Supplementation of wildflowers to support biological pest control and pollination provided by insects in desert agriculture

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Background

Modern agriculture is one of the world's largest contributors to global environmental change, yet it also holds significant potential to drive global sustainability (Rockström et al., 2017). The expansion and intensification of agricultural landscapes have led to widespread habitat loss and degradation, resulting in severe declines in biodiversity (Balzan et al., 2016). This decline is primarily driven by the increased use of chemical inputs, such as fertilizers, pesticides, and herbicides, which reduce the diversity and abundance of natural enemies and pollinators (Rusch et al., 2016). Consequently, critical ecosystem services essential for agricultural production, such as pollination and biological pest control, are compromised (Mei et al., 2021).

Addressing these challenges requires the restoration of biodiversity and ecosystem services within agricultural systems, achievable through practices that enhance key ecological functions like biological pest control and pollination. In recent years, ecological intensification has emerged as a promising strategy to reduce harmful environmental impacts while maintaining agricultural productivity. This approach focuses on enhancing biodiversity and ecosystem services by minimizing reliance on external inputs, thereby increasing the sustainability of farming (Garibaldi et al., 2019).

Ecological intensification often involves increasing environmental heterogeneity within and around agricultural fields, which can support greater species richness and promote ecosystem functions such as pollination and biological pest control (Stein et al., 2014; Tscharntke et al., 2021; Balzan et al., 2016). In this research, we examine the impact of wildflower strips adjacent to date plantations on insect attraction and investigate the optimal combination of wildflower species for future studies.

Wildflower strips provide critical resources such as food, shelter, oviposition sites, and overwintering habitats, attracting a diverse array of invertebrate and vertebrate communities, including pollinators and biological pest control agents (Albrecht et al., 2020). However, they may also support pest populations (Markó et al., 2013), and in some cases, they can be more attractive to certain insects than the crops themselves (Kowalska et al., 2022). Additionally, the implementation of wildflower strips can be challenging (personal experience), and there is still limited evidence that habitat diversification effectively enhances biological control (Baggen et al., 1999; Markó et al., 2013; Sunderland & Samu, 2000). Therefore, it is crucial to evaluate the benefits of flower strips within specific agricultural systems.

While existing research on wildflower strips and the relationship between habitat heterogeneity and biodiversity has primarily focused on temperate climates, their impact on arid environments remains less well understood. In arid regions, stark differences exist between agricultural land and the surrounding natural desert environment, which are likely to influence both the abiotic and biotic components of these ecosystems (Schäckermann et al., 2022). The limited natural vegetation in arid environments, due to low rainfall, makes crops particularly vulnerable to pest outbreaks, as natural predator populations have low chances of survival (Kowalska et al., 2022).

Moreover, in these regions, the capacity of nature to recover from agricultural activities is limited. Habitat diversification in such areas may offset the ecological impact of farming by enhancing landscape biodiversity. Increased biodiversity can support natural pest control, improve crop pollination, and potentially enhance soil health (Kowalska et al., 2022).

The objective of our study is to create habitats for biodiversity within agricultural areas by establishing wildflower strips composed of naturally occurring desert plants. We aim to create win-win situations for both wildlife and farmers: providing habitats and resources for the former, while offering ecosystem services to the latter. Our research focuses on identifying the best flowering plant species to support these goals.

The following objectives guided our research:

Identify the most successful and adaptive native flower species that can thrive under agricultural conditions (e.g., fertilizers, water availability, salinity, and shading by crops).

Assess the attractiveness of wildflowers to ecosystem service providers, such as biological pest control agents (insects, birds, and bats), and pollinators.

Develop a seed mix and protocol for farmers that is easy to use and applicable across a variety of crops.

Implementation and Methods

Choosing Plants

Plant selection was based on a desert study from several years ago that monitored the development, bloom timing, and insect attractiveness of desert plants in flood channels. Observations began four weeks after flash floods and continued through the peak bloom period. Plants that exhibited desirable qualities, such as attractive and diverse flowers, were included in the initial list of potential candidates for the wildflower strip study. This list was subsequently reviewed by regional botanists to assess the suitability of each species for agricultural settings, considering factors such as irrigation practices, water quality, fertilization, and the microenvironment created by the surrounding crops.

Collection of Seeds

Once potential plant candidates were identified, seeds were collected from several sources: a) seed banks, b) fellow researchers, and c) flower patches adjacent to roads and kibbutzim. Care was taken to avoid collecting seeds from nature reserves or pristine natural habitats. However, not all desired plant species could be sourced in this manner, leading to the exclusion of some plants from the final list.

Growing Flower Strips

Trial Seeding and Monitoring of Development in Pots

In August 2022, we began growing the first batch of flowering desert plants from seeds at the Mop-Southern Arava Research Station (Figure 1), located in the Hevel Eilot Regional Council near Yotvata. This station provided a controlled environment for studying the interactions involving native desert wildflowers (figure 2). Germination rates, plant growth, and flowering were closely monitored over several months. Once plants reached peak bloom, the pots were moved outdoors and arranged in a strip next to date trees (Figure 3).

Upon placement in the field, we conducted visual observations to monitor insect activity and used a Vortis suction sampler to collect natural enemies of pests, helping us assess the effectiveness of the flower strips in attracting beneficial insects.

Figure 1: Mop-Southern Arava Research station, purple locations indicate flower strips, yellow the big flowering field and green the net house.

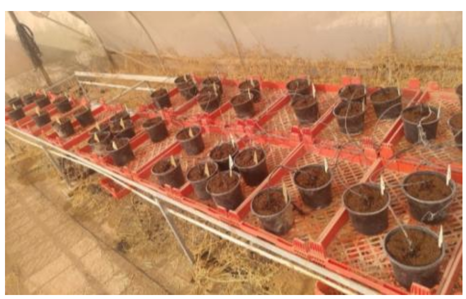

Figure 2: Desert wildflower seeds growing inside potted soil in the net house

Figure 3: Different desert flower varieties blooming outside after transplanting them from the net house.

Seeding and Development Directly in the Soil Next to Date Plantations

From 2023 to April 2024, the second phase of the research was initiated, which involved planting wildflower strips directly into the soil adjacent to date trees at the Mop-Southern Arava Research Station. The seed mixes used in this phase consisted of flowering species that had been identified as successful based on the results from the first stage of the project. These species were selected for their favorable seed germination rates, growth patterns, flowering success, and insect attractiveness. All three flower strips received the same seed variety, but not all plants developed equally in all strips (Figure 4, 5, 6)

a). Strip 1 (Figure 4): contained *Echium judaeum, Centaurea crocodylium L., Silene vulgaris, Hyoscyamus desertorum, Baileya multiradiata*, and *Lotus lanuginosus* flowers. Weekly observations and suction sampling were conducted.

Figure 4: Flower strip 1

b) Strip 2 (Figure 5): This strip featured a similar mix of species with the addition of *Aaronsohnia factorovsky*. Weekly observations and suction sampling were conducted at three different times. Both above mentioned flower strips were established in January 2023.

Figure 5: Flower strip 2

The third flower strip was discontinued after a while because reeds took over. The flower strip was in total shade for most of the day.

Instead of strip 3 the flower field was used for data collection (Figure 6) which was already present prior to the start of this research, having been established by senior researchers.

We utilized this existing flower field for monitoring insect abundance.

c) flower field: (8x11 m) provided a more extensive habitat under intense sunlight, in contrast to the smaller micro-strips (0.6x0.8 m).

Figure 6: Motis Flower strip/Flower field

All strips were irrigated daily, though minimally, and maintenance included weeding and pruning every three weeks to preserve the structure and prevent overgrowth.

Insect data collection

1. **Suction Sampling**

The Vortis suction sampler (Figure 7) was used to capture small insects and life stages from the smaller strips (1 and 2). These samples were then identified in the laboratory using a microscope (Figure 8a). The collected insects were examined under an electron microscope for detailed morphological analysis. Insects were classified into orders using dichotomous keys and expert consultations. Non-insect arthropods were documented separately. We examined tiny insects and their developmental stages, including eggs, larvae, and pupae. Their basic morphology such as mouthparts, wing shape, wing number, body segmentation, eye structure, and antennae length, was utilized to categorize them into distinct orders.

Figure 7: Collection of tiny insects and unseen developmental stages of insects

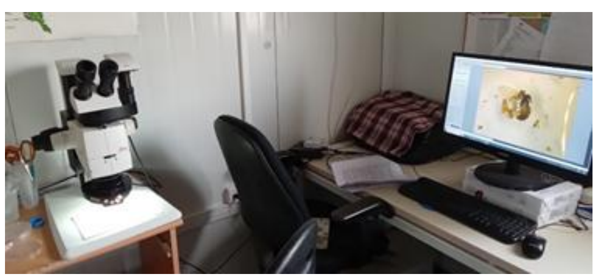

Figure 8a: Microscope analysis of suction samples

Insect suction samples were taken from the flower strips and preserved in ethanol before being kept cool in the refrigerator.

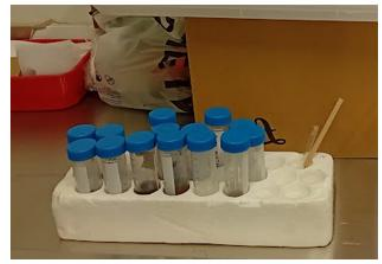

Figure 8b: Suction Samples preserved in ethanol stored under cold conditions

2. Observational Monitoring

Insect activity in flower strips and field was monitored directly to minimize disturbances to the habitat (Figure 9). Environmental factors such as temperature and wind were recorded to assess their influence on insect activity. Throughout the experimental phase, several parameters were investigated, and all data were summarized in an Excel spreadsheet (Table 1). This spreadsheet was structured in a specific format that has been consistently used by multiple researchers across all phases of data collection, from December 2022 to the present.

Figure 9: Monitoring of different insects that visit the flower strips.

Table 1: Data collection sheet structure

Date	**Time**	**Temperature in degrees °C**	**Wind speed (low, medium, high)**	**Family of insect**	**Size of insect**	**Flower that insect was seen on**	**Comments**

Data Analysis

The collected data were analyzed in Excel using descriptive statistics, including pivot tables, charts, and graphs, to identify patterns and relationships among various variables. This analysis focused on examining the growth processes of the flowers, determining which insects were attracted to specific flower species, and understanding the influence of environmental factors, such as wind and temperature, on these interactions.

Results

Flower growth

Of the fifteen species tested, thirteen successfully germinated, but only eight progressed to flowering in the pots in the net house (Figure 10).

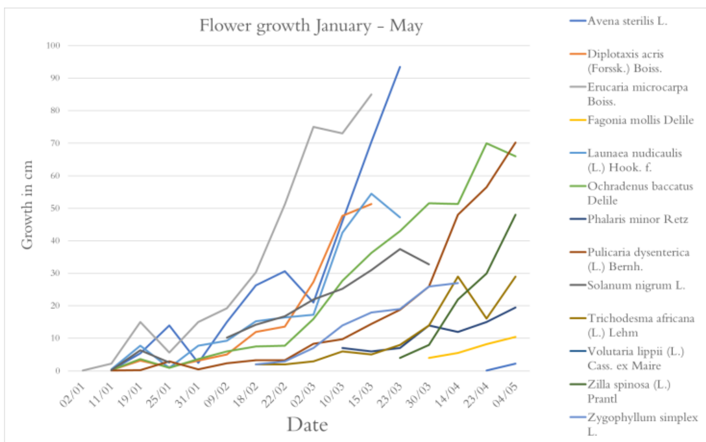

Figure 10: Flower growth rates between January and May

Insect activity

Two key observations are guiding the results: yellow and white flowers, particularly *Erucaria microcarpa Boiss.* and *Aaronsohnia factorovskyi*, appear to be the most attractive to insects (Figure 11). Second, hoverflies were the most dominant insect group observed, followed by wasps, bees, and flies. Additionally, a parasitoid wasp was occasionally observed on *Erucaria microcarpa Boiss.* and *Zygophyllum simplex L.*, among other plants (Figure 12).

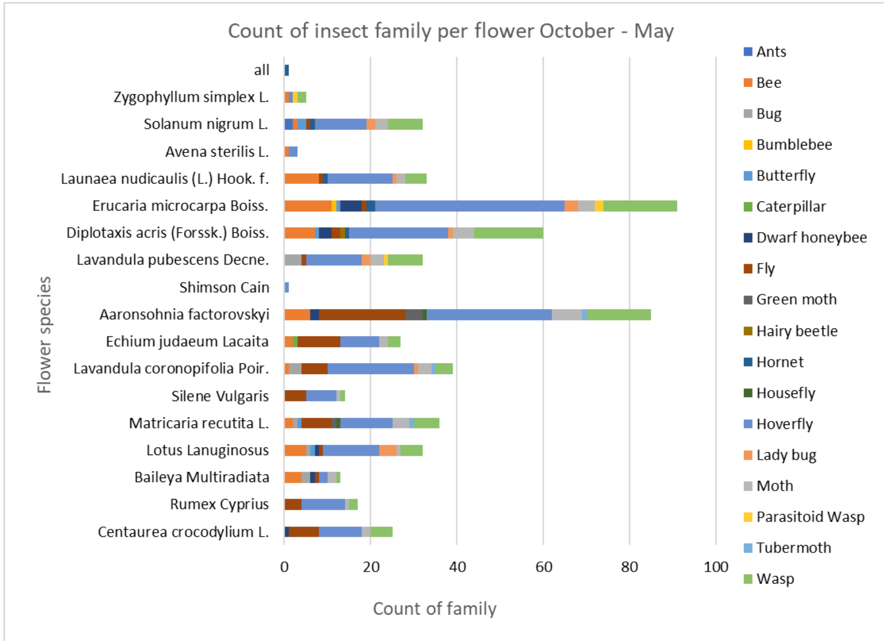

Figure 11. Different insects on different flower varieties.

Figure 12. The parasitoid wasp that was commonly observed: **A digger wasp (*Ammophila Sabulosa*)**

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Distribution of Species Counts Across Different Wind Conditions

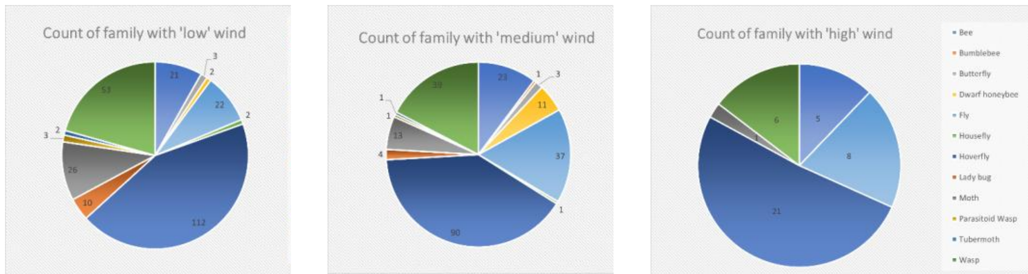

Figure 13: Impact of Wind Levels on Insect Abundance and Diversity in Flowering Strips

The total number of insects was significantly higher during periods of low wind compared to high wind conditions (Figure 13). Furthermore, insect diversity peaked during low and medium wind levels.

Insect behavior and distribution

…30 insect samples that were collected using the Vortis suction sampler were systematically organized in Excel sheets, which facilitated the analysis of insect behavior like the buzz pollination, pollinator mimicry, and feeding on the floral tissues, the various insect orders present in the flower strips (figure 14).
The analysis of small insects under the microscope revealed nine insect orders, including Hemiptera, Thysanoptera, Diptera, Lepidoptera, Hymenoptera, Odonata, and Orthoptera, along with other arthropods, found within the flower strips.

								INSECT ORDERS							
			Hemiptera	Hemiptera	Hemiptera	Thysanoptera: Thrips	Neuroptera: Lacewings, Dobsonflies, Antlions, others	Coleoptera: Beetles	Diptera: Flies, Gnats, Midges, Mosquitoes	Lepidoptera: Moths, Butterflies, and Skippers	Hymenoptera: Wasps, Bees, Ants, Sawflies, Horntails	Odonata: Dragonflies, damselflies	Orthoptera: Grasshoppers, crickets, katydids	Other Arthropods Caterpillars piders,mite
Date of sample collection	Time of sample collection	Flower strip	Heteroptera: True Bugs	Auchenorrhyncha: cicadas, leafhoppers	Sternorrhyncha :aphids, scales, whiteflies									
9.01.24	Afternoon	Junk yard	23	8	4	11	2	1	25	2	6	2	3	2
9.01.24	Afternoon	Back strip	57	14	8	27	7	2	44	13	24	1	5	2
16.01.24	Afternoon	Junk yard	18	6	6	5	4	2	22	5	9	1	2	1
16.01.24	Afternoon	Back strip	46	16	13	13	11	6	37	7	31	3	1	3
23.01.24	Midmorning	Junk yard	12	11	8	10	9	5	47	9	27	2	4	4
23.01.24	Midmorning	Back strip	37	23	15	30	13	9	58	12	42	1	2	5
1.02.24	Afternoon	Junk yard	11	5	7	13	2	1	11	1	9	5	2	3
1.02.24	Afternoon	Back strip	43	18	11	24	7	3	45	4	28	2	3	4
13.02.24	Midmorning	Junk yard	16	9	7	12	5	2	34	8	12	1	1	1
13.02.24	Midmorning	Back strip	34	14	18	16	11	7	49	11	22	2	1	2

Figure 14. Insect Collection, Identification, and Behavioral Analysis in Flower Strips

Attractiveness of flowers to insects in flower strips seeded permanently into the ground in 3 locations

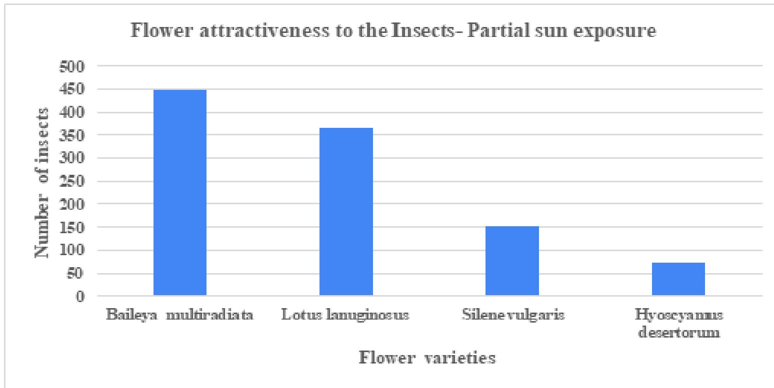

Figure 15. **Flower strip 1 - Situated under partial sunlight exposure *Insect Attraction to Different Flower Varieties***

In contrast to the other four flower varieties, *Baileya multiradiata* was observed to attract more insects to Flower Strip 1 (Figure 15). Butterflies, such as the Desert and Pima Orange Tips, also found the nectar-rich blossoms especially enticing.

Lotus lanuginosus, which featured prominently in both flower strips, attracted numerous insects.

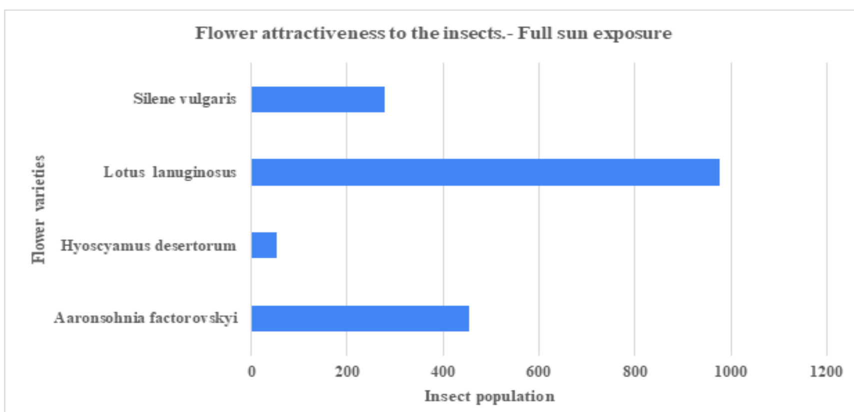

Figure 16. **Flower strip 2- Situated under full sun exposure. *Insect Attraction to Different Flower Varieties***

The bright color and abundant nectar of the *Aaronsohnia factorovsky* bloom drew a variety of insects, like pollinators such as bees, butterflies, and beetles (figure 16).

In contrast, fewer insects were drawn to the flowers of *Silene vulgaris* and *Hyoscyamus desertorum*. In contrast to species with more vibrant colors and richer nectar, *Hyoscyamus desertorum* had toxic alkaloids and attracted fewer visitors.

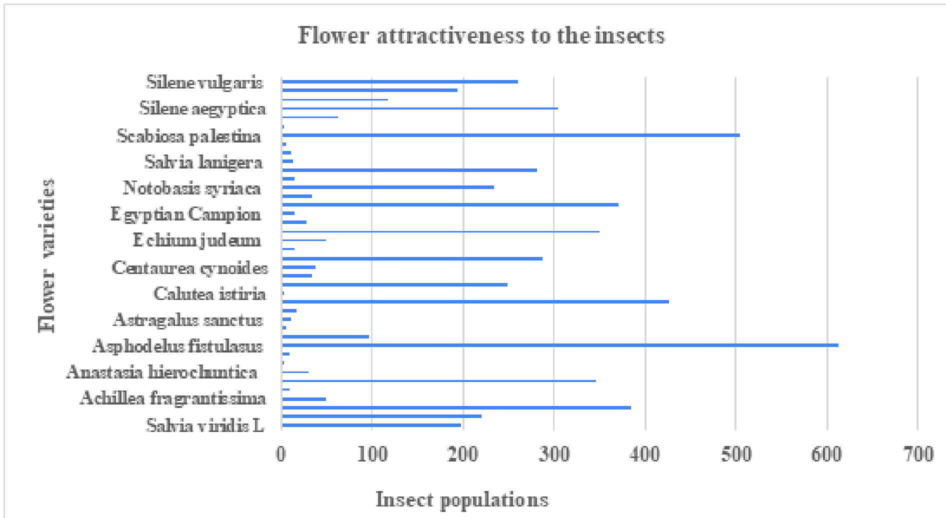

Figure 17. Flower field- Situated under full sun exposure. Insect Attraction to Different Flower Varieties

In flower field (figure 17) *Scabiosa palestina, Asphodelus fistulosus, Calutea istiria, Egyptian campion,* and *Salvia lanigera* flowers drew a lot of insects. Scabiosa *palestina* stood out for its vivid hue, copious amounts of nectar, and easily accessible pollen.

Effects of temperature on different insect sizes

Small, medium, and tiny insects thrived in higher temperatures in both full sun exposure (Figure 19) and partial sun exposure (Figure 18) flower strips, compared to larger insect species that were not observed in such high numbers under the same conditions

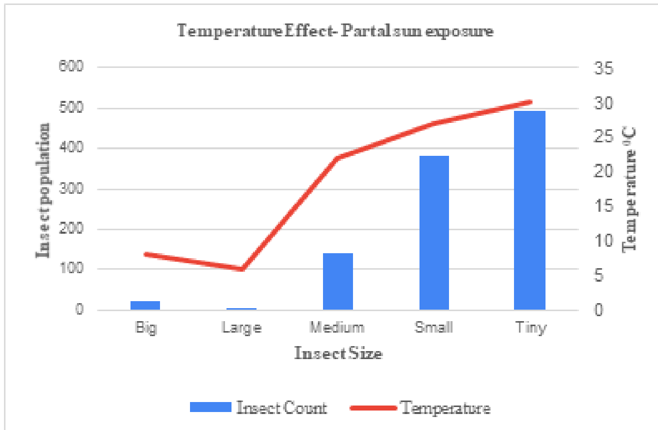

Figure 18. Insect Population and Temperature vs. Insect Size in flower strip 1 - partial sun exposure

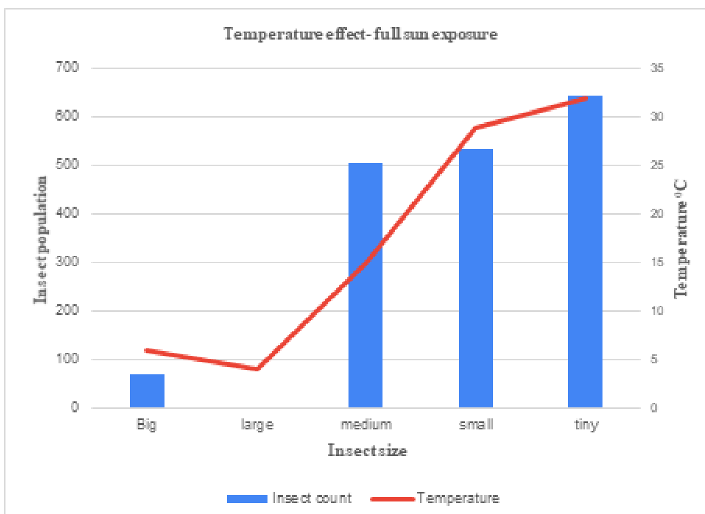

Figure 19. Insect Population and Temperature vs. Insect Size in Flower strip 2 - under full sun exposure

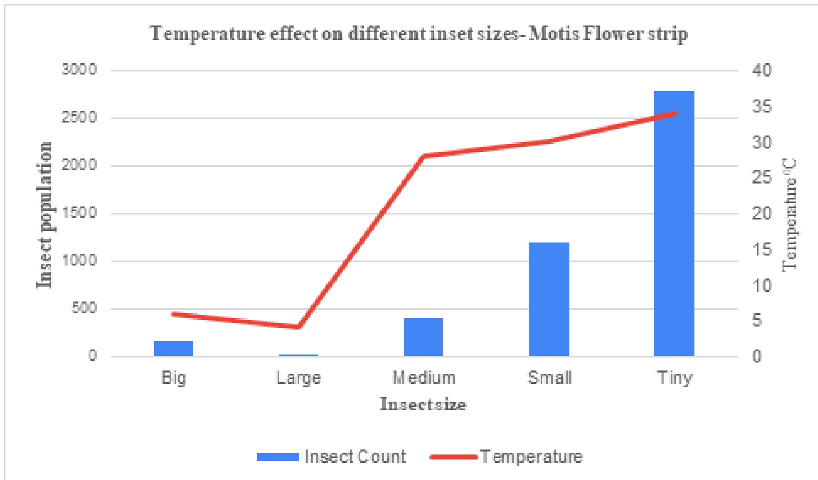

Figure 20. Insect Population and Temperature vs. Insect Size in flower field - full sun exposure

Population of different sizes of insects in the flower strips

Compared to Flower Strip 1, Flower Strip 2 and flower field exhibited a significantly higher abundance of small insects (Figure 22).

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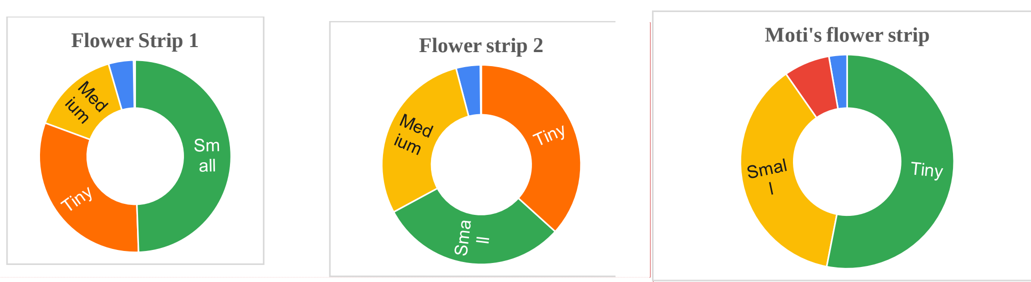

Figure 22. Insect Size Distribution Across the three flower strips

Specific insects present in the flower strips

Flower strip 1

Asphodelus fistulosus distinguished itself among the 18 flower species under observation by attracting a wide variety of insects in significant quantities, as illustrated in the graph (Figure 23). Also, *Aaronsohnia factorovsky* and *Baileya multiradiata*, were very attractive for insects.

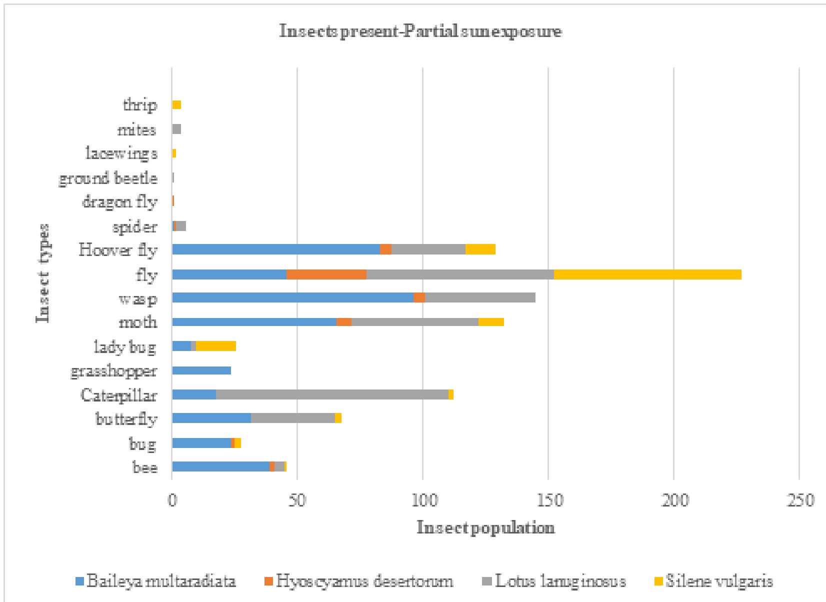

Figure 23: Insect Population Distribution Across four main flower varieties at the partially shaded flower strip 1.

Flower strip 2

In this flower strip (Figure 24), insects such as grasshoppers, wasps, and flies exhibited higher abundances. Specific flowers, including *Silene vulgaris*, *Aaronsohnia factorovsky*, and *Lotus lanuginosus*, attracted these insects.

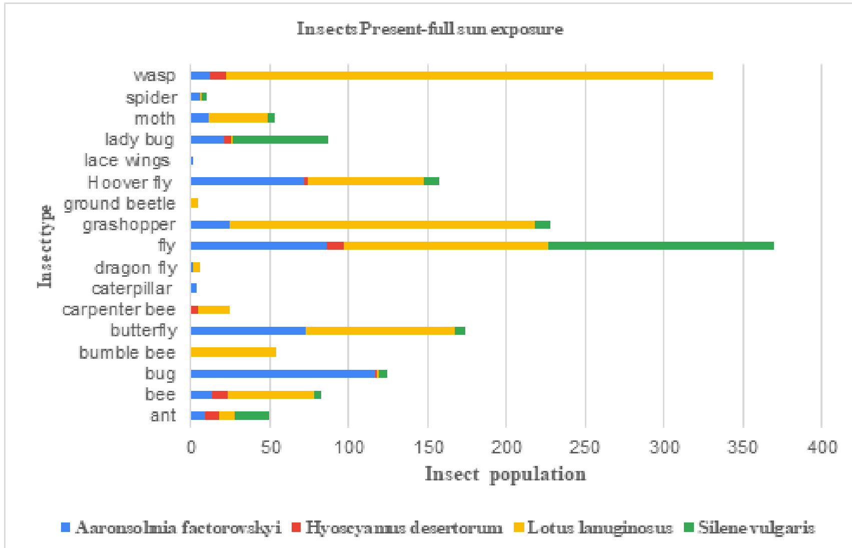

Figure 24: Insect Population Distribution Across four main flower varieties in flower strip 2

Flower field

This flower field consisted of a high variety of flowers that were planted in clustered flower patches. These flowers attracted a variety of insect pollinators, including hoverflies, butterflies, moths, and wasps (Figure 25).

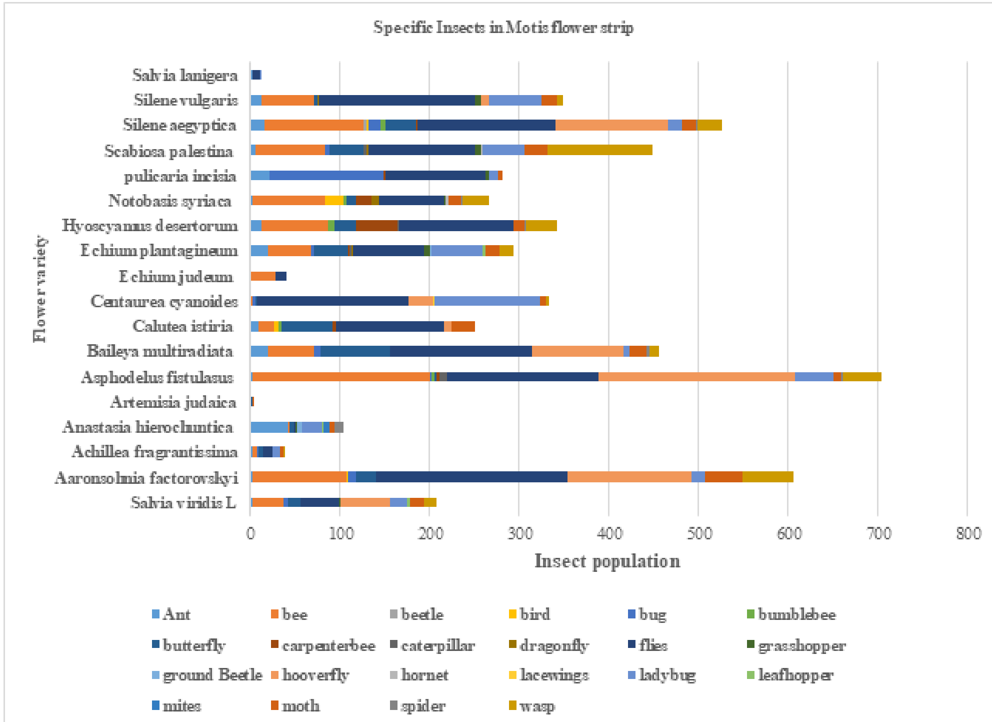

Figure 25: Insect Population Distribution Across four main flower varieties at flower field

The impact of time of day on insect abundance

Insect abundance increased in the morning hours with higher temperatures. As temperatures increased throughout the day, the afternoons had the highest insect abundance. Insect activity declined in the evening as the temperature dropped and the amount of daylight began to fade (Figure 26).

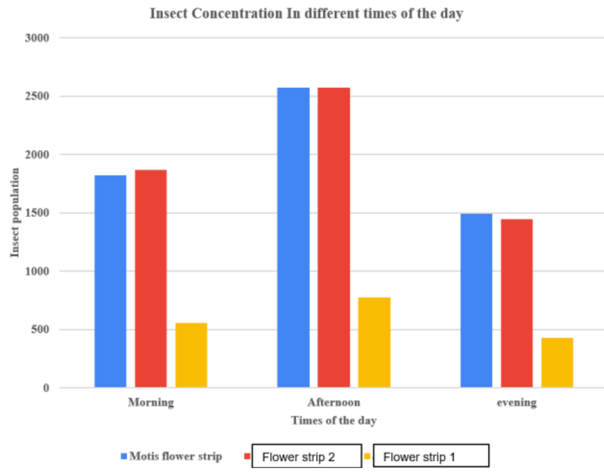

Figure 26. Insect population at different times of the day in the three flower strips

Microscopic examination of suction samples collected at different times of the day

Compared to other insect orders, Diptera were dominant throughout the entire experimental season in both flower strips 1 and 2, as observed in the microscope analysis (Figure 28). Additionally, Hymenoptera and the Heteropteran suborder of Hemiptera were also found in significant quantities. Several ecological and environmental factors were identified as contributing to the dominance of Diptera, particularly larvae and pupae, in the morning samples from both the junkyard and back flower strips.

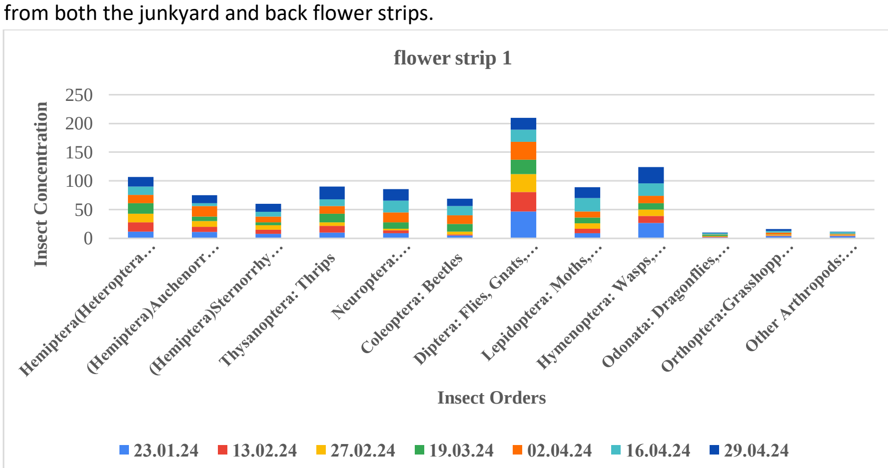

Figure 27. Insect Orders in flower strip 1

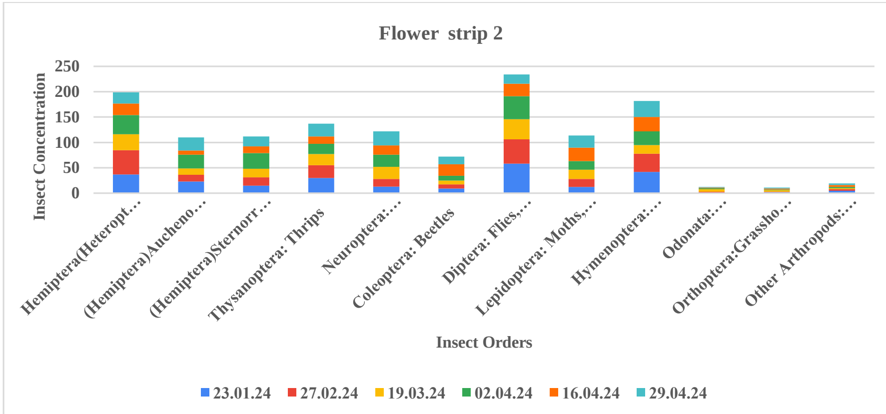

Figure 28: Insect Orders in flower strip 2

Diptera, Hemiptera and Hymenoptera were the most prominent flower strips in the afternoon hours (Figures 29 and 30).

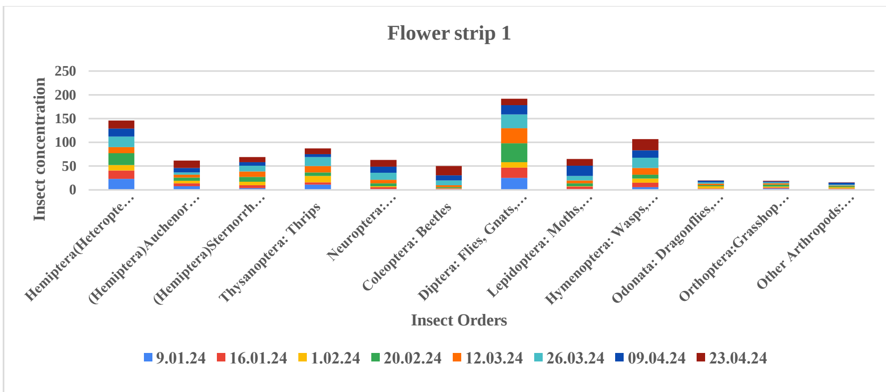

Figure 29. Insect Order Concentration in flower strip 1

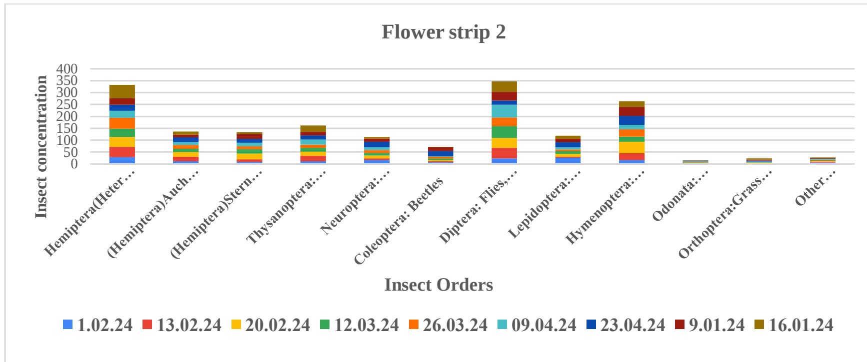

Figure 30. Insect Order Concentration in flower strip 2

General insect orders in the experimental area

The general results of the microscope study of these samples showed that the most prevalent insect order in the experimental site was Diptera. In total we found 12 orders to be commonly present in the flower strips (figure 31). We also identified significant populations of Heteroptera (true bugs) and Hymenoptera (bees, wasps, and ants).

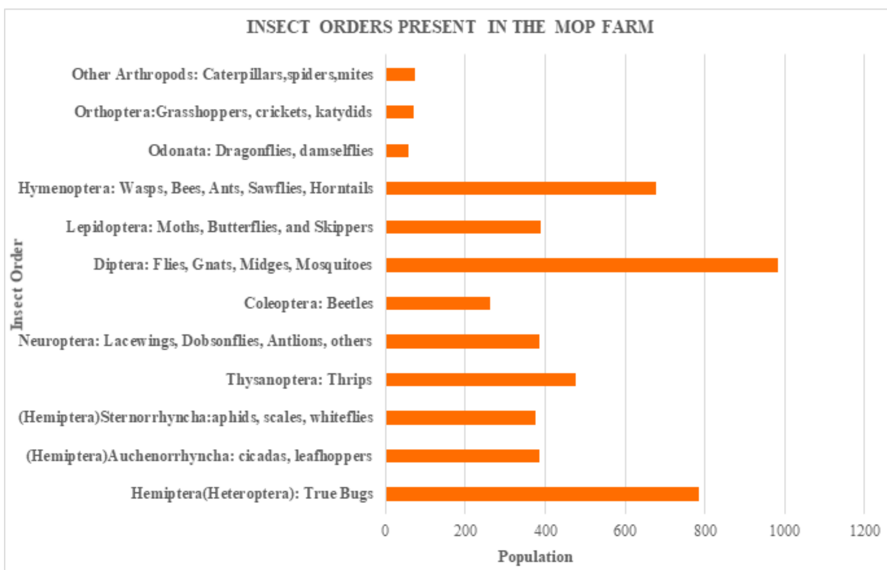

Figure 31 Common insect orders that were identified across the three flower strips in the experimental area.

Preparation of flower strips in Samar date plantations

The organic date plantation of Kibbutz Samar was chosen to test 10 flowers trips starting in fall 2024. After meetings with the farmer, suitable locations were chosen in cooperation with the irrigation expert of the plantation. Subsequently, on October 27th and 28th 2024 ten flower strips of 12 m2 were established in and around the date plantation of Samar (figure 32)

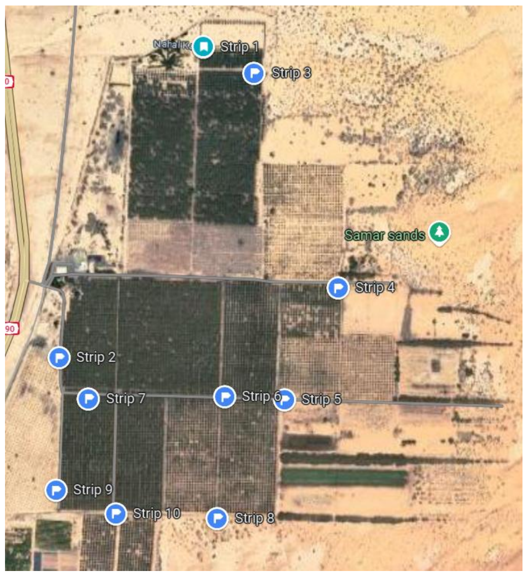

Figure 32. Flower strip's locations at different parts of Samar Dates plantation

Each plot is comprised of 19 flower species which include the following:

1 Aaronsohnia factorovsky Warb. & Eig

2 Pulicaria crispa; Pulicaria undulata

3 Trichodesma africana

4 Ochradenus baccatus

5 Zygophyllaceae simplex

6 Rumex Cyprius Murb; Rumex roseus L.

7 Launaea nudicaulis

8 volutaria lippii

9 Haplophyllum tuberculatum

10 *Fagonia mollis Delile*

11 *Diplotaxis acris*

12 *Matricaria Recutita L.*

13 *Lavandula pubescens Decne*

14 *Lavandula coronopifolia Poir.*

15 *Centaurea pallescens Delile*

16 *Erucaria microcarpa*

17 *Echium judeaum*

18 *Lotus lanuginosus*

To monitor the performance of these flower strips, vegetation coverage is assessed monthly using a drone with a camera (figure 33). The collected images are analyzed through the ImageJ software to quantify flower coverage.

Figure 33 aerial views of two among the 10 flower strips that were captured using the drone.

Additional measurements, including plant height and flower counts for each species, are being recorded. This data collection is to continue in 2025 until the end of May.

Future plans

Blooming patterns will be tracked bi-weekly to record which species are flowering in each plot. Insect collection will be done using a Vortis insect suction sampler, with each sampling session lasting approximately 10 seconds. Both the flower strips, and the date trees will be sampled for insects. The collected insects will be preserved in ethanol-filled viles labeled with the date, time, flower strip number, and the collector's name. These viles will be refrigerated to maintain sample integrity.

Further analysis will involve examining the samples under an electron microscope to classify insects into taxonomic orders and differentiate pests from beneficial species. The data collected on vegetation coverage, plant height, flower counts, blooming patterns, and insect diversity will be analyzed to evaluate the efficacy of the flower strips in attracting beneficial insects, particularly parasitoids. This analysis will also identify the most effective flower species for future implementation. Statistical methods will be employed to detect significant patterns and refine strategies for flower strip deployment. The timeline for this phase includes seed collection from March to April 2024, plot establishment in October 2024, and ongoing monitoring, sampling, and analysis starting mid-December 2024 and continuing throughout 2025.

Discussion

Native wildflower strips in arid agroecosystems offer significant potential to enhance plant and insect biodiversity while aiding pollination and natural pest control. Specific wildflower species suited for these strips can be used in tailored seed mixes, with varied flowering times providing year-round resources for insects. However, long-term research is needed to explore their full ecological benefits, including pollination and biological pest control ecosystem services.

The results of this study highlight the importance of environmental conditions, flower morphology, and insect behavior in shaping the dynamics of insect populations in desert agroecosystems. Despite some challenges with seed germination and blooming in the first experiment, the findings offer valuable insights into the factors that influence insect attraction and plant-pollinator interactions in wildflower strips.

Not all seeds developed and not all plants bloomed, suggesting that potted soil and high levels of irrigation may not have been ideal for certain desert species. These species might require specific treatments, such as scarification or stratification, to promote germination and flowering. Further research is needed to understand these limitations better and optimize growth conditions for desert plants in agroecosystems.

Flower morphology plays a crucial role in attracting pollinators. Yellow and white flowers appeared to be the most attractive to insects in the flower strips, consistent with previous studies suggesting that these colors are often preferred by a wide variety of pollinators (Brenner, 2005). Among the flower species examined, *Baileya multiradiata* in Flower Strip 1 stood out for attracting more insects compared to other varieties. This species has a historical reputation for its horticultural value in California, and its ecological significance extends to desert ecosystems (Kearney & Peebles, 1942). The flower's erect position and sweet aroma, coupled with the windy spring conditions, made it particularly attractive to native bees (Hodoba, 1995). Similarly, *Lotus lanuginosus* attracted numerous insects due to its complex structure and distinctive fragrance, supporting efficient pollination through frequent insect visits. Likewise, *Aaronsohnia factorovsky* drew a wide range of insect pollinators with its vibrant color and nectar-rich flowers, which served as both visual and olfactory cues. In contrast, less vibrant species such as *Silene vulgaris* and *Hyoscyamus desertorum* attracted fewer pollinators, with the latter's toxic alkaloids further deterring insect visitation.

Flower strips which contained species such as *Scabiosa palestina* and *Asphodelus fistulosus*, also attracted substantial insect populations. The combination of vivid floral color, abundant nectar, and accessible structures in these plants provided ideal conditions for pollinators, including bees, butterflies, and hoverflies. These findings are in line with the idea that floral traits like color, aroma, and structural accessibility are critical factors in determining insect attraction and pollinator efficiency (Brenner, 2005).

Environmental factors, particularly temperature and wind conditions, significantly influenced insect activity and population dynamics. Small and medium-sized insects, such as flies and bees, were more abundant in both full and partial sun-exposed flower strips, probably because they are more efficient at heat dissipation and have faster metabolic responses to environmental changes. Conversely, larger insects, with slower metabolic rates, showed lower abundance in sun-exposed habitats. Wind also played a crucial role in insect abundance, with calm conditions facilitating easier flight, more effective foraging, and better communication among insects. In contrast, higher winds resulted in a decrease in insect populations, as foraging became more challenging.

The study also revealed that smaller insects thrived in denser flower environments, where they could more effectively exploit microenvironments within flower structures. These microhabitats, combined with shorter life cycles and higher reproductive rates, may allow small insects to establish and maintain larger populations within the flower strips.

Specific flower species also contributed to the success of various insect orders. *Asphodelus fistulosus* was particularly effective in attracting a broad range of insect pollinators, including hoverflies, butterflies, moths, and wasps, likely due to its vibrant color and high nectar content. *Aaronsohnia factorovsky* and *Baileya multiradiata* also attracted substantial numbers of insects, indicating their high ecological value for pollinator communities. These findings suggest that floral traits, such as color, nectar availability, and floral morphology, play a critical role in shaping the composition and abundance of insect populations within flower strips.

In terms of temporal patterns, insect activity varied throughout the day, reflecting both environmental conditions and insect behavioral cycles. Insects were most active in the morning, emerging from nocturnal shelters to forage for food and mates. As the day progressed and temperatures rose, insect activity increased, reaching its peak in the afternoon when conditions were optimal for feeding and reproduction. In the evening, as temperatures dropped and light diminished, insect activity declined, with many insects returning to shelter or ceasing activity altogether. These patterns reflect the natural daily rhythms of insect behavior, driven by environmental cues such as temperature and light availability.

The dominance of Diptera, particularly in the morning, was evident across the flower strips. This can be attributed to several factors, including the presence of organic debris, such as decaying plant material and standing water from irrigation, which provided ideal conditions for Dipteran larvae and pupae. These insects thrive in damp, nutrient-rich environments, which were abundant in the flower strips. The availability of food sources, such as nectar, honeydew, and prey insects, likely contributed to the high abundance of other insect orders, including Hymenoptera and Hemiptera, within the same habitats. The structural complexity of the flower strips provided additional niches for these insects to reproduce and shelter, fostering a well-established trophic interaction and resource partitioning among insect orders in this ecosystem.

The afternoon hours also saw a rise in Diptera populations, as the warmer temperatures promoted increased activity and emergence. Similarly, the presence of Hymenoptera, Hemiptera (suborder Heteroptera), and Thysanoptera increased in the afternoon, likely due to the favorable environmental conditions that promoted their activity and visibility. This further supports the idea that temperature, light, and humidity fluctuations play significant roles in driving insect behavior and distribution patterns within the flower strips.

Over the course of the experimental season, nine insect orders were regularly observed in the flower strips, suggesting a stable and diverse insect community. This is indicative of a robust ecological system that supports pollination and other essential ecosystem functions. The potential for even greater insect biodiversity over time, as plant species bloom and seasonal fluctuations affect insect populations, presents an opportunity for further investigation in future experimental phases.

The integration of native wildflower strips into arid agroecosystems offers considerable potential for enhancing plant and insect biodiversity, improving pollination services, and promoting natural pest control. Flower strips can be designed using tailored seed mixes to provide year-round resources for pollinators. However, challenges remain, including the high costs and labor involved in establishment and maintenance, knowledge gaps regarding seed mixes and management practices, and potential ecological risks, such as the support of pests or invasive species. Addressing these challenges requires further research, stakeholder engagement, and adaptive management strategies to maximize the benefits of wildflower strips while minimizing risks.

In conclusion, this study underscores the importance of flower morphology, environmental conditions, and insect behavior in shaping the dynamics of pollinator populations in desert agroecosystems. Future research should continue to explore the ecological benefits of wildflower strips, including their potential for enhancing biodiversity and ecosystem services, and address the challenges associated with their implementation and management.

Meanwhile, implementing wildflower strips comes with challenges:

- **Cost and Labor**: Establishment and maintenance can be costly and time-consuming. Specifically, seed collecting is time consuming and complex, next to the necessary common tasks such as weeding the flower strips in the establishment phases.
- **Knowledge Gaps**: Farmers often lack information on seed mixes and management practices.
- **Balancing Goals**: Conservation efforts may conflict with agricultural productivity.
- **Ecological Risks**: wildflower strips might support pests, outcompete crops for insects, include invasive species, or cause issues like root disease due to irrigation excesses.

Overcoming these challenges requires further research with stakeholder engagement, education, and adaptive management to maximize the benefits of wildflower strips while minimizing risks.

Outreach

Key Meetings Following the Successful Completion of the Initial Research Stages

This long-term project has witnessed numerous substantial and regular meetings involving many stakeholders. In the starting phases, the meetings were primarily between Jessica Schäckermann, Laura Brohm (intern 1), and fellow (senior) researchers such as Moti Harari, and Oren Hoffman. Following the first year of Laura's internship, after observing the potential of flowering strips adjacent to desert agriculture, meetings with potential farmers were set up to discuss the implementation of larger flowering strips for her PhD studies. Simultaneously, two other interns at the Arava Institute for Environmental Studies, Josh Epstein and Ebby Soita performed more experiments and research on suitable flowering species, the design of the strips, and insect attractiveness.
Potential farmers that were met with were Neot Smadar date plantation and Samar date plantation. The meetings were attended by Intern Ebby Soita, PhD candidate Laura Brohm, Dr. Jessica Schäckermann, Prof. Michal Segoli, Prof. Carmi Korine and Noam Weiss from the bird sanctuary in Eilat, next to the farmers and irrigation specialists.

Additionally, there were numerous meetings with Oren Hoffman to discuss the selection of flower species, seed collection and seed germination, and flower strip design. The collection of desert wildflower seeds was conducted between late March 2024 and mid-April 2024. This effort resulted in the acquisition of seeds from 36 distinct wildflower species.

Conferences

The project included participation in multiple conferences over the years. Here is a list of all the conferences where poster presentations were given by one of the researchers involved in the project:

1. **Poster presentation by Laura Brohm**

The Israeli Society of Plant Sciences Conference, February 6th 2023. The David Lopatie Conference Centre, Weizmann Institute of Science, Israel.

2. **Poster presentation by Laura Brohm**

The Multidisciplinary Student Conference on Sustainability and Environmental Innovation, July 9th 2024. Marcus Family Campus in Be'er Sheva, Israel.

3. **Poster presentation by Jessica Schäckermann**

Landscape 2024, 16-17 September. Berlin, Germany.

4. **Poster presentation by Laura Brohm**

The 52nd Annual Conference on Science and the Environment, 25-26 September 2024. Ben-Gurion University of the Negev in Be’er Sheva, Israel.

5. **Poster presentation by Jessica Schäckermann**

4th Israeli Conference for Conservation Science. 27th of October 2024, Jerusalem.

The poster on the following page was presented at several recent conferences, while earlier conferences featured different posters showcasing the data available at the time.

The poster highlight that the project has provided valuable insights, particularly in seed germination and flower growth. Desert flowering plants typically begin flowering two months after germination and thrive in sunny or partially shaded areas, while fully shaded spots tend to attract invasive species. Certain species, like *Erucaria microcarpa Boiss.*, *Aaronsohnia factorovskyi*, and *Diplotaxis acris (Forssk.) Boiss.*, attract both pollinators (bees, butterflies) and natural enemies (ladybugs, wasps). Additionally, analysis of 31 insect samples revealed 476 wasp samples, many of which could serve as pest control agents. Despite harsh conditions in the southern Arava Valley, native wildflowers can thrive and provide crucial ecosystem services, supporting pollinators and pest control. The study emphasizes the value of plant diversity in agriculture, where carefully chosen species with different growth rates and flowering times ensure continuous food and shelter for beneficial insects.

Wildflower strips in desert agriculture, to support biological pest control and pollination

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Background


Picture 1, (Mathias Tschumi, 2018)

The start of the agricultural intensification in the Southern part of Israel has negatively altered the local environment. An increase in the use of chemical inputs has simplified the agricultural system, and resulted in a reduction in the diversity and abundance of natural enemies and pollinators in the agroecosystem, **impeding the provision of ecosystem services.** To enhance and recover biodiversity, a known strategy (picture 1) is sowing wildflower strips adjacent to the farmland. However, this is a new concept to arid environments.

Project goal

Reintroduce native desert plants to agricultural areas as flowering strips, to enhance biodiversity and support ecosystem services.

Research objectives

1. Understanding the impact of wildflowers on ecosystem service providers: such as pest natural enemies and pollinators.
2. Providing tools to design the ideal wildflower strip.

Methods

The experiment consisted of producing flower strips near crop fields by sowing two mixes of native flower seeds in pots in a nethouse, and one in the soil, in October and January.
We studied:

- Availability of seeds.
- Germination success, and growth rates of different plant species (figure 1 & 2).
- Attractiveness of flowering plants to pollinators and parasitoids, by monitoring the abundance and richness of ecosystem service providers (figure 2).


Picture 2

The Arava valley

The southern Arava valley, is a hyper-arid desert area, with mean annual temperature of 25.4°C (January: 15.8°C - July: 33.8°C) and 27.6 mm of yearly rain on average, with no precipitation during June-August.
Several settlements (Kibbutzim) are located along the valley and grow date plantations and field crops such as potatoes, onion, melons and pumpkin.

Results


Erucaria microcarpa Boiss.

- 24 out of 29 species germinated (*figures 1 & 2*).
- 17 species flowered, averagely two months after germination (*figures 1 & 2*).
- Yellow and white flowers (*Erucaria microcarpa Boiss. & Aaronsohnia factorovskyi, graph 3*) seem the most attractive for insects.
- The Hoverflies are the most abundant insect group (*figure 3*).
- Data on insects < 1mm, likely including species of parasitoid wasps, is yet to be analyzed.


Aaronsohnia factorovskyi

Figure 1

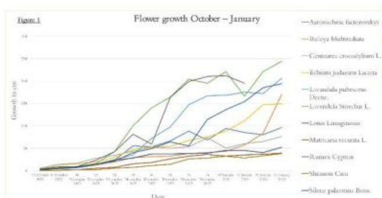
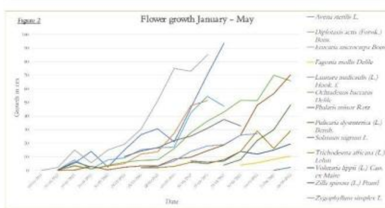


Figure 2



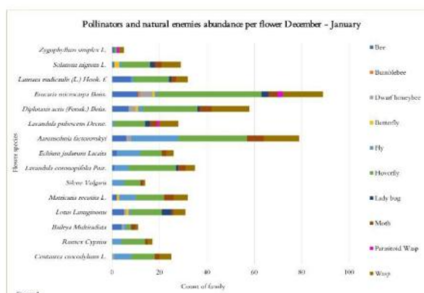


Figure 3

Discussion

- Specific wildflower species grow well in a flower strip setting: the combination of seeds for flower strips could rely on these species.
- The different growth and flowering timescales could be beneficial for providing shelter and food for beneficial insects all year round.
- Flowering plants are attractive for beneficial insects, some plant species are more attractive than others.
- Longer-term research is needed to understand the full potential of flowering strips to enhance biodiversity and related ecosystem services in arid agricultural settings.

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- Picture 1: Carrington, D. (2018) *Stripes of wildflowers across farm fields could cut pesticide spraying*, The Guardian. Available at: https://www.theguardian.com/environment/2018/jan/31/stripes-of-wildflowers-across-farm-fields-could-cut-pesticide-spraying (Accessed: February 1, 2023).
- Picture 2: *Trip Arava Desert* (no date) Walk about love - Israel national trail. Available at: https://www.walkaboutlove.org.il/en/... (Accessed: February 1, 2023).
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