# Bee Community Response to Underseeded Legumes in Agricultural Landscapes of Switzerland

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**Abstract**

Pollinators, especially bees, play a crucial role in flowering plant seed production and reproduction. Significant declines in pollinator populations have been recorded for decades due to a variety of factors, among which are habitat fragmentation, lack of flowering resources and reduced nesting site availability due primarily to agricultural intensification. Underseeded legumes are sown under crops and flower after harvest, providing benefits to both the soil and the pollinator community. By underseeding legumes, agricultural landscapes have the potential to provide floral resources in areas lacking adequate nectar and pollen sources. Since clovers are an essential foraging resource for both honeybees and wild bees, all underseeded mixes were required to include at least one species of clover. Fields throughout canton Vaud, Switzerland participated in legume underseeding in an effort to promote pollinator richness. We present a hypothesis that fields with underseeded legumes, particularly clovers, encourage greater honeybee abundance and wild bee abundance and diversity. We also predict that bumble bees will be the most affected by underseeding due to their preference for red clovers (*Trifolium pratense*). Various correlations between the bee community and field variables were evaluated using Kendall's rank correlation and each variable's predictive power was tested using generalized additive mixed models (GAMM). Our findings indicate that underseeding had a significant effect on wild bee abundance, wild bee diversity and honeybee abundance; the effect was stronger with increasing clover coverage. Our findings demonstrate the potential benefits of underseeding legumes in agricultural fields as a late-season flowering resource for bees.

*Keywords*: Pollinator, agricultural intensification, floral resources, bee diversity, *Trifolium pratense*

# Introduction

## *Pollinator Importance*

Pollinators are biotic agents that facilitate flowering plant fertilization through pollen transport from the male anther to the female stigma of a flower (Das et al., 2018; Wilcock and Neiland, 2002). Seed production of flowering plants depends upon pollinators to maintain genetic diversity within the plant population (Cunningham-Minnick et al., 2019; Riday et al., 2015). Pollinators are essential to the successful production of many vegetables, fruits and crops which are crucial for global food production (Das et al., 2018; Vanbergen, 2013). The reproductive success of > 75% of flowering plants depends upon insect pollination services (Klein et al., 2006; Potts et al., 2016). Successful pollination supports not only the yield and quality of flowering crops, but also the vital ecological processes within a natural ecosystem (Gallai et al., 2009; Gill et al., 2016; Khalifa et al., 2021; Potts et al., 2016).

## *Pollinator Declines and Agriculture*

Despite their importance, pollinator populations have exhibited significant declines over the past few decades in response to numerous threats (Dupont et al., 2011; Potts et al., 2010). Declining pollinator populations are considered a major threat for ecosystem functioning and crop production upon which humans depend (Gallai et al., 2009; Rhodes, 2018). A variety of factors drive pollinator declines including habitat loss and fragmentation, lack of floral and nesting resources, pesticide use, invasive species, disease, pollution and climate change (Dicks et al., 2021; Goulson et al., 2015; Hellerstein et al., 2017; Potts et al., 2010, Vanbergen, 2013; Winfree, 2010). Wild bees are primarily limited by fragmented habitats, lacking floral resources and reduced nesting site availability (Dicks et al., 2021; Potts et al., 2010, Vanbergen, 2013; Van der Sluijs et al., 2013; Winfree, 2010). The main drivers of honeybee declines include limited floral resources, pathogens and pesticide use

(Douglas et al., 2020; Goulson et al., 2015; Rowland et al., 2021). Each pollinator decline driver is influenced by changes in land use and management due to agricultural intensification (Goulson et al., 2015; Hofmann et al., 2019; Potts et al., 2010).

Major changes in landscape composition are a direct result of intensive agriculture (Vanbergen, 2013; Williams et al., 2009). Prior to the 1950s, agricultural landscapes were made up of small polycultures and flower-rich grasslands found between trees and hedges (Robinson and Sutherland, 2002). Over time, landscapes turned homogeneous as agriculture became dominated by monocultures, intensive pastures and frequently mowed grasslands (Robinson and Sutherland, 2002; Mazoyer and Roudart, 2006; Vray et al., 2019). Agricultural intensification has increased the use of pesticides while simultaneously decreasing resources and habitat availability (Vanbergen, 2013).

***Wild Bee Decline Drivers***

Wild bee populations provide essential pollination services for crop production and native plants in natural ecosystems (Vanbergen, 2013; Winfree, 2010). Therefore, declines in wild bee populations pose a major threat to both the human population and terrestrial ecosystems alike (Dicks et al., 2021; Potts et al., 2010; Winfree, 2010). Habitat fragmentation increases the probability of wild bee population extinction and reduces gene flow between populations which can lead to a loss of genetic diversity (Exeler et al., 2010). Fragmented habitats can also reduce pollination services provided by wild bees resulting in lower crop yields (Steffan-Dewenter and Tscharntke, 1996). Increased fragmentation alters wild bee community composition and threatens the stability of plant-pollinator networks (Grass et al., 2018). Trait differences make some species more susceptible to population declines; for example, habitat fragmentation may be more detrimental to smaller species as they are more limited by flight distance (Everaars et al., 2018; Hines and Hendrix, 2005). Reduced habitat connectivity can increase extinction of specialists and poor dispersers, especially in the face of climate change (Bommarco et al., 2010; Vanbergen, 2013). Habitat fragmentation has been linked with changes in flowering plant species richness, which indirectly impacts the wild bee community (Theodorou et al., 2020).

A lack of floral resources has been identified as a key driver of wild bee declines (Goulson et al., 2015; Scheper et al., 2014). Agricultural intensification has majorly influenced floral resource availability through habitat loss, homogenous mowing regimes and intensive animal husbandry (Le Féon et al., 2010; Goulson et al., 2015; Johansen et al., 2019). Many natural and extensive agricultural habitats have been converted to intensive agricultural landscapes which limits the growth and dispersion of native flowering plants (Goulson et al., 2015). As agriculture intensified, landscapes became uniform and frequently mowed (Johansen et al., 2019; Robinson and Sutherland, 2002). Homogenous and frequent mowing regimes limit temporal diversity of flowering plants which results in few resources for wild bees, particularly later in the season (Johansen et al., 2019). Due to the benefits of delayed mowing, many farmers have adopted a later first-cut date. This has increased the frequency of late-season mowing which can lead to flowering resource shortages (Johansen et al., 2019). Resource shortages later in the season are a major concern as considerable declines have been recorded in late-flowering resources (Hofmann et al., 2019). Mass flowering crops may offer foraging resources for certain species however, they have the potential to alter pollinator communities and often only provide a short and synchronous burst of floral resources (Vanbergen, 2013). Intensive animal husbandry produces landscapes monopolized by foraging crops which reduces the diversity of floral resources available to the wild bee community (Le Féon et al., 2010). Wild bee conservationists agree that increasing floral resource abundance and diversity will benefit wild bee populations (Goulson et al., 2015; Klaus et al., 2021).

Availability of quality nesting sites is essential for the maintenance of robust wild bee populations (Harmon-Threatt, 2020). Wild bees utilize a variety of nesting habitats such as: old burrows, bare soil, holes in wood or hollow plant stems with materials for the interior such as leaves or resin (Goulson et al., 2015; Winfree, 2010). Nesting site habitat has declined as a result of habitat loss, habitat disturbance and climate change (Goulson et al., 2015; Harmonn-Threatt, 2020). Since species differ in their nesting preferences, certain species' reproduction will be more limited than others depending on the type of habitat lost (Winfree, 2010). Human disturbance, primarily through agriculture, can reduce the availability of appropriate nesting sites; for example, anthropogenic soil changes can decrease nesting site quality for digger bees due to changes in soil features (Xie et al., 2013). Nesting behaviour influences species' responses to climate change which will therefore have long-term effects on wild bee community composition (Pardee et al., 2022). Restoration of natural habitat is essential to improve availability of bee nesting sites (Goulson et al., 2015). Habitat fragmentation, reduced floral resources and lack of nesting sites have caused major declines in wild bee populations and are crucial considerations for wild bee conservation (Goulson et al., 2015; Scheper et al., 2014; Winfree, 2010).

***Honeybee Decline Drivers***

Bees are the most important of all the pollinators and honeybees (*Apis mellifera*) provide the greatest pollination services worldwide (Khalifa et al., 2021). Declines in wild pollinator populations have increased farmer's dependency on honeybee pollination, although studies suggest diverse wild bee populations can complement and possibly surpass honeybee pollination services (Aizen and Harder, 2009; Breeze et al., 2014; Garibaldi et al., 2013). Honeybee declines have resulted from a lack of floral resources, pathogens and pesticide use (Douglas et al., 2020; Goulson et al., 2015; Rowland et al., 2021). Reduced habitat area and habitat diversity can jeopardize pollination services primarily by limiting floral resources

(Aizen and Harder, 2009; Durant, 2019). Managed honeybee populations are often moved from location to location to increase pollination services and honey production; therefore, honeybee hives should be placed in areas with diverse flowering resources (Hellerstein et al., 2017). Nutritional stress due to a lack of floral resources has been reported in honeybee colonies and is a concern for overall hive health (Hellerstein et al., 2017; Naug, 2009). Nutritional stress may increase hive susceptibility to disease, which would therefore produce synergistic negative effects on honeybee populations (Naug, 2009).

Greater intensity in honeybee colonies has elevated the negative effects produced by pathogens (Potts et al., 2010; Vanbergen, 2013). The varroa destructor mite is the most influential honeybee pathogen and has caused numerous honeybee colony losses; varroosis decreases hive immunity which increases the potential for co-infection with other pathogens (Le Conte et al., 2010, Vanbergen, 2013). During 2015 in the USA, nearly 45% of all honeybee hives were affected by varroa mites (Hellerstein et al., 2017). Research indicates other diseases have produced significant honeybee colony losses such as chronic bee paralysis and sacbrood disease (Budge et al., 2020; Rowland et al., 2021). Intensification of honeybee pollination has substantially increased hive density, creating the perfect environment for disease spread (Rowland et al., 2021).

Agricultural intensification was a response to a demand for higher crop yields which increased the utilization of fertilizers, pesticides, and heavy machinery (Hofmann et al., 2019). Often, contemporary farming practices are unsuited for pollinator populations (Wilcock and Neiland, 2002). Pesticides and insecticides are commonly used in agriculture to kill insects in an effort to increase crop yields (Douglas et al., 2020). Neonicotinoids are neurotoxic insecticides which can lead to insect death within a few minutes (Van der Sluijs et al., 2013). Only a small proportion of the active neonicotinoid enters the crop to protect it while the remaining concentration pollutes surrounding surface and groundwater where it can persist for many years (Van der Sluijs et al., 2013). Sublethal levels of neonicotinoids can severely decrease a colony's performance by influencing foraging success, central nervous system damage and disease susceptibility (Van der Sluijs et al., 2013). Pesticide use should be limited in crop fields, especially during honeybee pollination (Hellerstein et al., 2017). Lack of floral resources, disease, and pesticide use have all significantly contributed to honeybee declines and must be considered for the health of future hives (Douglas et al., 2020; Goulson et al., 2015; Rowland et al., 2021).

***Human Activity and Bee Decline Drivers***

Increased human activity plays a direct or indirect role in all influential bee decline drivers (Cane and Tepedino, 2001; Marshman et al., 2019). It is essential to understand the ways in which humans can impact bee populations to ensure pollinator conservation actions incorporate appropriate solutions (Marshman et al., 2019). Invasive species act as agents of change as they threaten native ecosystems and can be introduced by chance or through human activity (Dicks et al., 2021; Stout and Morales, 2009). Invasive plant species pose a large threat to pollinator populations as their alteration of the plant community can disrupt bee foraging behaviour, population distribution and plant pollinator networks (Stout and Morales, 2009).

Negative human-made impacts on ecosystems such as climate change and pollution continue to negatively impact pollinator populations as these problems are continually disregarded (Vanbergen, 2013). Climate change causes range shifts in both plant and pollinator species which can alter the composition of a natural ecosystem (Rahimi et al., 2021). With increasing temperatures, prediction models suggest that most wild bee species will shift to higher latitudes (Rahimi et al., 2021). Cold-adapted species will be driven to the edge of their climatic range increasing their risk of extinction (Vanbergen, 2013). Certain areas will therefore be left with much lower wild bee diversity while specialist species in higher latitudes will suffer from increased competition (Rahimi et al., 2021). It is important to be aware of the potential impacts of climate change on bee populations however, each species will react differently to any given threat (Rahimi et al., 2021). Influences and interactions at the ecosystem level must also be considered (Rahimi et al., 2021). Generally, pollution can decrease habitat quality and availability while heavy metal pollution is known to decrease both abundance and diversity of wild bees (Moroń et al., 2012). There are many different types of pollution which can have direct and indirect effects on pollinator populations; for example, polluted air traps more heat in Earth's atmosphere which contributes to warming temperatures (Kinney, 2018).

***Wild Bees vs Honeybees***

Findings regarding the relationship between wild bees and honeybees are highly contradictory. Honeybees may outcompete wild bees for general flowering resources and deplete local supplies (Herbertsson et al., 2016). Research suggests these effects are more significant in landscapes with low flowering resource diversity (Herbertsson et al., 2016). Some studies demonstrate honeybees' ability to facilitate alien plant reproduction and alter flowering plant community composition, to the detriment of wild bees (Abe et al., 2011). Resource competition between honeybees and bumble bees may lead to bumble bee population declines (Thomson, 2016). Other studies suggest positive interactions between honeybees and wild bees may increase pollination efficiency. Findings indicate that behavioural interactions between honeybees and wild bees could increase honeybee pollination efficiency by up to five times (Dupont et al., 2011; Greenleaf and Kremen, 2006). In contrast, some studies suggest diverse wild bee populations can complement and even surpass honeybee pollination services (Breeze et al., 2014; Garibaldi et al., 2013). Rader et al. (2012) found the contributions of unmanaged insect pollinators were equal to or greater than that of the managed honeybees. Their findings highlight the importance of specific management practices to consider both the requirements of farmed honeybees and wild pollinator populations (Rader et al., 2012). Many complex direct and indirect interactions exist between honeybee and wild bee populations which are important considerations for the implementation of bee conservation actions.

***Bee Vulnerability***

Trait differences leave some species more vulnerable to population declines caused by spatial changes including habitat fragmentation, reduced nesting sites or resource shortages (Everaars et al., 2018; Hines and Hendrix, 2005). For example, larger solitary bees with high pollen requirements are disproportionally disadvantaged by reduced floral resources while fragmentation may benefit cavity-nesting bees by increasing edge habitat (Everaars et al., 2018). Intensive agricultural practices can reduce community connectivity and produce disproportional effects on different bee species (Everaars et al., 2018; Potts et al., 2010). Species-specific traits play an important role in response to habitat loss which can lead to significant changes in wild bee community composition (Bommarco et al., 2010). Colony size, colony cycles, nesting behaviour and proboscis length have all been identified as traits which may affect a species' vulnerability to different threats (Persson et al., 2015). Conservation actions for wild bee communities must evaluate the effects of threats on different bee species to promote successful conservation strategies (Klein et al., 2006).

Analyses based on effects of habitat alterations and species-specific traits identify late-flying bee species as the most vulnerable to population declines and extinction (Hofmann et al., 2019). Intensive land use and loss of preferred host plant species are established as the main contributing factors disproportionally affecting late-flying bee species (Hofmann et al., 2019; Scheper et al., 2014). Greater declines have been observed in late-flowering pollen and nectar sources than early-flowering resources (Hofmann et al., 2019). In addition, mowing intensity is generally much greater later in the season, which can lead to flowering resource shortages (Johansen et al., 2019). Current conditions tend to benefit the diversity of spring-flying, city-dwelling and high-temperature tolerating species (Hofmann et al., 2019).

***Underseeding Legumes***

Cover crops or underseeded crops are planted to cover the ground surface between main crop rotations, initially used to promote soil health (Sharma et al., 2018). Cover crops have been successfully implemented to improve agroecosystem services including soil health, weed suppression, reduced soil erosion and possible increased crop yields (Mallinger et al., 2019; Meyer, 2005; Sharma et al., 2018). Many legumes perform well in N-fixation, weed control and separating hardpans (Wallace and Scott, 2008). An additional positive impact of underseeding is the possible benefit to bee communities, which has only recently been explored. Mallinger et al. (2019) found that additional floral resources through cover crops have the potential to attract many wild bee individuals. They also found that the wildflower mix has a significant influence on the diversity of bee visitors (Mallinger et al., 2019). It is important to consider the effects and the desired result of the introduced floral mix as some plants will be more beneficial to honeybee populations and others more beneficial to certain wild bees (Hicks et al., 2016; Urbanowicz et al., 2020).

Fabaceae, specifically clovers, act as an essential foraging resource for a wide range of bee species (Jones et al., 2021; Kanduth et al., 2021; Rundlöf et al., 2014). The white clover (*Trifolium repens*) is a fundamental resource for honeybees, is the second most foraged flowering plant species in the UK (Jones et al., 2021), and honeybees perform 87% of *T. repens* pollination in Russia (Zolotarev, 2021). The red clover (*Trifolium pratense*) is a vital floral resource especially for bumble bees (Goulson et al., 2005; Kanduth et al., 2021; Rundlöf et al., 2014). These two types of clover provide resources for many individuals in the bee community, especially those found in agricultural landscapes (Jones et al., 2021; Rundlöf et al., 2014); in our study, underseeded mixes were required to include at least one clover species. Underseeded legumes will begin to grow and flower post main crop harvest; wheat and triticale are typically harvested between mid-July to mid-August, depending on weather conditions (Anken et al., 2004; Wójcik-Gront and Studnicki, 2021). The benefits of additional floral resources later in the season have the potential to significantly support the bee community. Landscapes with a higher proportion of bee-nesting appropriate habitats will have a greater capacity to support larger pollinator populations.

Agripol, the Agriculture and Pollinators project, aims to encourage pollinator friendly agricultural techniques which benefit local pollinator communities. The cantons of Vaud, Jura and Bern participate in Agripol in collaboration with Prométerre, Fondation Rurale Interjurassienne and the Federal Office of Agriculture (OFAG). Our study, in association with Agripol, investigates the impact of underseeding legumes in cereal fields on local bee abundance and diversity. The aim is to increase floral resources in agricultural landscapes at a time when resources are lacking, specifically for vulnerable late-flying wild bee species and managed honeybees. This was evaluated by surveying fields participating in the Agripol underseeding measure across canton Vaud, Switzerland. Based on our desired area of focus, we tested the following hypothesis:

H1. Flowering legumes act as an important foraging resource for many bee species. Therefore, fields with high floral coverage from underseeded legumes will yield the most abundant and diverse bee communities.

To further explore the impacts of underseeded legumes on the bee community, we also considered the surrounding landscape composition. We tested the following hypothesis:

H2. Landscapes with a higher proportion of varied natural habitat appropriate for bee nesting can support larger pollinator populations. Therefore, areas diverse in meadows, floral strips, floral hedgerows, forest edges, dry grasslands, orchards or shrubs will encourage more abundant and diverse bee communities.

# Methods

### *Site Selection*

This experiment was conducted in agricultural fields throughout canton Vaud, Switzerland during late August and September of 2021. This study was affiliated with the Agriculture and Pollinators project (Agripol), an association developing sustainable agricultural measures which benefit both wild bees and honeybees. Selected fields participated in the underseeding legumes measure (measure 77AQ) of the Agriculture and Pollinators project. Farmers were given a choice to implement underseeding in their fields for financial compensation, therefore this was not a full control experiment. To investigate the effects of underseeded legumes on honeybee abundance, wild bee abundance and wild bee diversity, participating plots and controls were determined according to the following criteria. A total of 50 plots were chosen from participating fields and were selected using QGIS (geographic information system) which helped filter for the specific criteria mentioned below (QGIS Development Team, 2021). All selected plots were located within at least one hive sector. Each hive sector was defined by a 2 km-radius circle centered around an apiary. Eligible fields were limited to those producing the following cereals: wheat, feed wheat, triticale and spelt; selected to maintain a standard harvest period and control for major differences between crops. We obtained maps from the Swiss Confederation displaying areas of dry grasslands, extensive agriculture, dry habitat and floral strips (Maps of Switzerland – Swiss Confederation, 2021). When possible, plots were selected in areas with varying levels of each habitat type. Most plots were located in only one type of habitat; after applying all other criteria, plots were then selected based on their proximity to multiple bee friendly habitat types. Fifty plots were selected across canton Vaud from fields meeting the previously mentioned criteria and a minimum distance between fields set to 1 km. Initial observations suggested there were neither bees nor flowers present in fields without underseeding. A total of 24 underseeded fields failed to produce flowers; these fields acted as controls since they produced the same outcome as non-underseeded fields. Participating plots were located in 14 municipalities across canton Vaud including: Apples, Attalens, Begnins, Bioley-Magnoux, Cuarnens, Dizy, Grandson, Lutry, Maracon, Monnaz, Prevenloup, Rances, Servion and Vuarrens.

**Figure 1.** Example of an underseeded field which failed to produce flowers. Vuarrens, 2021.

### *Agricultural Practices*

Farmers participating in the underseeded legumes measure were required to follow specific guidelines to ensure consistent undersowing methods were used across all participating fields. Underseeded mixes were required to be sown in autumn, planted alongside the cereal crop or sown in early spring after comb harrow weeding was complete. Floral mixes were limited to those including at least one type of clover. Farmers were provided with specific sowing densities which differed depending on the floral mix. The OHterramix-legume mix was sown at 14 kg / ha while the UFA-ceralegu mix was sown at 13 kg / ha. After the main crop was harvested, undersowing remained in place and additional overseed was added at this time if necessary. A cleanup cut was allowed during the 10 days following harvest and then mowing or grazing could only occur after flower buds had withered.

***Study Area***

Each agricultural field was surveyed post-harvest for a minimum of one visit during late summer of 2021. First visits were conducted between August 20 – 30, 2021. Fields with less than 5% floral coverage were classified as unsuccessful, while fields with more than 5% floral coverage were visited a second time. Second visits were conducted between August 31 – September 14, 2021. Upon arrival at each site, observations were recorded for blooming stage, specific floral mix, time, temperature, and weather conditions. Blooming stage was ranked on a scale of 1 - 8 for dicotyledons (Table 1). Ranks were made to the nearest tenth to better represent the actual blooming stage.

**Table 1.** Descriptions for each of the eight blooming stages of dicotyledons.

| **Blooming Stages of Dicotyledons** | | |
|---|---|---|
| **Stage** | | **Description** |
| 1 | Rosette | most plants have 3 leaves |
| 2 | Flower buds | buds just visible on ~ 50% of plants |
| 3 | Seed production | buds present on ~ 50% of plants |
| 4 | Start of bloom | ~ 10% floral bloom |
| 5 | Full bloom | ~ 50% floral bloom |
| 6 | End of bloom | high bloom with some wilting |
| 7 | Fruiting | ~ 50% plants with fruit |
| 8 | Seed dispersion | seed transportation |

A description of the immediate surrounding landscape composition was recorded for each plot; this included a brief explanation and proportion of each habitat type surrounding the cereal field. The level of natural habitat appropriate for bee nesting was ranked on a scale of 1 – 5 based on visual plot observations and QGIS landscape composition in a 1 km-radius. A rank of 1 was assigned to areas with a low availability of bee friendly habitat (less than 10%). A rank of 5 was assigned to areas with a high availability of bee friendly habitat (more than 50%). A varied landscape of meadows, semi-natural pastures, floral hedgerows, dry grasslands and floral strips would provide sufficient nesting sites and floral resources to support a large and diverse bee community (Mandelik et al., 2012; Martins et al., 2018). Landscapes matching such a description would be ranked as a 5.

***Sampling Methods***

When the field size allowed, three 50 m x 50 m zones of two line segments were surveyed (Figure 2). The two smallest plots (74730 and 440020) only allowed for two 50 m x 50 m zones. A marker was placed at the beginning of each survey line to pinpoint the corner of the two perpendicular line segments. A virtual measuring tape was used to ensure the surveyed area reached 50 m. Surveyed zones within one field were as distanced as possible. Surveys were conducted at a controlled speed of 10 sec/m and bee observations were recorded from one meter on either side of the walked path. Honeybees were counted, while wild bees were collected. Wild bees were caught using an aerial net of 40 cm diameter. Captured wild bees were then carefully collected into small containers and killed with ethyl acetate. All collected wild bees were pinned and identified. Identifications were then verified by a bee expert (Christophe Praz).

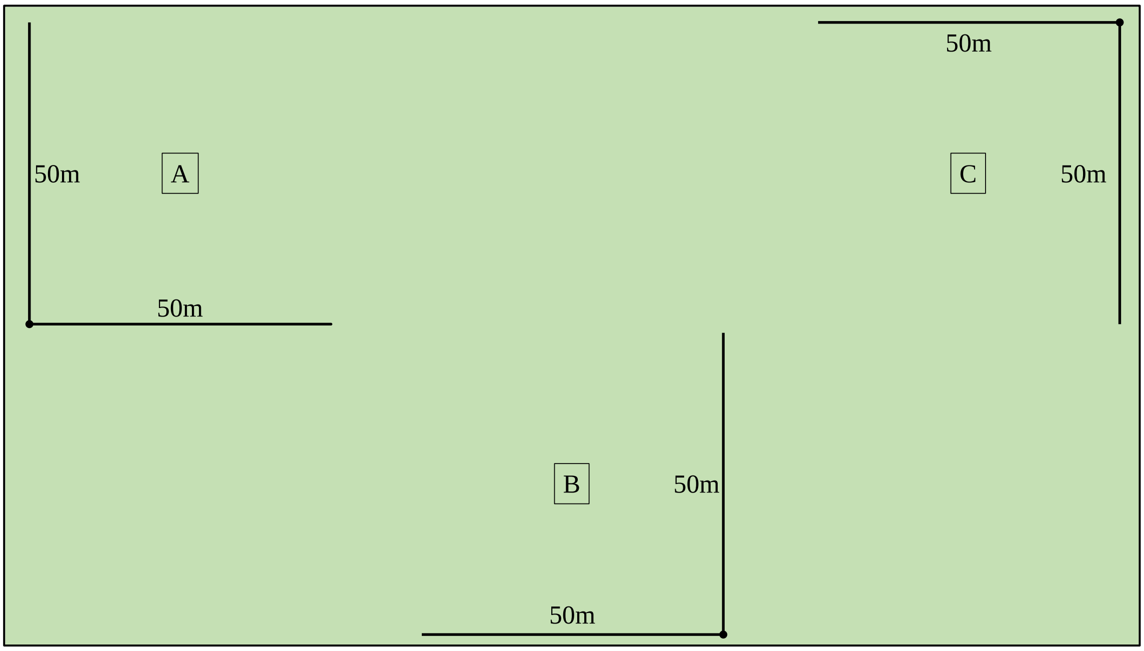


**Figure 2**. Example of field collection methods in underseeded fields. Three transects (A, B, C) of two 50 m x 50m perpendicular line segments were surveyed, when field size allowed.

***Data Analysis***

Bee abundance and diversity data was analysed using R studio (R Core Team, 2021). The Shapiro-wilk test revealed a non-normal distribution and a skewness test detected a highly positive skew. A Fligner-Killeen test was used to test variance homogeneity. A Kendall's rank correlation was used to establish the association present between bee occurrences and field variables. A Kendall's rank correlation was selected since our data is non-linear, both our dependent and independent variables are quantitative, and our data has a non-normal distribution. Kendall's rank correlation is non-parametric and uses a more robust approach to estimate the measure of association. Generalized additive models (GAM) were selected for fitted lines as they best explained the data and can be regulated to prevent overfitting. Scatter plots were created with GAMs to visualize the relationship of honeybee abundance, wild bee abundance and diversity against floral coverage and flowering stage. To compare the simultaneous influence of multiple fixed effects, we created generalized additive mixed models (GAMM). A GAMM was selected since both our dependent and independent variables are quantitative and data has a non-linear shape. GAMMs were used to establish the predictive power of floral coverage, blooming stage, level of natural habitat and temperature with plot ID as a random effect. A total of 24 fields failed to flower so these datapoints acted as our controls. Data from the three surveyed transects in each field (A, B, C) were combined due to low abundance, and the two smallest plots (74730 and 440020) were excluded from analysis.

## Results

### *Bee Specimens*

A total of 47 wild bee specimens from 11 different species were collected during August – September 2021 (Table 2). Species belonged to three of the seven bee families: *Andrenidae*, *Apidae* and *Halictidae*. A total of 440 honeybees (*Apis mellifera*) were observed during both visits in summer 2021; 136 honeybees were observed during visit 1 and 304 honeybees were observed during visit 2.

**Table 2**. Indicates the number of individuals collected, organised by species and family.

| Family | Species | # of Individuals |
|---|---|---|
| *Andrenidae* | *Andrena flavipes* | 1 |
| *Apidae* | *Bombus humilis* | 8 |
| | *Bombus lapidarius* | 13 |
| | *Bombus pascuorum* | 5 |
| | *Bombus ruderatus* | 6 |
| | *Bombus sylvarum* | 3 |
| | *Bombus terrestris* | 3 |
| | *Xylocopa valga* | 4 |
| | *Xylocopa violacea* | 2 |
| *Halictidae* | *Halictus scabiosae* | 1 |
| | *Halictus simplex* | 1 |

***Wild Bee Abundance***

A significant correlation was found between wild bee abundance and floral coverage for both visits combined ($\tau = 0.36$, $p < 0.001$) (Figure S1). Based on Kendall's rank correlation, the positive association between floral coverage and wild bee abundance was more significant for the second visit ($\tau = 0.49$, $p = 0.004$) than for the first visit ($\tau = 0.23$, $p = 0.068$). The data had a steeper trend during the second visit which yielded larger effect sizes and abundance levels were overall higher during the second visit (Figure 3). The greatest per field abundance was 2 individuals at ~ 60% floral coverage for visit 1. During the second visit, the greatest per field abundance was 14 individuals at ~ 80% floral coverage (see supplementary data, Table S1). A significant correlation was also found between wild bee abundance and flowering stage when both collection times were analysed together ($\tau = 0.24$, $p = 0.044$) (Figure S2). The outcome from the GAMM indicated floral coverage had the strongest predictive power ($F = 13.63$, $edf = 1.93$, $p < 0.001$) for wild bee abundance while flowering stage also had predictive power ($F = 7.55$, $edf = 1.84$, $p = 0.013$). Temperature and level of natural habitat did not have predictive power for wild bee abundance.

Wild Bee Abundance vs Floral Coverage – Visit 1

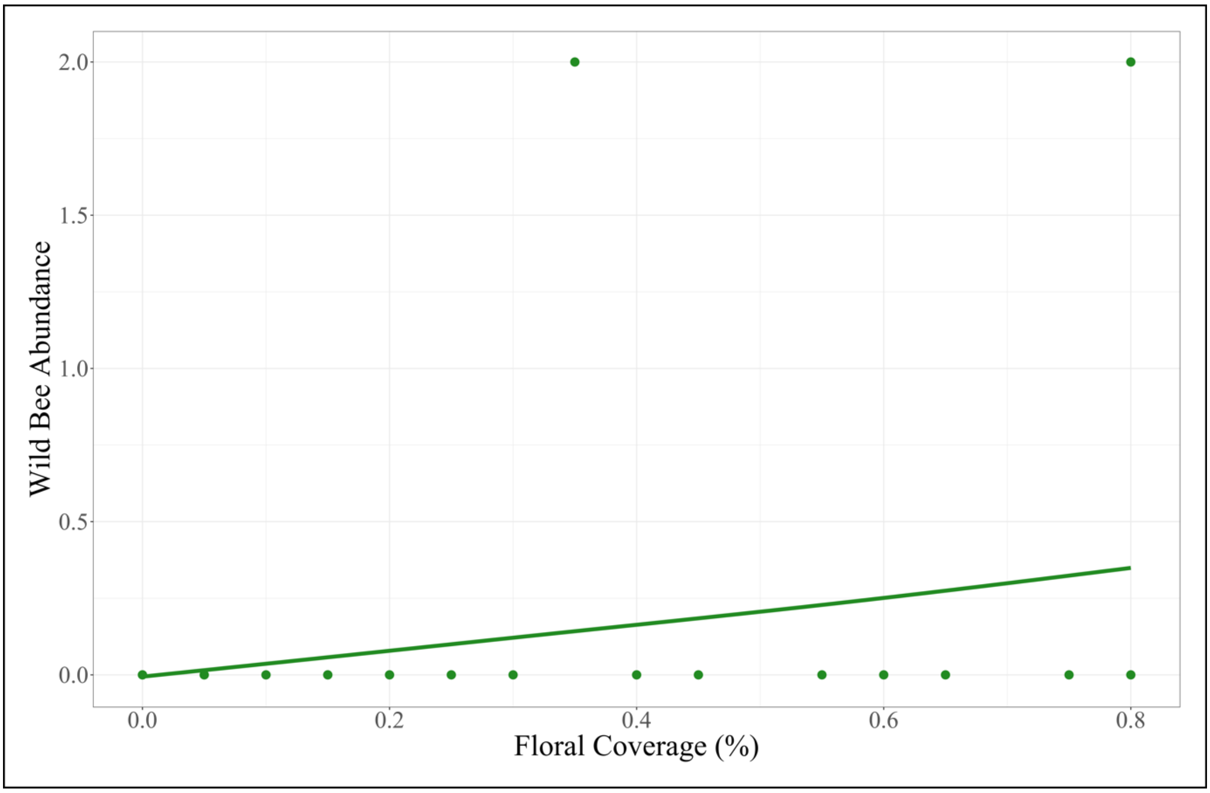


**Figure 3a**.

Wild Bee Abundance vs Floral Coverage – Visit 2

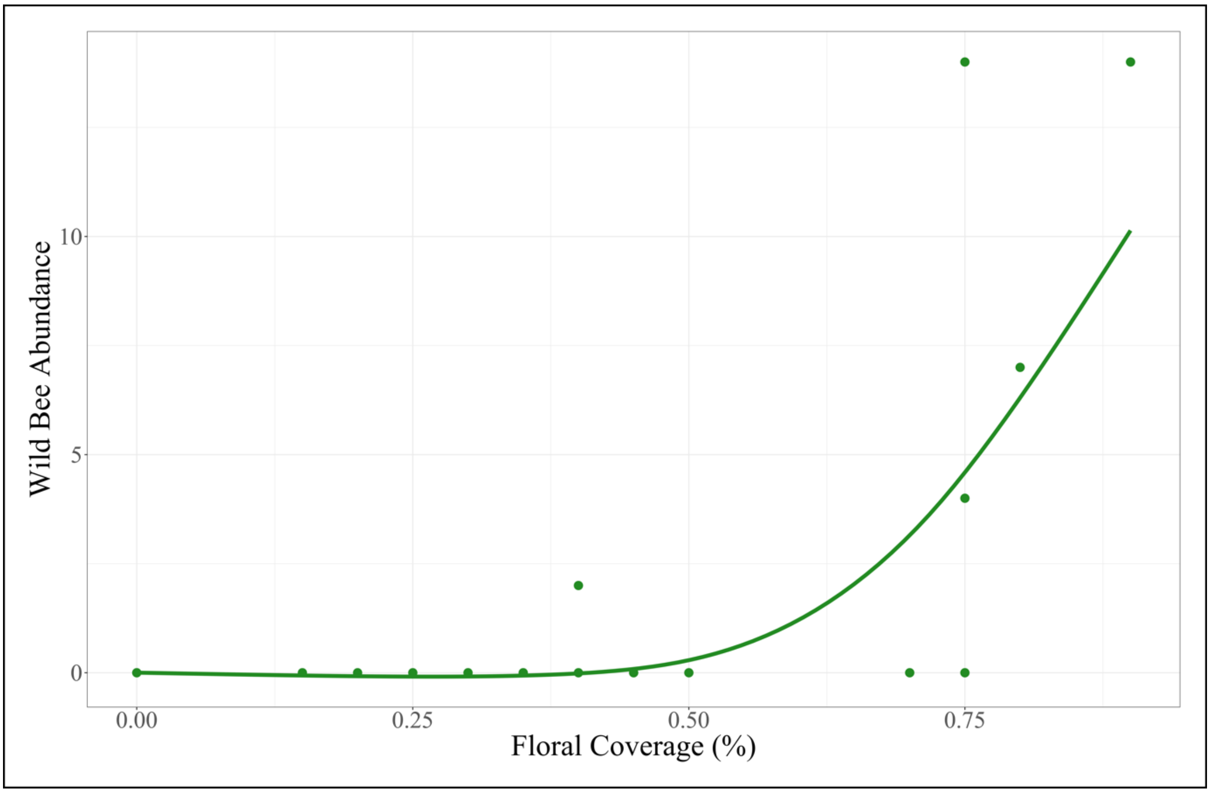


**Figure 3b.**

**Figure 3.** Abundance of wild bees in relation to the percentage of floral coverage per field. Fitted lines based on generalized additive models (GAM). a) Wild bee abundance vs % floral coverage for visit 1. b) Wild bee abundance vs % floral coverage for visit 2.

### *Wild Bee Diversity*

There was a significant correlation found between wild bee diversity and floral coverage for both visits combined. ($\tau = 0.36$, $p < 0.001$) (Figure S3). Kendall's rank correlation revealed the correlation between floral coverage and wild bee diversity was significant for the second visit ($\tau = 0.49$, $p = 0.005$) but not for the first visit ($\tau = 0.23$, $p = 0.068$) (Figure 4). The greatest per field diversity was observed during the second visit; six species were found in a field with ~ 80% floral coverage (Table S1). For the first visit, the greatest per field diversity was two species at ~ 60% floral coverage. A significant correlation was found between wild bee diversity and flowering stage when both visits were considered ($\tau = 0.23$, $p = 0.049$) (Figure S4). The results from the GAMM revealed floral coverage had the greatest predictive power for wild bee diversity ($F = 11.97$, $edf = 1.92$, $p < 0.001$) and flowering stage also had a predictive effect ($F = 5.70$, $edf = 1.75$, $p = 0.043$). Temperature and level of natural habitat did not hold predictive power for wild bee diversity.

Wild Bee Diversity vs Floral Coverage – Visit 1

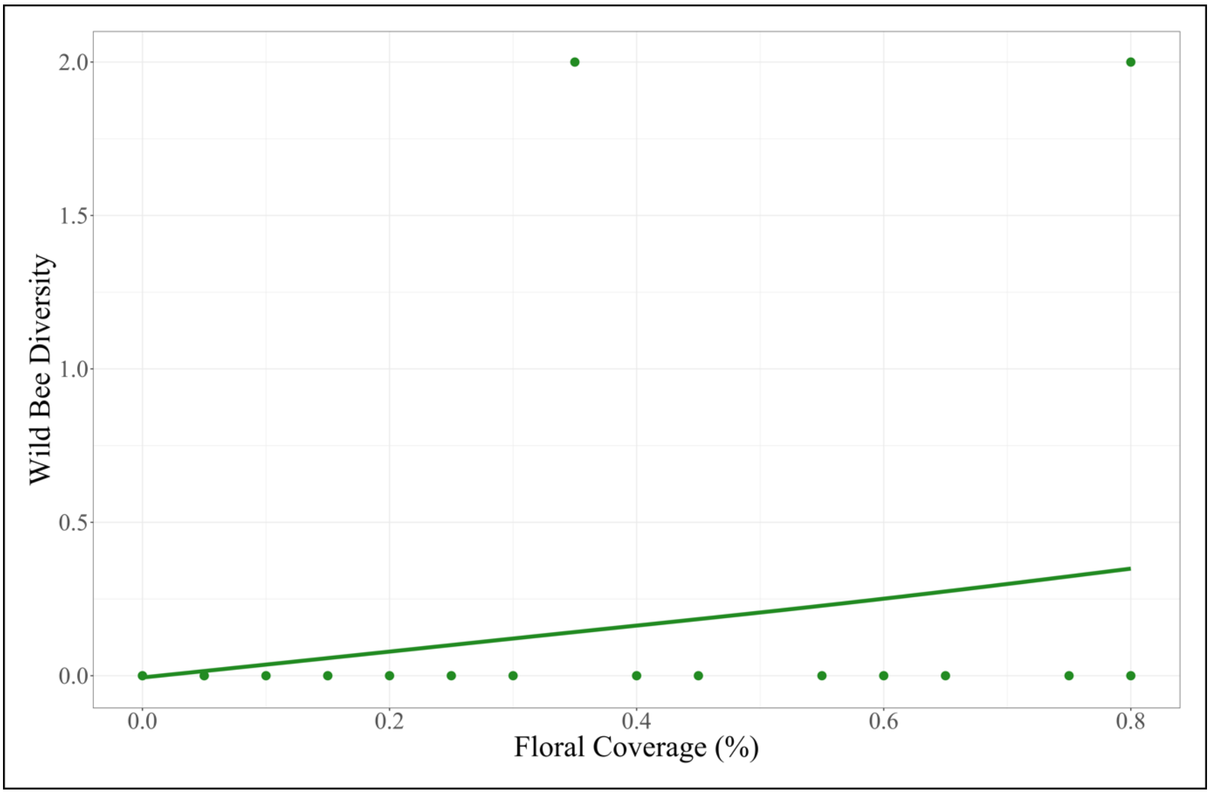


**Figure 4a**.

Wild Bee Diversity vs Floral Coverage – Visit 2

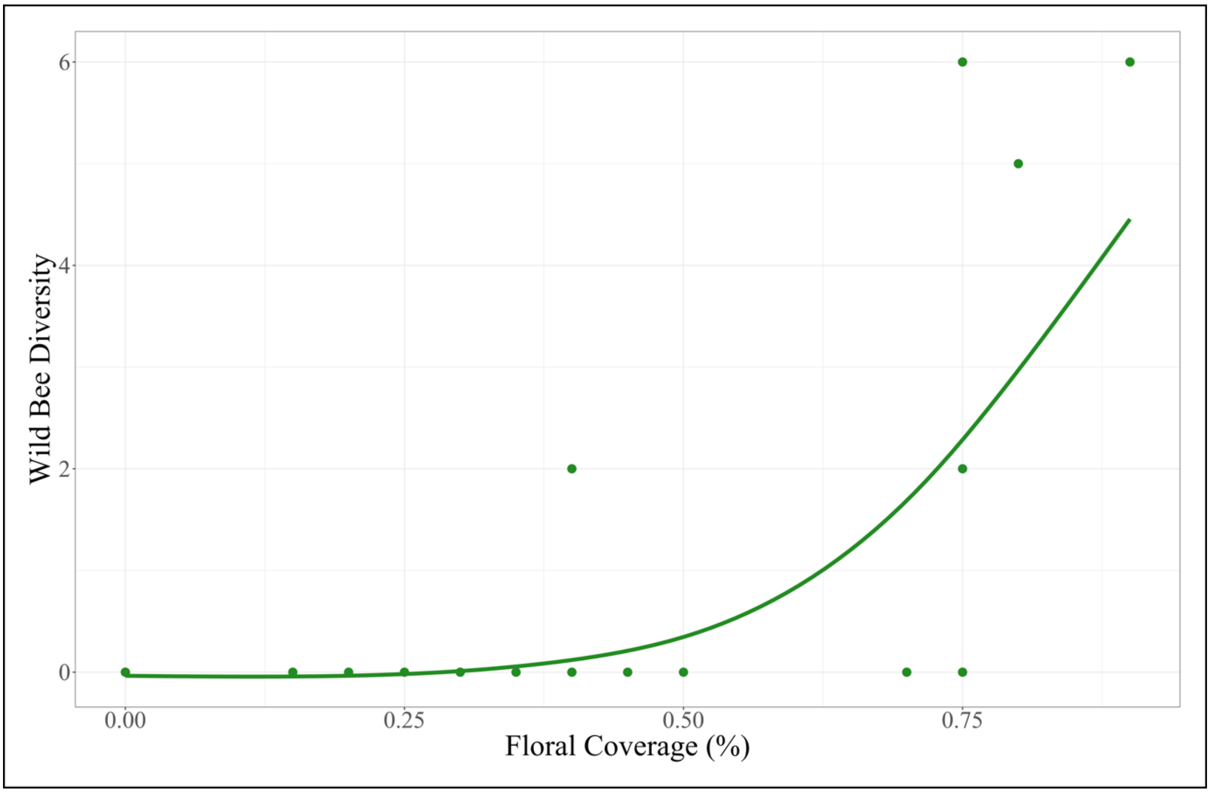


**Figure 4b.**

**Figure 4.** Relationship between floral coverage and wild bee diversity in underseeded fields. Fitted lines based on generalised additive models (GAM). a) Wild bee diversity vs % floral coverage for visit 1. b) Wild bee diversity vs % floral coverage for visit 2.

### *Honeybee Abundance*

Honeybee abundance was generally higher in fields with more floral coverage and fields in later blooming stages (Figure S5). A significant correlation was observed between honeybee abundance and floral coverage for both visits combined ($\tau = 0.64$, $p < 0.001$), and for visit 1 ($\tau = 0.63$, $p < 0.001$) and visit 2 ($\tau = 0.47$, $p = 0.002$) individually (Figure 5). The greatest abundance was recorded during the second visit; the highest per field abundance at the first visit was 25, while during the second visit the highest per field abundance was 52 (Table S1). Flowering stage was significantly related with honeybee abundance for both visits combined ($\tau = 0.49$, $p < 0.001$) (Figure 6). The outcome from the GAMM indicated coverage had the greatest predictive power for honeybee abundance ($F = 20.36$, $edf = 1$, $p < 0.001$). Flowering stage also had predictive power ($F = 18.00$, $edf = 1$, $p < 0.001$) as did temperature ($F = 7.82$, $edf = 1$, $p = 0.008$) whereas the level of natural habitat did not have predictive power for honeybee abundance ($F = 2.10$, $edf = 1$, $p = 0.154$).

Honeybee Abundance vs Floral Coverage – Visit 1

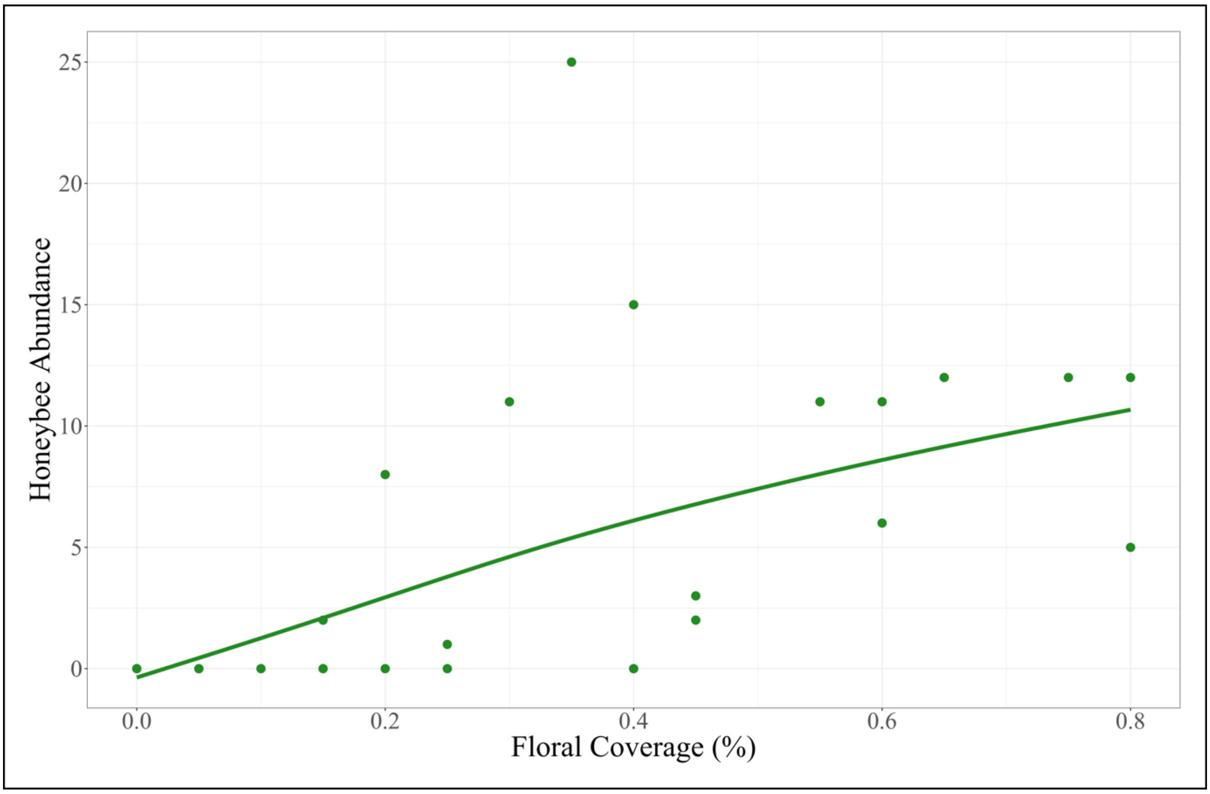


**Figure 5a.**

Honeybee Abundance vs Floral Coverage – Visit 2

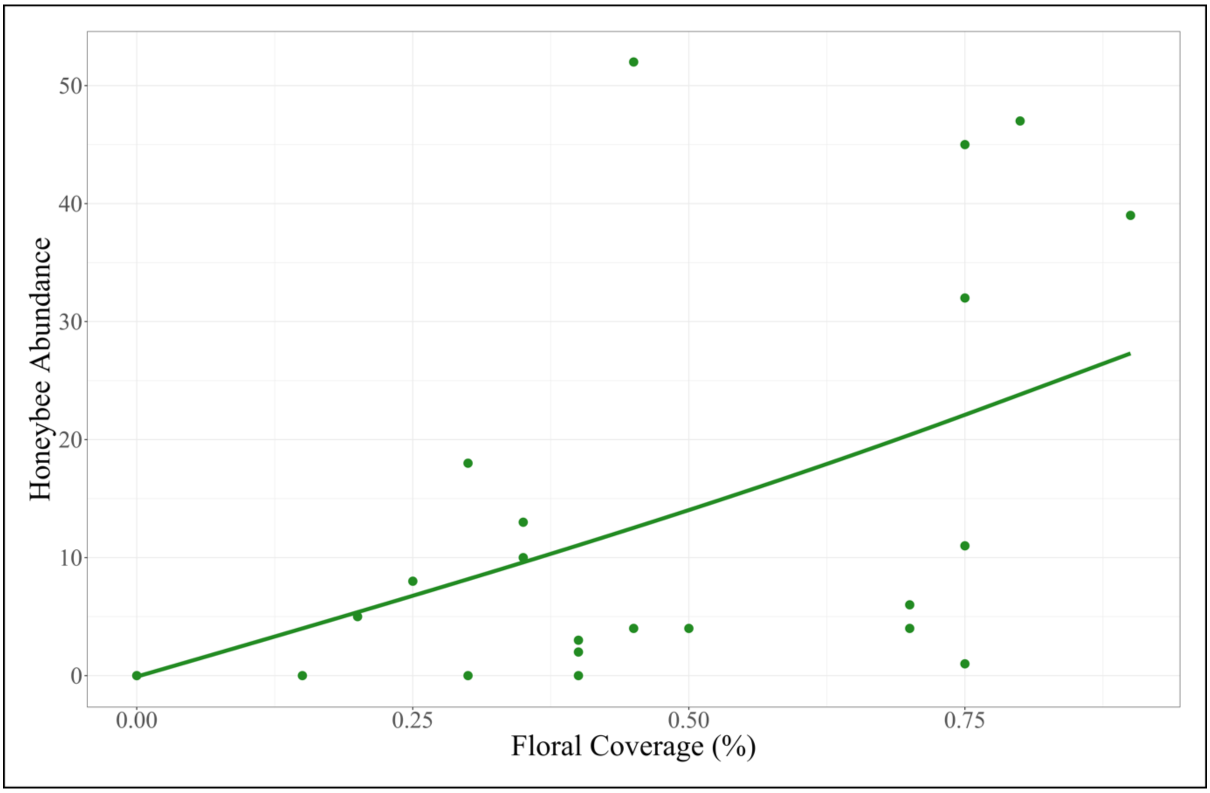


**Figure 5b.**

**Figure 5.** Abundance of honeybees in relation to the percentage of floral coverage. Fitted lines based on generalized additive models (GAM). a) Honeybee abundance vs % floral coverage for visit 1. b) Honeybee abundance vs % floral coverage for visit 2.

Honeybee Abundance vs Flowering Stage

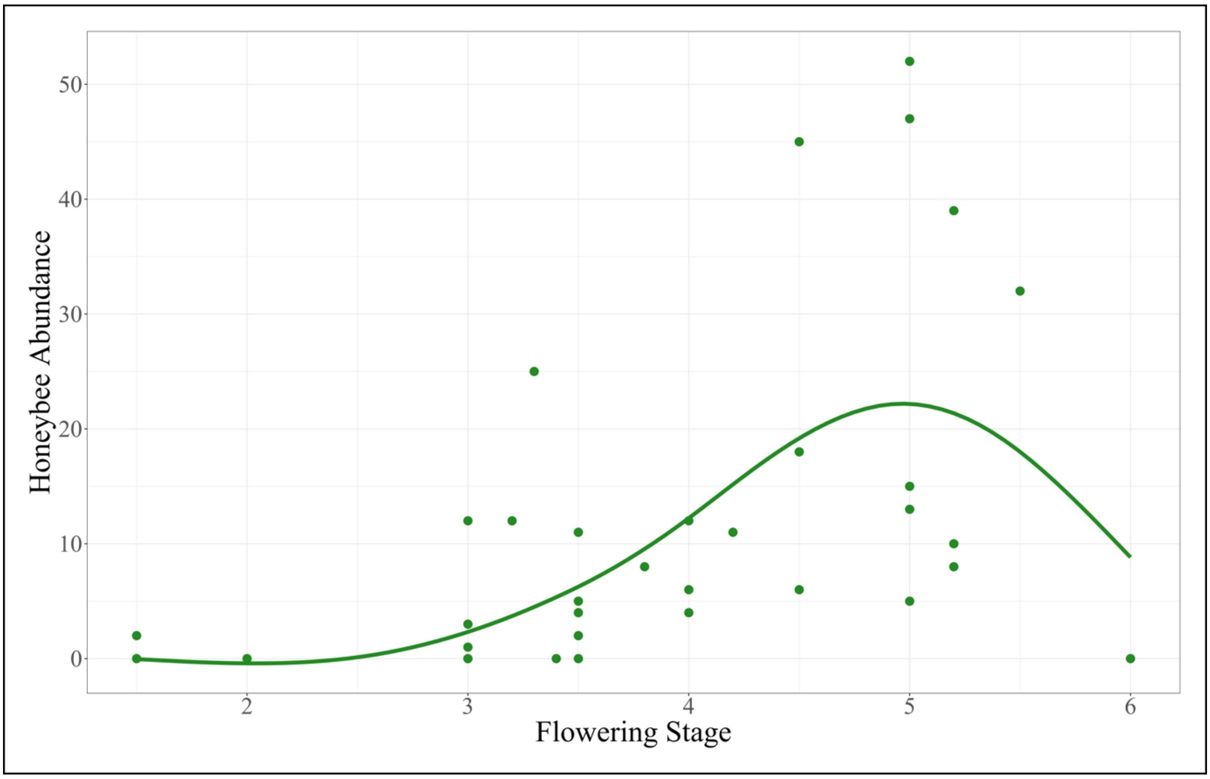


**Figure 6.** Relationship between honeybee abundance and flowering stage in underseeded fields for both visits. Fitted line based on generalized additive model (GAM).

***Wild Bees and Honeybees***

Honeybee abundance and wild bee abundance followed a similar response to changes in floral resource availability. Increased floral coverage was related with greater wild bee abundance and honeybee abundance. Kendall's rank correlation indicated a significant correlation between honeybee abundance and wild bee abundance for visit 2 ($\tau = 0.47$, $p < 0.001$) and both visits combined ($\tau = 0.44$, $p < 0.001$) (Figure 7).

Wild Bee Abundance vs Honeybee Abundance

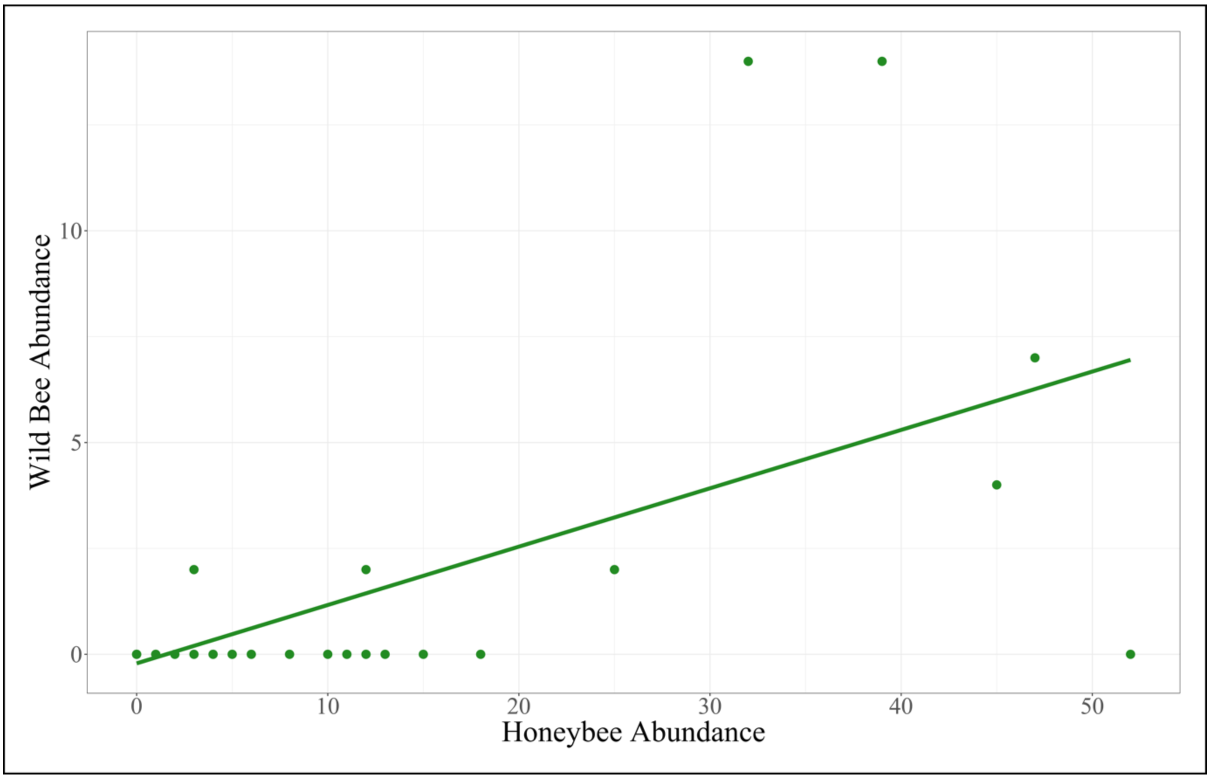


**Figure 7.** Relationship between wild bee abundance and observed honeybee abundance for both visits (linear regression model (LM)).

## Discussion

### *Overview*

In this project, we analyse how underseeded legumes in cereal fields influence managed honeybees and the wild bee community. We investigate (1) the effect of floral coverage, (2) the effect of flowering stage, and (3) the influence of the surrounding habitat. Our analysis suggests that higher floral coverage from undersowing in agricultural fields promotes the presence of a more abundant and diverse bee community, which has also been found in past research (Mallinger et al., 2019). Bumble bees were the most collected genus, likely a result of the late collection time and since clovers were the principal underseeded legume (Balfour et al., 2018; Goulson et al., 2005; Kanduth et al., 2021). Further studies are needed with precise descriptions of land use to determine what correlations exist between the surrounding habitat and the bee community. Underseeded legumes act as a floral resource for vulnerable late-flying species during a crucial time when food sources are limited (Hofmann et al., 2019; Scheper et al., 2014). Therefore, underseeding legumes in cereal crop fields may act as an important part of pollinator restoration efforts in agricultural landscapes.

***Wild Bees***

Our evidence suggests that greater underseeded floral coverage in agricultural fields provides valuable flowering resources for the bee community. In our study, wild bee abundance and diversity is greatest in fields with more floral resource availability. Therefore, successful bloom in underseeded fields was essential for the efficacy of this method (Scheper et al., 2015). Wild bees are limited by the availability of floral resources (Goulson et al., 2015; Scheper et al., 2014), particularly later in the season when flowers are in short supply (Hofmann et al., 2019). Our study demonstrates that providing additional floral resources during the summer can benefit wild bees as fields with greater coverage attracted more abundant and diverse wild bee communities. Additional flowering resources through implementation of floral strips and hedgerows have demonstrated positive effects for wild bee communities (Mandelik et al., 2012; Martins et al., 2018). It is therefore an interesting finding that underseeding in cereal fields can provide additional floral resources in areas that would typically provide no benefit to bees, while simultaneously improving soil health (Mallinger et al., 2019; Meyer, 2005; Sharma et al., 2018).

Due to an early blooming stage, the data from visit 1 revealed few sites with bees and most sites without. As a result of poor weather conditions, full bloom occurred approximately one month later than expected. Rain delayed the cereal harvest, which in turn delayed the underseeding bloom. This temporal change would have significantly influenced bee community composition plus bees are highly sensitive to changes in precipitation and temperature (Soroye et al., 2020; Tuell and Isaacs, 2010).

Thirty-eight of the forty-seven collected wild bee specimens are bumble bees, which can be attributed to their preference for *Trifolium pratense,* the late collection period and their commonness (Goulson et al., 2005; Kanduth et al., 2021; Rundlöf et al., 2014). This highlights the importance of temporal changes in wild bee community composition as underseeded legumes may only benefit certain groups at specific times. All collected individuals belonged to a total of 11 wild bee species, some of the most widespread and common species found in Switzerland (IUCN, 2014). Therefore, our findings indicate that underseeded legumes may increase populations of common bee species, but further research is needed to determine if underseeding can also support species of conservation concern.

Once flowers were in full bloom, we observed a significant increase in both wild bee abundance and diversity. A flowering stage of 5 - 5.5 (full bloom) yielded the largest wild bee communities. The timing of full bloom is therefore an important consideration for the implementation of underseeding legumes to ensure resources will be available when they are most advantageous (Cutler et al., 2015; Duchenne et al., 2020). The results from the GAMM indicate the predictive power of both floral coverage and blooming stage for wild bee abundance and diversity. This outcome is consistent with our Kendall's rank correlation results and highlights the importance of successful growth in underseeded fields for measure efficacy. Our findings support the previous work of Mallinger et al. who found that cover crops could increase bee visitation rates in Northern USA (2019). Our results demonstrate a positive correlation between underseeded floral coverage and wild bee abundance and diversity, as is consistent with our initial hypothesis, H1.

***Honeybees***

Honeybee abundance was greatest in full bloom fields with high floral coverage. The number of honeybee individuals during visit 2 was double that of visit 1, indicating the influence of increased floral coverage. All selected fields were within 2 km of a managed honeybee hive, which ensured honeybees were present in the area. Nonetheless, it is important to determine whether underseeded legumes can act as a foraging resource for honeybees. Often, honeybees lack a variety of resources later in the season which can reduce honeybee colony survival capacity (Jones et al., 2021; Requier et al., 2017).

The white clover (*Trifolium repens*) was shown to be the second most foraged plant in the UK for honeybees (Jones et al., 2021). The majority of underseeded floral mixes included *Trifolium repens* which may explain honeybee visitation rates. Honeybee abundance was greatest in fields with a blooming stage of 5 (full bloom); further studies should be done to precise the timing of full bloom post-harvest to maximize the benefits to the bee community. The outcome from the GAMM indicates the predictive power of floral coverage, blooming stage, and temperature for honeybee abundance. These results emphasize the importance of high floral coverage to ensure positive effects of underseeding. Positive effects will be greatest at full bloom, which is an important consideration for the implementation of this measure. The predictive power of temperature highlights the relevance of including climate data in analysis and the important influence of weather on bee behaviour (Soroye et al., 2020; Tuell and Isaacs, 2010). Honeybee abundance is greatest in fields with increased underseeded floral coverage, as is consistent with our initial hypothesis, H1.

***Wild Bees vs Honeybees***

A positive relationship is present between honeybee abundance and wild bee abundance. Our findings demonstrate that underseeded floral resources in cereal fields are appealing to both wild bees and honeybees. Honeybee abundance ranged from 0 to 52 individuals while wild bee abundance ranged from 0 to 14 individuals. Since all plots were located within at least one hive sector, honeybees were guaranteed to reside in the nearby area which may explain the greater abundances observed in honeybees. Previous findings regarding the complex links between honeybees and wild bees suggest different potential interactions (Garibaldi et al., 2013; Greenleaf and Kremen, 2006; Thomson, 2016). It is essential for future research to focus on the complex interactions between managed and unmanaged bees to produce the most effective conservation strategies. In regard to underseeding, both wild bees and honeybees can benefit from the additional availability of floral resources.

Our results suggest that honeybee and bumble bee visitation rates are the most influenced by legume underseeding. *Trifolium repens* is a preferred foraging resource of honeybees (Jones et al., 2021), and *Trifolium pratense* is a preferred foraging resource of bumble bees (Goulson et al., 2005; Kanduth et al., 2021). Since *Trifolium repens* and *Trifolium pratense* were the principal underseeded legumes, it is possible that the underseeded mix influenced bee community visitation (Mallinger et al., 2019). Depending on the desired outcome of underseeding, the target group or bee species must be identified and matched with the most appropriate floral mix. Native floral mixes should typically be the most appropriate for supporting native wild bee populations, however further research should be conducted across various geographical locations to establish the most effective underseeded mixes (Bendel et al., 2019).

### ***Natural Habitat***

Each field received a rank on a scale of 1 – 5 to represent the proportion of natural habitat appropriate for bee-nesting (1 = low - less than 10%, 5 = high - more than 50%). A landscape comprised of various semi-natural pastures, meadows, floral hedgerows, dry grasslands and floral strips has the capacity to support a large and diverse wild bee population (Mandelik et al., 2012; Martins et al., 2018). A highly varied landscape allows many species to take advantage of various nesting opportunities and ensures foraging resources will follow different seasonal patterns (Mandelik et al., 2012). We hypothesized that fields in areas with a higher proportion of natural habitat would have the greatest bee abundance and diversity.

The highest ranking of natural habitat in this study was a 3 and was only recorded at three different fields. Therefore, most fields were located in landscapes ranked as 1 or 2 in regard to bee-nesting appropriate natural habitat. Our analysis did not indicate any significant correlations between the proportion of natural habitat and the bee community, which is inconsistent with our initial hypothesis, H2. Future studies should consider a larger variety of landscapes to determine the impact of natural habitat on the interaction between underseeded legumes and the bee community.

***Limitations***

In scientific research, there are always limitations and shortcomings that must be addressed. For our study, farmers were required to sow legumes either in autumn with the cereal crop or in early spring after comb harrow weeding was complete. Although underseeded mixes were planted by farmers using consistent techniques, we experienced high variation in the success of floral bloom between fields. Some fields produced 90% floral coverage, whereas others produced 0% floral coverage. It is difficult to pinpoint the precise reason for these differences, as most farmers have witnessed much greater success in previous years. A possible explanation is the cold weather experienced in early summer 2021, as low temperatures can limit legume growth in temperate climates (Nösberger et al., 2019). It is also possible that differences in crop type or underseeded mix played a role in the variation of success between fields. No correlation of this possibility was observed in the data, however for future studies it would be best to further standardize the crop type and underseeded mix to minimize the influence of confounding factors. A cleanup cut was allowed during the 10 days following harvest, it is possible that in some fields this had an impact on legume growth. Future studies should investigate if a cleanup cut can influence underseeding growth.

Only fifty plots were considered in this study due primarily to time constraints. As 24 plots were considered unsuccessful, only 26 plots could be analyzed for the second visit. By increasing the sample size for future studies, the results would have more power and provide a better representation of the actual population. Our limited collection period means the cold and rainy weather influenced all of our findings. Lastly, to produce more robust and convincing results in a reproduction of this study, observations must be made across multiple localities and seasons to account for the effects of weather and climate.

Each bee collection method has its benefits and disadvantages (Prendergast et al., 2020). All specimens in our study were caught using an active search-and-net method with an aerial net of 40 cm. This collection method allows for human error as netting requires skill, observations can be missed and catch rates can vary with weather conditions (Prendergast et al., 2020). However, an active search-and-net method is affordable, very transportable, ensures specimens are in good condition and allows for catch and release, which was essential in our study as honeybees were not collected (Prendergast et al., 2020).

***Future Research***

Our evidence demonstrates that underseeding legumes may provide important bee foraging resources in agricultural landscapes. Despite this, further research on the topic is necessary to better understand the impact of underseeded legumes on pollinator abundance and diversity. Landscapes with a higher proportion of natural habitat appropriate for bee nesting should have a higher threshold for supporting larger pollinator communities (Martins et al., 2018). Landscape composition did not differ greatly between fields participating in this study; further research should be conducted throughout various landscapes to quantify the impacts of natural and semi-natural habitats.

Due to cold and rainy weather, full bloom occurred a month later than expected which would have influenced bee community composition. This study should be reproduced across multiple years to observe the difference in legume bloom during various weather conditions. Due to time and weather constraints, the sample size for our study was low. Replicating our study with an increased sample size across a larger temporal and spatial scale would provide more robust results regarding the effects of late-season floral resource availability on pollinator community composition. Future studies should consider the influence of climate, latitude, bee functional traits, surrounding landscape composition and the impact of flowering species selection. To avoid the potential influence of confounding factors, future studies should standardize the crop type, underseeded mix and option for a cleanup cut. Research which focuses on solutions for vulnerable bee populations can provide important insight into vulnerable bee community responses, essential for effective pollinator conservation.

***Conclusions***

In summary, our results indicate that underseeding legumes in cereal fields provides sufficient flowering resources to support honeybees and common wild bees. A significant correlation was observed between floral coverage and abundance for both wild bees and honeybees, demonstrating the considerable potential benefits of underseeding. With clovers as the primary cover crop, bumble bees were the most frequently collected genus as is consistent with our expectations (Goulson et al., 2005; Kanduth et al., 2021). Our findings are consistent with our initial hypothesis, H1; fields with high underseeded floral coverage had the greatest honeybee and wild bee abundance and diversity. Our second hypothesis, H2 could not be decisively tested as our sample size of natural habitat was very limited.

Floral resources are typically lacking in agricultural fields, particularly later in the season (Hofmann et al., 2019; Scheper et al., 2014). Our evidence suggests that relatively small-scale areas of clover could mitigate the loss of pollinators by providing an important late-season flowering resource. Floral mix plays an important role in the attracted bee community which is an essential consideration when implementing underseeding as a pollinator conservation measure (Goulson et al., 2005; Mallinger et al., 2019). Our findings are very relevant to pollinator conservation strategy and management. Late-flying bee species are the most vulnerable to population declines and possible extinction (Hofmann et al., 2019). Our results suggest underseeding can benefit late-flying individuals of common species; however, further research is needed to confirm whether threatened species can also benefit. Bee communities have suffered greatly in agricultural landscapes due to major changes in landscape composition and lack of resources. Underseeding legumes may be an important element for pollinator restoration in agricultural landscapes by providing floral resources for late-flying honeybees and wild bees.

**Supplementary Data**

Wild Bee Abundance vs Floral Coverage

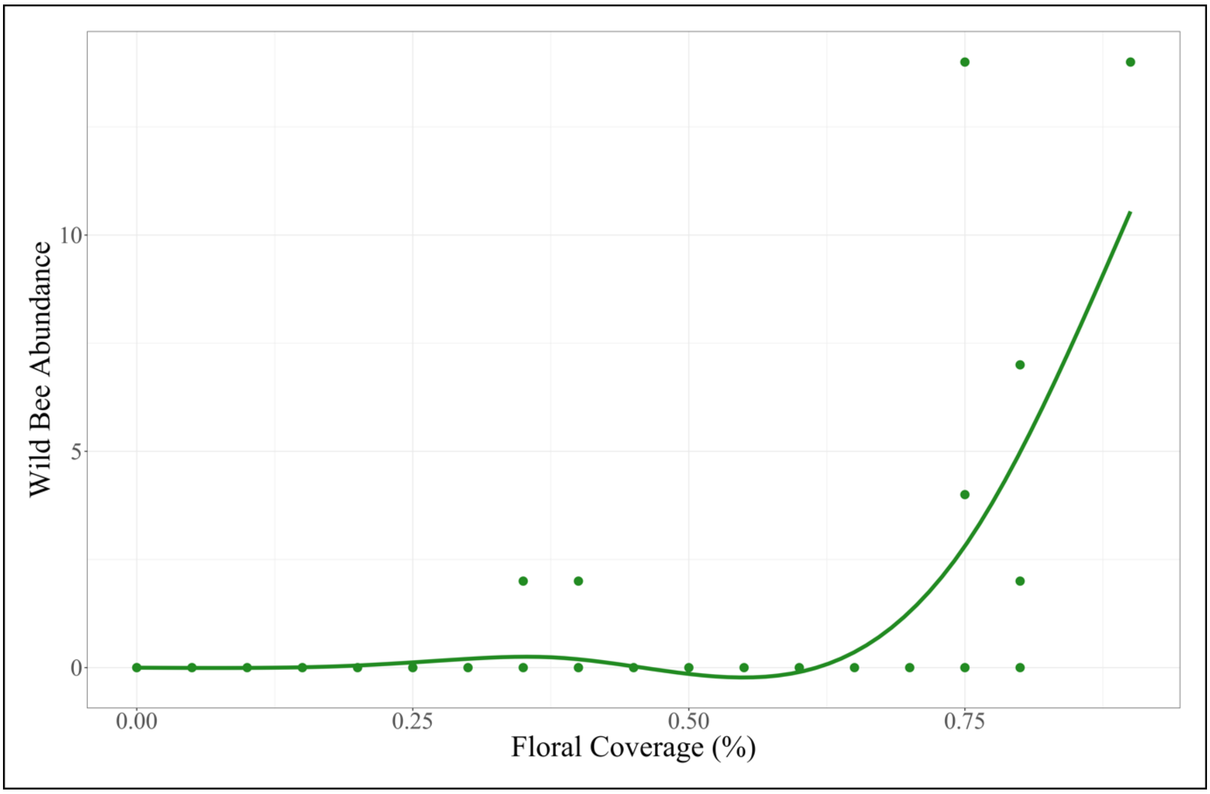


**Figure S1.** Relationship between wild bee abundance and % floral coverage. Fitted line based on generalized additive model (GAM).

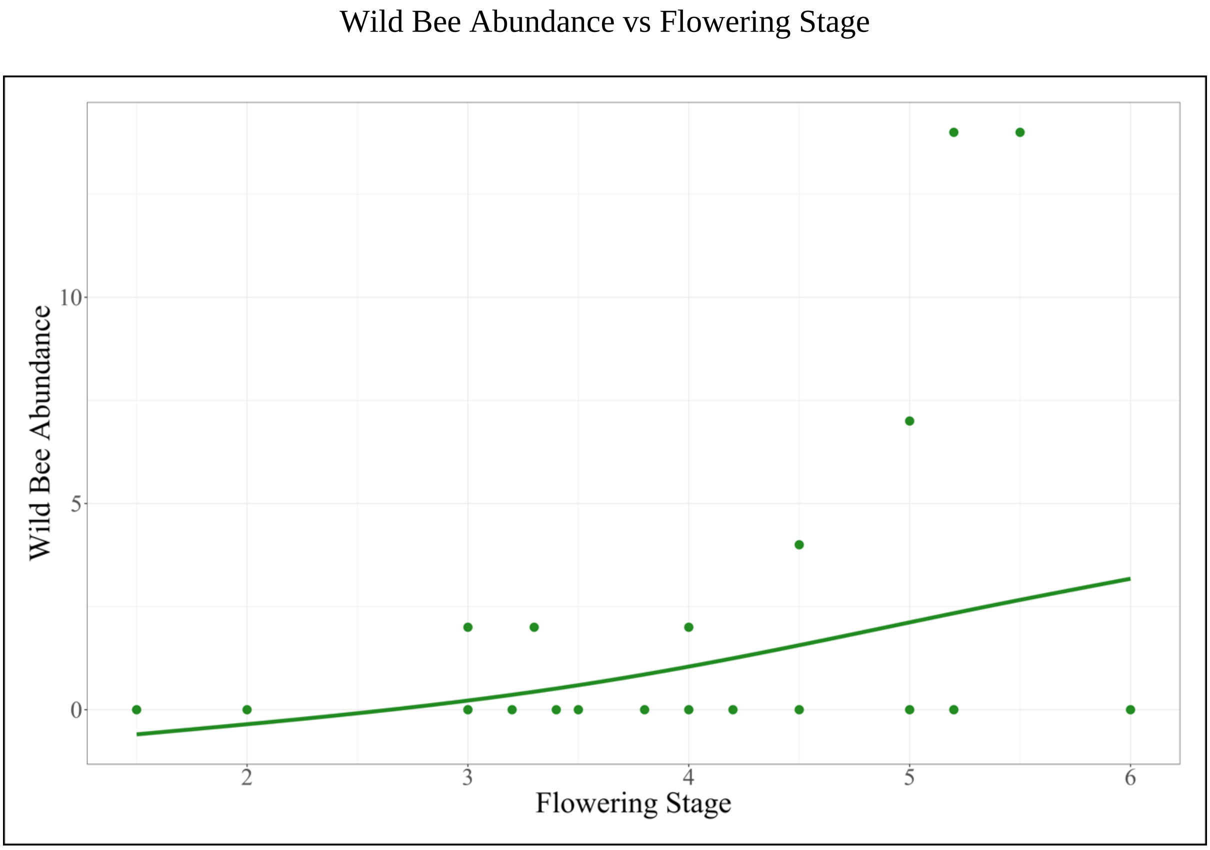


**Figure S2.** Relationship between wild bee abundance and flowering stage based on both visits combined. Fitted line based on generalized additive model (GAM).

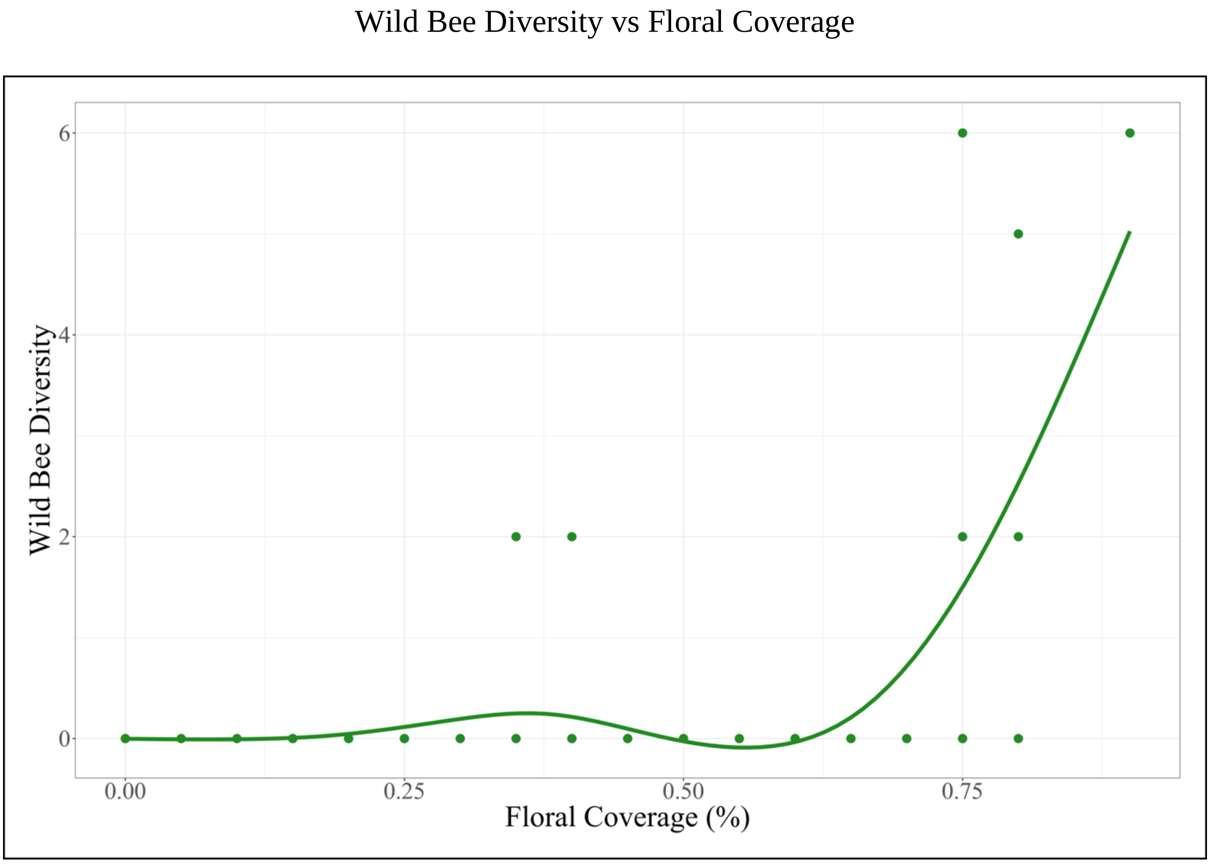


**Figure S3.** Relationship between wild bee diversity and % floral coverage for both visits combined. Fitted line based on a generalized additive model (GAM).

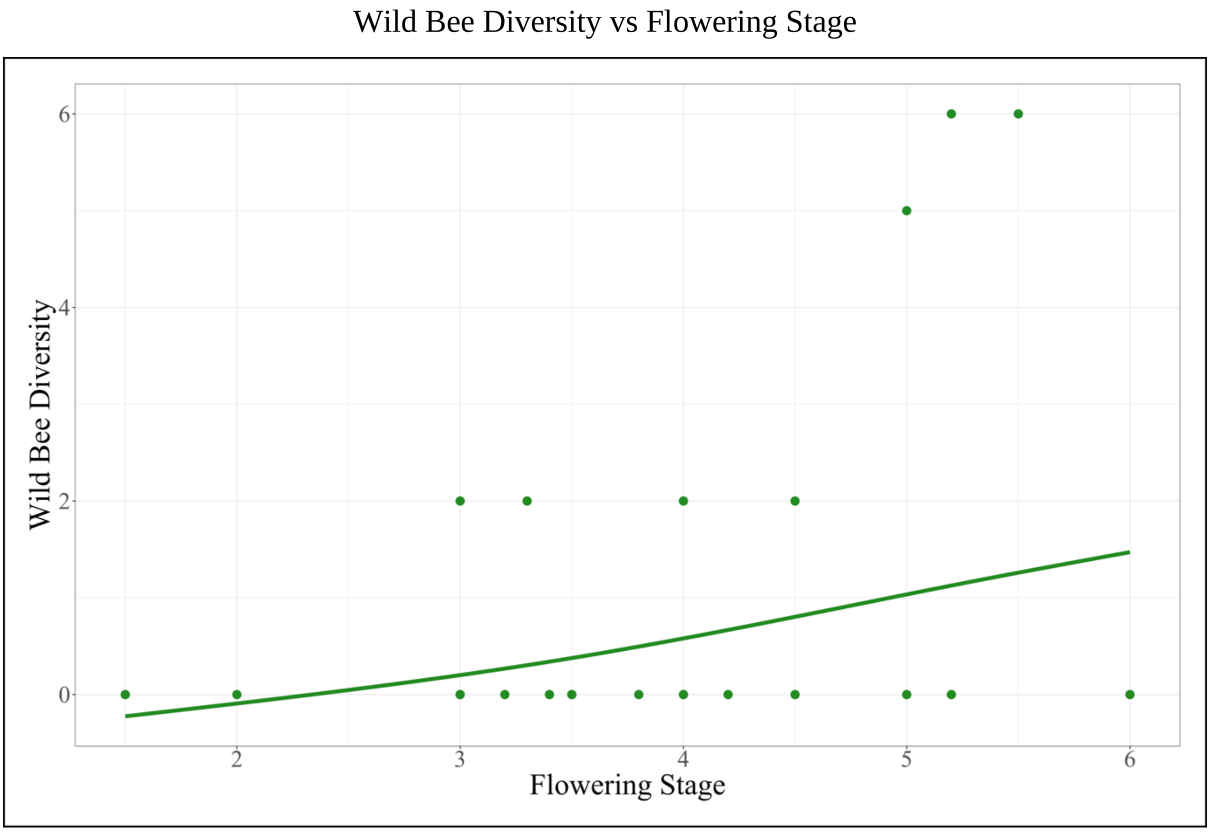


**Figure S4**. Wild bee diversity in relation to flowering stage. Both visits considered and fitted line is based on a generalized additive model (GAM).

Honeybee Abundance vs Floral Coverage

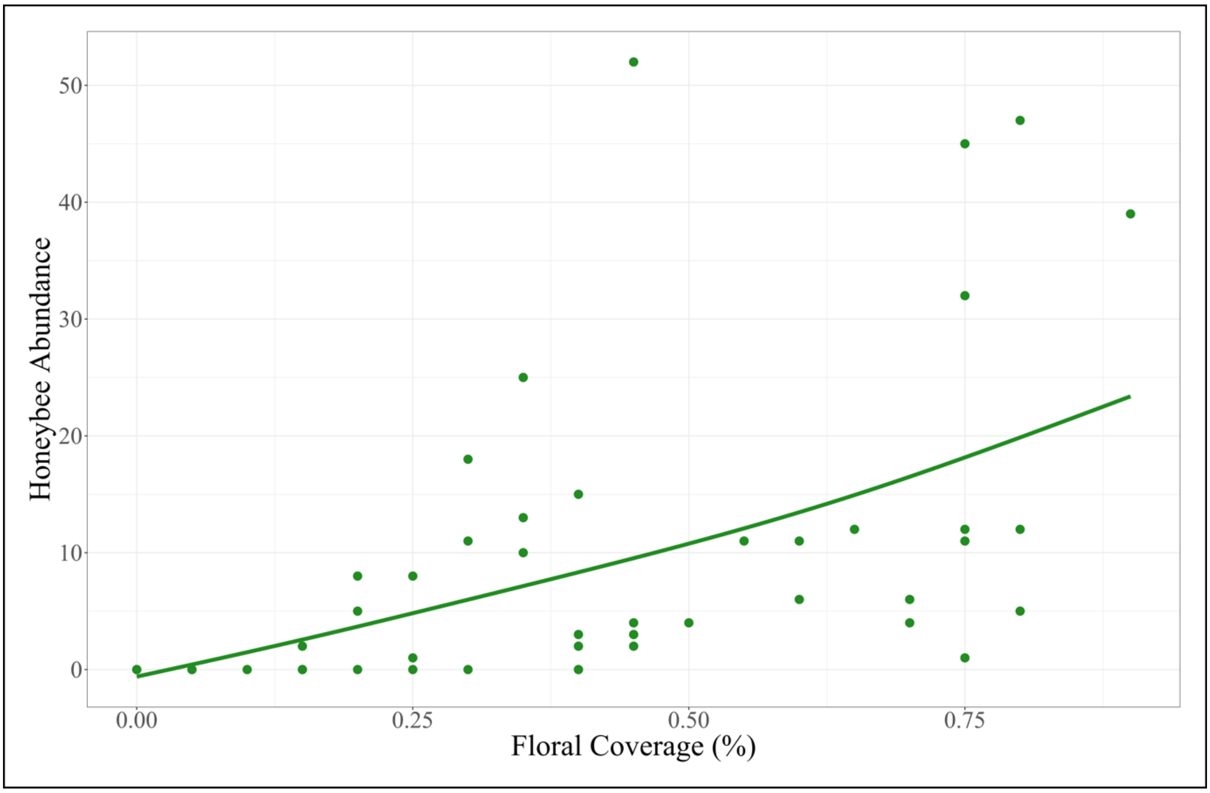


**Figure S5.** Relationship between honeybee abundance and percent of floral coverage. Data from both visits with fitted line based on generalised additive model (GAM).

**Table S1**. Field visit observations and collection data.

| Plot ID | Date | Coverage | Coverage type | Bloom | Habitat | HB | Failed? | Diversity | Abundance |
|---|---|---|---|---|---|---|---|---|---|
| **Visit 1** | | | | | | | | | |
| 144252 | 24.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 440020 | 24.08.21 | 20% | mix - red clover & crimson clover | 3 | 2 | 6 | | 0 | 0 |
| 415182 | 24.08.21 | 25% | mix - red & white clover | 3 | 1 | 1 | | 0 | 0 |
| 405702 | 24.08.21 | 15% | white clover | 3.5 | 1 | 2 | | 0 | 0 |
| 449352 | 24.08.21 | 10% | mix - red & white clover | 3.5 | 1 | 0 | X | 0 | 0 |
| 167583 | 27.08.21 | 0% | 0% clover | N/A | 2 | 0 | X | 0 | 0 |
| 439988 | 27.08.21 | 20% | mix - white clover & alfalfa | 3.8 | 2 | 8 | | 0 | 0 |
| 175260 | 27.08.21 | 0% | 0% | N/A | 1 | 0 | X | 0 | 0 |
| 454721 | 27.08.21 | 0% | 0% | N/A | 2 | 0 | X | 0 | 0 |
| 396564 | 27.08.21 | 80% | mix - red & white clover | 3.5 | 1 | 5 | | 0 | 0 |
| 412098 | 24.08.21 | 40% | mix - red & white clover | 2 | 3 | 0 | | 0 | 0 |
| 162951 | 24.08.21 | 0% | 0% - plowed | N/A | 1 | 0 | X | 0 | 0 |
| 90797 | 24.08.21 | 0% | 0% cover | N/A | 1 | 0 | X | 0 | 0 |
| 165312 | 30.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 408740 | 30.08.21 | 0% | 0% - plowed | N/A | 1 | 0 | X | 0 | 0 |
| 129758 | 30.08.21 | 60% | lotier | 4.5 | 1 | 6 | | 0 | 0 |
| 104314 | 30.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 30497 | 26.08.21 | 40% | mix - red & white clover | 1.5 | 1 | 0 | | 0 | 0 |
| 436746 | 26.08.21 | 75% | mix - red & white clover | 3 | 2 | 12 | | 0 | 0 |
| 460870 | 26.08.21 | 40% | lil white | 5 | 1 | 15 | | 0 | 0 |
| 412413 | 26.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 438064 | 26.08.21 | 0% | 0% cover | N/A | 1 | 0 | X | 0 | 0 |
| 60614 | 26.08.21 | 5% | mix - red & white clover | N/A | 1 | 0 | X | 0 | 0 |
| 113253 | 26.08.21 | 5% | mix - red & white clover | N/A | 1 | 0 | X | 0 | 0 |
| 208738 | 20.08.21 | 45% | 30% clover, 30% daisy, 20% lotier, 20% parsley | 3 | 2 | 3 | | 0 | 0 |
| 31372 | 20.08.21 | 5% | mix - red & white clover | N/A | 1 | 0 | X | 0 | 0 |
| 415330 | 20.08.21 | 10% | mix - red & white clover | 3 | 1 | 0 | X | 0 | 0 |
| 429192 | 20.08.21 | 0% | 0% clover | N/A | 2 | 0 | X | 0 | 0 |
| 82457 | 26.08.21 | 5% | 5% clover cover, plowed | N/A | 2 | 0 | X | 0 | 0 |
| 439669 | 26.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 100148 | 26.08.21 | 45% | mix - red & white clover | 1.5 | 2 | 2 | | 0 | 0 |
| 82460 | 26.08.21 | 15% | mix - red & white clover | 1.5 | 1 | 0 | | 0 | 0 |
| 111106 | 26.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 124647 | 07.09.21 | 35% | mix - red & white clover | 3.3 | 3 | 25 | | 2 | 2 |
| 392343 | 20.08.21 | 80% | mix - red & white clover | 4 | 2 | 12 | | 2 | 2 |
| 19760 | 20.08.21 | 60% | mix - red & white clover | 3.5 | 1 | 11 | | 0 | 0 |
| 71425 | 20.08.21 | 65% | 70% mixed red & white clover & 30% daisy | 3.2 | 1 | 12 | | 0 | 0 |
| 415154 | 20.08.21 | 55% | mix - red & white clover | 3.5 | 2 | 11 | | 0 | 0 |
| 141909 | 21.08.21 | 15% | mix - red & white clover (just cut) | 3 | 2 | 0 | | 0 | 0 |
| 83729 | 21.08.21 | 25% | mix - red & white clover | 3 | 1 | 0 | | 0 | 0 |
| 161932 | 21.08.21 | 20% | mix - red & white clover | 3 | 3 | 0 | | 0 | 0 |
| 140296 | 21.08.21 | 5% | mix - red & white clover | 3 | 1 | 0 | X | 0 | 0 |
| 32167 | 21.08.21 | 0% | 0% clover | N/A | 1 | 0 | X | 0 | 0 |
| 32203 | 21.08.21 | 5% | mix - red & white clover | 3 | 1 | 0 | X | 0 | 0 |
| 91042 | 21.08.21 | 15% | mix - red & white clover | 3 | 2 | 0 | | 0 | 0 |
| 431896 | 21.08.21 | 15% | mix - red & white clover | 3 | 1 | 0 | | 0 | 0 |
| 74730 | 21.08.21 | 15% | mix - red & white clover | 3 | 1 | 0 | | 0 | 0 |
| 184716 | 21.08.21 | 15% | mix - red & white clover | 3.5 | 1 | 0 | | 0 | 0 |
| 447009 | 21.08.21 | 15% | mix - red & white clover | 3 | 1 | 0 | | 0 | 0 |
| 449379 | 21.08.21 | 30% | mix - red & white clover | 3.5 | 2 | 11 | | 0 | 0 |
| 399163 | 24.08.21 | 5% | mix - red & white clover | 3 | 1 | 0 | X | 0 | 0 |
| **Visit 2** | | | | | | | | | |
| 440020B | 07.09.21 | 40% | mix - red clover & crimson clover | 5.4 | 2 | 7 | | 2 | 2 |
| 400892B | 07.09.21 | 35% | mix - 75% white, 25% red clover | 5 | 2 | 13 | | 0 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 415182B | 07.09.21 | 0% | Plowed - 0% | N/A | 1 | 0 | | 0 | 0 |
| 439988B | 09.09.21 | 25% | mix - white clover & alfalfa | 5.2 | 2 | 8 | | 0 | 0 |
| 396564B | 01.09.21 | 0% | Plowed - 0% | N/A | 1 | 0 | | 0 | 0 |
| 412098B | 07.09.21 | 50% | mix - red & white clover | 3.5 | 3 | 4 | | 0 | 0 |
| 129758B | 07.09.21 | 30% | lotier | 6 | 1 | 0 | | 0 | 0 |
| 30497B | 31.08.21 | 40% | mix - red & white clover | 3 | 1 | 3 | | 2 | 2 |
| 436746B | 31.08.21 | 75% | mix - red & white clover | 3 | 2 | 1 | | 0 | 0 |
| 460870B | 31.08.21 | 15% | plowed - 15% (mixed clover) | 6 | 1 | 0 | | 0 | 0 |
| 208738B | 31.08.21 | 70% | 20% clover, 30% daisy, 30% parsley, 20% lotier | 4 | 2 | 6 | | 0 | 0 |
| 100148B | 31.08.21 | 40% | 80% daisy, 20% clover mix | 3.5 | 2 | 2 | | 0 | 0 |
| 82460B | 31.08.21 | 0% | Plowed - 0% | N/A | 1 | 0 | | 0 | 0 |
| 124647B | 14.09.21 | 35% | mix - red & white clover | 5.2 | 3 | 10 | | 0 | 0 |
| 392343B | 31.08.21 | 90% | mix - 70% red & 30% white clover | 5.2 | 2 | 39 | | 6 | 14 |
| 19760B | 31.08.21 | 80% | mix - 60% red & 40% white clover | 5 | 1 | 47 | | 5 | 7 |
| 71425B | 06.09.21 | 70% | 70% mixed red & white clover & 30% daisy | 4 | 1 | 4 | | 0 | 0 |
| 415154B | 31.08.21 | 75% | mix - 70% red & 30% white clover | 5.5 | 2 | 32 | | 6 | 14 |
| 141909B | 08.09.21 | 45% | mix - red & white clover | 3.5 | 2 | 4 | | 0 | 0 |
| 83729B | 08.09.21 | 40% | mix - red & white clover | 3.4 | 1 | 0 | | 0 | 0 |
| 161932B | 08.09.21 | 30% | mix - red & white clover | 4.5 | 3 | 18 | | 0 | 0 |
| 91042B | 08.09.21 | 45% | white clover | 5 | 2 | 52 | | 0 | 0 |
| 431896B | 08.09.21 | 20% | mix - red & white clover | 5 | 1 | 5 | | 0 | 0 |
| 74730B | 08.09.21 | 20% | mix - red & white clover | 5.2 | 1 | 5 | | 0 | 0 |
| 449379B | 08.09.21 | 75% | mix - red & white clover | 4.5 | 2 | 45 | | 2 | 4 |
| 208738B | 06.09.21 | 75% | mixed clover & lotier | 4.2 | 2 | 11 | | 0 | 0 |

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