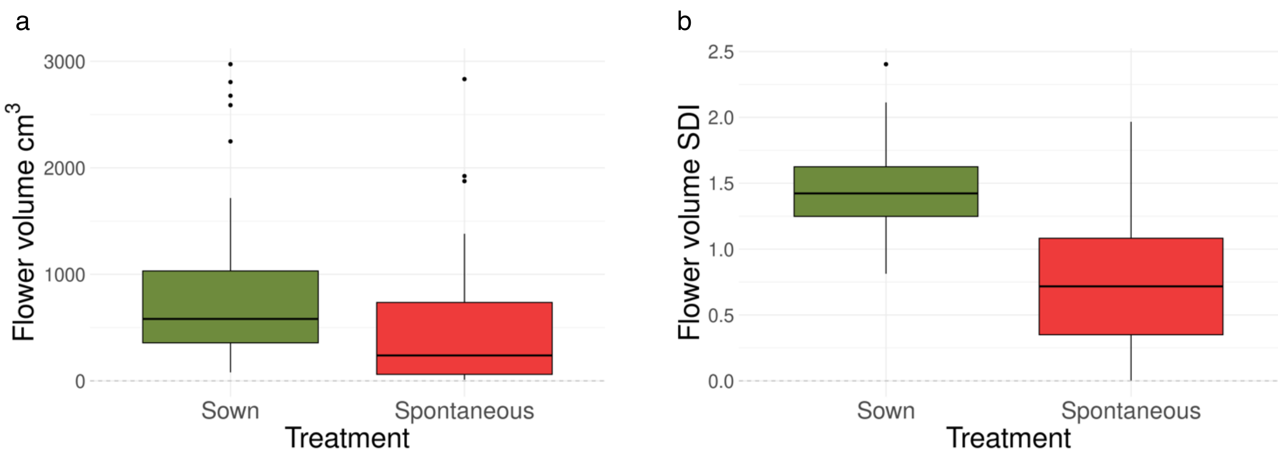

Fig. 10. Differences between parcels with flower strips (Sown) and with spontaneous vegetation (Spontaneous) of (a) Flower volume (cm³) and (b) Flower volume diversity (Shannon Diversity Index) of wild bees in both years and all rounds (n=36). Flower volume is taken as the sum per parcel, while Flower volume diversity is represented by the Shannon Diversity Index per parcel.

Flower volume effect on wild bee abundance and diversity

Table 5. Results of linear mixed effects model showing the effects of flower volume on wild bee abundance, also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee abundance	estimate + SE	p.value
Flower volume	-0.050 ± 0.092	0.594
Data collection year (2023)	0.466 ± 0.296	0.127
Average temperature	0.096 ± 0.046	0.044*
BFF Q1 area	0.0002 ± 0.0007	0.776

Flower volume did not show a significant effect on the abundance of wild bees (*p*=0.594, Table 5). Instead, the average daily temperature during the surveys had a significant positive influence on bee abundance (Table 5), the increase per degree higher temperature was 0.096 more bees (Table 5). No significant effects of data collection year and BPA Q1 area on bee abundance were found.

Table 6. Results of linear mixed effects model showing the effects of flower volume on wild bee diversity, also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee diversity (Shannon Diversity Index)	estimate + SE	p.value
Flower volume	0.079 ± 0.071	0.273
Data collection year (2023)	-0.136 ± 0.159	0.402
Average temperature	0.0004 ± 0.025	0.989
BFF Q1 area	-0.0001 ± 0.0003	0.809

Flower volume did not show a significant effect on wild bee diversity (*p*=0.273, Table 6). No significant effects of data collection year, average daily temperature, and BPA Q1 area on bee abundance were found.

Flower volume diversity effect on wild bee abundance and diversity

Table 7. Results of linear mixed effects model showing the effects of flower volume diversity on wild bee abundance, also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee abundance	estimate + SE	p.value
Shannon Div. Flower	0.176 ± 0.093	0.073
Data collection year (2023)	0.532 ± 0.302	0.091
Average temperature	0.118 ± 0.048	0.018*
BFF Q1 area	-0.00002 ± 0.0007	0.977

Flower volume diversity showed a marginally significant effect on the abundance of wild bees ($p = 0.073$, Table 7). To test the significance of this value, the confidence interval (95%) was calculated, which reported the values -0.03 (2.5%), 0.35 (97.5%), indicating non-significance. The average daily temperature during the surveys had a significant positive influence on bee abundance, the increase per degree higher temperature was 0.118 more bees (Table 7). No significant effects of data collection year and BPA Q1 area on bee abundance were found.

Table 8. Results of linear mixed effects model showing the effects of flower volume diversity on wild bee diversity, also considering survey year, average daily temperature, and BPA Q1 as variables.

Response: wild bee diversity (Shannon Diversity Index)	estimate + SE	p.value
Shannon Div. Flower	0.257 ± 0.078	0.002**
Data collection year (2023)	-0.125 ± 0.169	0.470
Average temperature	-0.001 ± 0.026	0.960
BFF Q1 area	-0.0001 ± 0.0003	0.679

Flower volume diversity had a significant effect on wild bees' diversity (p=0.002, Table 8, Figure 11). An increase of one unit in the Shannon Diversity Index of flower is associated with an expected average increase in the Shannon Diversity Index of bees of 0.257 units. Neither survey year, nor average daily temperature, nor BPA Q1 area had a significant effect on wild bee diversity (Table 8).

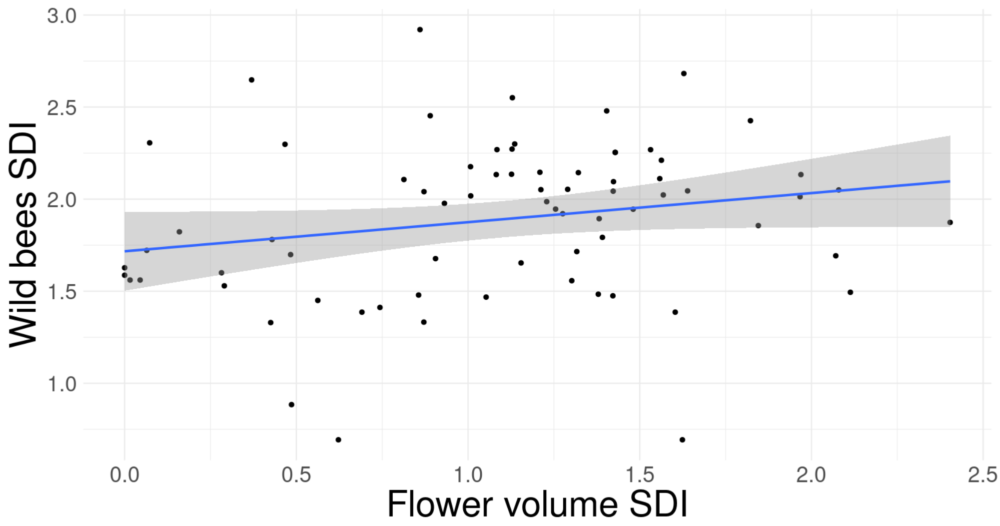

Fig. 11. Effects of flower volume diversity on wild bee diversity. Flower volume diversity and wild bee diversity are represented by the Shannon Diversity Index per parcel per survey round. Flower volume diversity showed a significant positive correlation with wild bee diversity (*p*=0.002, n=36).

Vane traps method test

A total of 645 arthropod individuals were sampled with the vane traps, 355 in the rows with high vegetation and 290 in the rows with low vegetation, including: Hymenoptera, Diptera, Hemiptera, Coleoptera, Thysanoptera, and other no flying insects. In the rows with high vegetation an average of 2.33 ± 0.47 wild bees per vane trap were captured, while in the rows with low vegetation an average of 2.17 ± 0.42 wild bees per vane trap were captured (Appendix, Table V).

Vegetation height showed no significant effects on wild bee capture rate (*p*=0.7423) and no significant effects on total insect capture rate (*p*=0.1648). These results showed that there was no significant difference between the two groups (high and low) in wild bee capture rate and in the total Insect capture rate (Fig. 12).

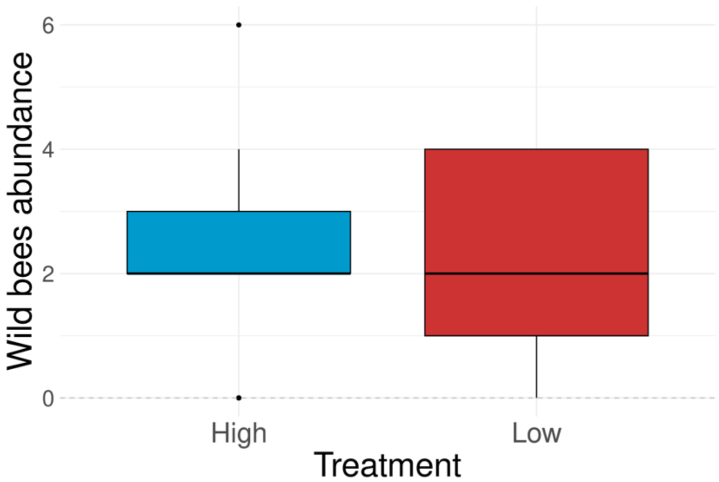

Fig. 12. Effects of different vegetation heights, high (blue) and low (red), on the capture rate of wild bees per trap with the catching method vane trap (n=24).

Discussion

The primary aim of this study was to investigate the role of flower strips in shaping wild bee populations within Swiss vineyards. We focused not only on the effects of flower strips on the abundance and diversity of wild bees but also on the role of flower volume and flower volume diversity. Our study showed that the number and diversity of wild bees in vineyards with flowering strips was significantly higher than in those with natural vegetation, even in the third and fourth year of sowing. It turned out that the flower strips had significantly higher values in terms of flower volume and diversity and that the diversity of the flower volume had a significantly positive influence on the bee diversity. The surrounding biodiversity promotion areas (Q1) showed no significant effect on the abundance and species richness of wild bees. Temperature, on the other hand, positively influenced wild bee abundance. Furthermore, we found no significant differences between the capture rates of vane traps in rows with high or low vegetation, indicating a good reliability of this method even under different visibility conditions.

In agreement with our initial hypothesis (H1), the results showed a significant effect in promoting wild bees, both in abundance and diversity, by using flower strips with a more diverse and abundant flora in vineyards. In the context of Swiss viticulture, these results are supported by Bättig et al. (2022). Implementing conservation strategies for bee communities is imperative due to their widespread decline in various regions (Biesmeijer et al., 2006; Colla et al., 2008). It is essential to safeguard not only the number but also the variety of wild bee species, as this diversity plays a pivotal role in upholding plant diversity (Fontaine et al., 2006) and enhances the reproduction of both wild plants (Gomez et al., 2007) and cultivated crops (Hoehn et al., 2008). The parcels with flower strips, in agreement with the initial hypothesis (H2), showed a higher volume and especially a higher diversity of flowers than the spontaneous vegetation parcels. There is substantial evidence indicating that habitat loss is a leading cause of bee population decline (Winfree et al., 2009). Conserving these habitats is imperative to provide adequate nesting sites and food resources, not only in quantity and variety but also over time (Potts et al., 2003). The findings of our study, showing a significant increase in flower volume and floral volume diversity in flower strips compared to the natural vineyard environments, support the efficacy of this intervention approach. These results encourage the implementation of these measures in favour of a higher and richer flora in vineyards, representing a positive step towards the conservation of wild bee populations. Despite the significant results of the flower strips, only flower volume diversity proved to be significant in promoting higher wild bee diversity, as initially hypothesised (H3). Indeed, in contrast to what was initially hypothesised (H3), flower volume did not significantly influence bee abundance and diversity and flower volume diversity proved not to be significant on wild bee abundance. These conflicting results leave open research questions that could be addressed by a more detailed study investigating, for example, the relationships between wild bees and plant species. Studies, such as that by Sydenham et al. (2023), show that specific plant species have a more significant positive effect on specific wild bee species, indicating intraspecific solid relationships. It has been observed that distinct bee species exhibited varied responses to diverse floral resource availability (Potts et al., 2003), wherein specific flower species provided unique support to distinct bee species. For this evidence, a more specific approach could be taken in future research, considering such intraspecific relationships, which could provide helpful information on the promotion of certain species by certain flower species. In this way, more adequate variables representing the supply of flowers could be integrated into the investigation. Regarding the biodiversity promotion areas (Q1) examined in the study, no significant effects were found on either the abundance or diversity of wild bees, contrary to initial hypotheses (H4). As the results of other studies concerning the effects of surrounding areas for the promotion of biodiversity on bees in flower strips remain contradictory (Scheper et al., 2015), this result is not surprising. Nevertheless, it might be worth evaluating the effect by considering other indices in addition to the total sum of these areas, such as plant composition, a reduction in the analysis radius considered, or by incorporating other landscape elements with a potential influence on bee populations. The initial hypotheses concerning the capture rates by the vane traps with different visibility (H5) were not confirmed, as no differences were observed in the captures by the traps placed in the low vegetation and those in the high vegetation. This result is of particular importance for our study, suggesting that there is no significant bias in the capture rates of vane traps due to higher visibility in low vegetation, a situation primarily found in parcels with spontaneous vegetation. A further surprising result, although not considered in the main research questions, was the non-significant difference in the volume and diversity of flowers between the two different years of data collection, thus observing good maintenance of the seed mixture several years after the sowing process.

The complexity of agroecosystems is very high, and considering all variables that may have a significant influence on wild bees is not possible. Nevertheless, it would be appropriate to optimize this investigation by evaluating more variables and considering those that have the most significant impact on bees. In the context of this master thesis, it was possible, despite the great heterogeneity between the different vineyards included in the survey, to find significant differences between parcels with flower strips and parcels with spontaneous vegetation. These results offer good points for promoting wild bees with flower strips in vineyards, considering the differences in agricultural management between the vineyards, the variance of the surrounding landscapes and the species composition between the different sown parcels.

Conclusions and implications

In conclusion, the findings of this study illustrate how flower strips have an effective positive impact on the abundance and diversity of wild bees in vineyards, regardless of the type of management. Nevertheless, the variables representing flower diversity and volume showed conflicting effects on bees. Therefore, we propose to consider other indices to represent the flower supply in the parcels and to investigate the effects of the increased presence and diversity of flowers in the flower strips on wild bees. These results may have broad implications for our understanding of the efficacy of flower strips with native perennial plants on wild bees in the context of viticulture and on the overall promotion of greater biodiversity and balance in the agroecosystems in focus. The current results provide a compelling rationale for further research over the long term, exploring with more specificity other variables of interest that may play an important role in restoring and maintaining wild bee biodiversity in relevant agricultural landscapes, such as vineyards.

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Appendix

Table I. Vineyards parcels data: Distance between pair (m), treatment (Sown, Control), seed mixture (Ress.projekt: adapted seed mixture from Agrofutura's Ressourcenprojekt, Trocken 2020: seed mixture from Agroscope and FiBL's project *Blühende Rebberge für Mensch und Natur*), sowing year, sown area (m^2) and production type (OELN: standard/conventional according to *Ökologischer Leistungsnachweis*, BIO: biological/organic) specified by pair number, site and treatment.

Pair number / site	Distance btw. pair m	Treatment	Seed mixture	Sowing year	Sown area m^2	Production type
1 Schinznach	190	Sown	Ress.projekt	2021	350	OELN
		Control		NA		OELN
2 Spiez	420	Sown	Ress.projekt	2021	2500	OELN / BIO
		Control		NA		OELN
3 Aesch	570	Sown	Ress.projekt	2021	300	OELN
		Control		NA		OELN
4 Volken	230	Sown	Ress.projekt	2021	400	OELN / BIO
		Control		NA		OELN
5 Volken	270	Sown	Ress.projekt	2021	1400	OELN
		Control		NA		OELN
6 Bözen/Hornussen	3170	Sown	"Trocken 2020"	2020	496	OELN
		Control		NA		OELN
7 Dörflingen	280	Sown	"Trocken 2020"	2020	352	OELN
		Control		NA		OELN
8 Twann-Tüschers	330	Sown	"Trocken 2020"	2020	384	OELN / BIO
		Control		NA		OELN / BIO
9 Echandens/Denges	190	Sown	"Trocken 2020"	2020	347.2	BIO
		Control		NA		BIO
10 Auvernier	1500	Sown	"Trocken 2020"	2020	480	BIO
		Control		NA		BIO

Table II. Meteorological data: Average daily temperature (°C), average minimum daily temperature (°C), average maximum daily temperature (°C), sum of total precipitation (mm/m^2), maximum sum of total precipitation (mm/m^2), specified by year and round. Minimum sum of total precipitation has been omitted, as it always equals zero. For the year 2023, the second and third rounds were considered together, as only one location had a third round.

Year	Round	Av. daily temp.	Min. temp.	Max. temp.	Tot. sum prec.	Max. tot. sum prec.
2022	1	25.84	20.85	28.18	3.17	15.10
	2	25.75	22.60	29.02	3.37	16.70
2023	1	25.70	15.85	23.44	4.66	34.10
	2(3)	25.75	21.42	26.09	5.41	8.20

Table III. Survey data: Average daily temperature, wild bee species, wild bees' number, wild bees Shannon Diversity Index, Flower volume (cm^3) and Flower volume Shannon Diversity Index for the 10 different vineyards, specified by year, round and treatment.

1 Schinznach

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm^3	Flower volume SDI
2022	1	Control	26.86	6	9	1.68	261.70	0.91
		Sown	26.93	9	14	2.14	576.22	1.32
	2	Control	24.48	10	27	2.01	343.91	1.97
		Sown	24.48	11	28	1.86	324.11	1.85
2023	1	Control	19.74	4	6	1.33	941.03	0.43
		Sown	19.68	10	12	2.25	2805.71	1.43
	2	Control	25.66	5	13	1.48	51.30	0.86
		Sown	25.67	10	16	2.13	535.53	1.97

2 Spiez

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm3	Flower volume SDI
2022	1	Control	25.79	4	4	1.39	33.26	0.69
		Sown	25.95	10	15	2.21	478.17	1.56
	2	Control	26.54	10	18	2.14	27.01	1.13
		Sown	26.25	8	22	1.95	316.22	1.48
2023	1	Control	19.10	5	10	1.56	152.69	1.30
		Sown	18.80	5	7	1.48	1289.38	1.42
	2	Control	21.42	7	12	1.70	10.45	0.48
		Sown	21.49	9	19	1.99	408.38	1.23

3 Aesch

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm^3	Flower volume SDI
2022	1	Control	27.36	11	23	2.27	78.63	1.08
		Sown	27.46	17	30	2.68	586.39	1.63
	2	Control	26.01	8	25	1.59	11.31	0.00
		Sown	26.01	8	22	1.79	384.26	1.39
2023	1	Control	19.96	5	6	1.56	1875.22	0.05
		Sown	19.90	8	9	2.04	2973.22	1.42
	2	Control	23.87	6	31	0.88	214.93	0.49
		Sown	23.83	12	43	1.87	720.63	2.40

4 Volken

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	28.18	4	5	1.33	726.25	0.87
		Sown	27.90	9	14	2.11	2588.51	0.81
	2	Control	28.10	10	27	1.78	271.92	0.43
		Sown	28.26	13	19	2.48	182.17	1.40
2023	1	Control	23.61	7	11	1.89	166.63	1.38
		Sown	23.44	5	8	1.49	330.37	2.11
	2	Control	26.07	8	21	1.65	200.46	1.15
		Sown	26.09	6	14	1.47	79.38	1.05

5 Volken

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	27.35	7	16	1.45	61.13	0.56
		Sown	26.62	9	11	2.15	162.94	1.21
	2	Control	27.80	19	110	1.60	15.74	0.28
		Sown	27.29	15	75	2.05	274.99	1.29
2023	1	Control	19.55	10	26	2.05	451.80	1.21
		Sown	19.42	7	13	1.69	424.70	2.07
	2	Control	23.98	6	19	1.48	112.55	1.38
		Sown	23.94	11	38	2.05	280.87	2.08

6 Hornussen/Bözen

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	27.83	4	5	1.33	587.36	0.78
		Sown	27.91	1	1	0.00	3666.57	1.29
	2	Control	25.93	17	49	2.49	706.18	0.67
		Sown	25.93	15	38	2.36	1298.12	0.49
2023	1	Control	19.78	7	8	1.91	157.73	1.47
		Sown	19.66	1	1	0.00	2580.16	1.65
	2	Control	23.83	6	34	1.06	742.19	1.94
		Sown	23.80	4	28	0.46	903.93	1.37

7 Dörflingen

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	23.26	2	2	0.69	1923.08	0.62
		Sown	23.07	9	12	2.02	883.05	1.57
	2	Control	22.67	17	24	2.65	59.15	0.37
		Sown	22.60	12	16	2.43	335.34	1.82
2023	1	Control	19.33	9	17	2.02	351.08	1.01
		Sown	19.08	11	21	2.27	864.30	1.53
	2	Control	24.18	9	31	1.41	427.36	0.74
		Sown	24.25	12	27	2.11	746.98	1.56

8 Twann-Tüschers

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	22.97	10	16	2.13	619.07	1.08
		Sown	22.97	12	22	2.30	704.90	1.14
	2	Control	29.02	12	34	2.31	922.22	0.07
		Sown	29.02	25	72	2.92	363.85	0.86
2023	1	Control	16.51	9	16	1.98	765.79	0.93
		Sown	16.35	12	23	2.09	1593.70	1.42
	2	Control	NA					
		Sown	NA					

9 Denges/Echandens

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	25.48	10	15	2.18	182.71	1.01
		Sown	25.48	7	7	1.95	2248.64	1.25
	2	Control	27.88	13	55	1.82	56.79	0.16
		Sown	27.88	24	149	1.72	664.54	1.32
2023	1	Control	15.85	8	20	1.72	1073.15	0.06
		Sown	15.95	13	32	2.27	2677.32	1.13
	2	Control	24.06	6	15	1.53	135.18	0.29
		Sown	24.13	10	27	2.04	424.97	1.64
	3	Control	21.98	10	65	1.63	348.91	0.00
		Sown	21.80	18	45	2.45	946.14	0.89

10 Auvernier

Year	Round	Treatment	Av. daily temp.	Wild bees species	Wild bees sum	Wild bees SDI	Flower volume cm³	Flower volume SDI
2022	1	Control	20.85	4	4	1.39	844.79	1.60
		Sown	20.85	2	4	0.69	593.54	1.62
	2	Control	24.81	11	27	2.04	54.85	0.87
		Sown	24.81	17	42	2.55	455.04	1.13
2023	1	Control	16.20	13	25	2.30	1381.31	0.47
		Sown	16.17	10	20	1.92	1503.47	1.28
	2	Control	24.69	5	6	1.56	2833.65	0.02
		Sown	24.69	10	12	2.25	1716.63	1.43

Table IV. Biodiversity promotion areas: BPA of quality 1 and 2 sum of area total (m^2) and sum of area percentage (%) specified by pair number, site and treatment within a radius of 500 meters.

Pair number / site	Treat.	BFF_Q1 Sum of area	BFF_Q1 Sum of area perc.	BFF_Q2 Sum of area	BFF_Q2 Sum of area perc.
1 Schinznach	Sown	405061.42	51.58	121051.26	15.41
	Control	326839.31	41.62	116749.96	14.87
2 Spiez	Sown	103230.03	13.14	61998.41	7.89
	Control	89587.72	11.41	61098.83	7.78
3 Aesch	Sown	547572.50	69.72	4600.01	0.59
	Control	344461.54	43.86	9266.11	1.18
4 Volken	Sown	611921.60	77.92	24302.82	3.09
	Control	554442.27	70.60	19858.73	2.53
5 Volken	Sown	680242.49	86.62	17036.13	2.17
	Control	661148.04	84.19	14041.81	1.79
6 Bözen/Hornussen	Sown	553579.55	70.49	80468.74	10.25
	Control	320052.86	40.75	79113.80	10.07
7 Dörflingen	Sown	470993.15	59.98	33359.92	4.25
	Control	468473.90	59.66	37278.70	4.75
8 Twann-Tüschers	Sown	159727.77	20.34	60991.27	7.77
	Control	115296.80	14.68	30303.61	3.86
9 Echandens/Denges	Sown	202685.94	25.81	0.00	0.00
	Control	358033.34	45.59	33889.16	4.32
10 Auvernier	Sown	414047.35	52.72	3039.36	0.39
	Control	376200.96	47.90	6564.03	0.84

Table V. Vane trap method test data: sum of captured insects sorted by order/'morpho-groups' specified by treatment and repetition.

Treat.	Rep.	Wild bees	Other Hymenoptera	Diptera	Hemiptera	Coleoptera	Thysanoptera	Other no flying insects
High	1	6	1	13	13	24	27	24
	2	12	7	12	12	24	20	23
	3	10	3	18	11	21	44	30
Low	1	10	3	16	14	20	14	17
	2	9	6	42	5	21	15	15
	3	7	4	12	8	26	16	10