BDEE 2021

sciforum

Conference Proceedings Paper

Pollinator Communities in Some Selected Hungarian Conventional, Organic and Permaculture Horticultures

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Abstract: Increasing agricultural intensification can have a large impact on pollinating communities in terms of number and diversity, which often show a declining trend these days. Pollination is an important regulating ecosystem service, providing about 84% of fruit and vegetable production. The diversity of pollinators and the appropriate number of individuals are key to efficient pollination. In study, we examined the impact of three farming systems (organic, permaculture, and conventional) on the temporal, average farm-level number and diversity of pollinator species groups. We sampled all together fifteen small-scale (0.3-2 hectares, 5-5 in all three types) farms in North-Central Hungary with similar agroecological features. All of them have horticultural production with diverse crop rotation. We used visual sampling method to register individual number and taxa of pollinators in 14 categories in May, July and August, 2020. Our results show that the abundance of some pollinator taxonomic groups was highest in case of permaculture farms and in some cases even significant differences were found (e.g. Apidae and Total number of pollinators taxonomic groups). On the other hand regarding taxonomic group Shannon diversity of the pollinator communities, we could not detect any significant difference between the farming types. Our results show that permaculture farms could maintain a diverse and abundant pollinator community during the studied period but we have to consider the farm management factors like plant protection measures, flower resources and biodiversity management on the farm also natural habitats around the farms and the attitude of the farmers towards protection of pollinators.

Keywords: agro-ecosystem; agroecology; pollination; ecosystem service; land use

1. Introduction

Increasing industrial agricultural intensification means a serious threat for biodiversity; pollinators are among the most affected groups [1, 2]. As a result of habitat fragmentation and farming practices that ignore diversity loss, pollinators have less and less nesting and feeding grounds available, resulting in a reduction in their diversity [3, 4]. Less intensive farming practices, such as forest gardens, organic and permaculture farming, which builds on the ecoystem functioning, increase plant heterogeneity and pollinator numbers and species richness [5, 6].

Without pollinators, 75 % of the cultivated crops' yields would drop, as pollination is essential for the fertilization of flowering crops [7]. Besides cultivated crops for human use, nearly 90% of wild plant species need pollinators for their fertilization [9], hence other ecosystem services and the natural habitats which provide them, are dependent directly or indirectly on the pollinators [10, 11]. Among the insect pollinators, wild bees and honey bees provide the highest pollination services [12]. Only in Europe, from the 264 cultivated crops 84 % and more than 4000 vegetables worldwide depend on pollination by bees [13]. Pollinators in Hungary are mostly bees, lepidopterans and hoverflies. We need to know more about the effects of agricultural practices and farming systems on the pollinator communities in order to protect pollinator species and their ecosystem service provision ability for their intrinsic value but also for the interest of humans. As global human population is constantly growing, the needs of individuals, including food, are an increasing challenge for agriculture, but the work of pollinators – or as we often call today: ecosystem service - is essential for production [8, 14]. Due to the increased demands, more and more areas are being intensively cultivated using synthetic pesticides and fertilizers as well as monoculture cultivation [15-17].

In our study we aimed to compare different horticultural farms regarding pollinator communities' abundance and diversity to see how the different farming systems (conventional, organic and permaculture) affect the results and which provides more ideal conditions for pollinators. The main consideration was that scientific knowledge on permaculture systems in regards to biodiversity indicators is missing. Our preliminary hypothesis was that permaculture farms provide the most ideal conditions and have the highest abundance and diversity of pollinators, while conventional have least.

2. Experiments

2.1.The study sites

Fifteen sites, 5 conventional (C), 5 organic (O) and 5 permaculture farms (P) in Hungary were selected with similar size (0.3-2 hectares) and agro-ecological features, horticultural production with diverse crop rotation (Fig.1.). All farms are small scale, with direct marketing to customers.

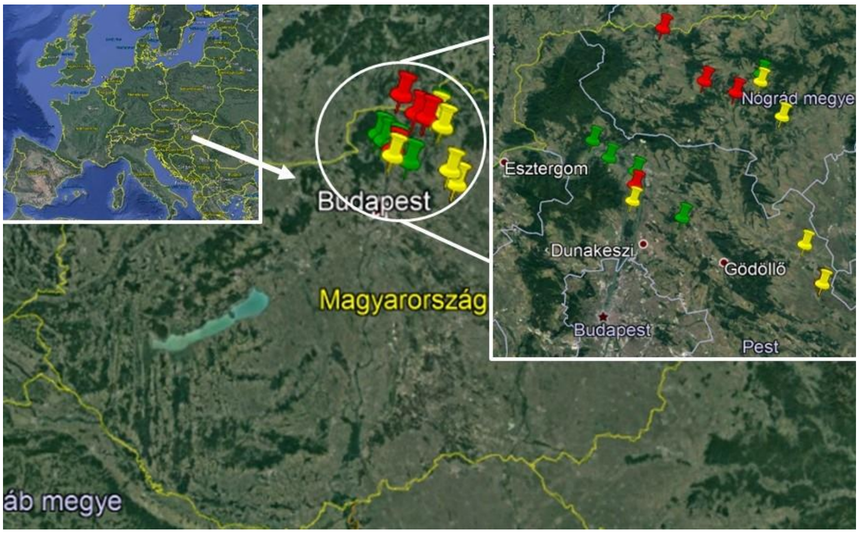

Figure 1. Location of the studied sites (green points: permaculture, yellow: organic, red: conventional farms) (Google Earth Pro 2020, own editing)

Permaculture farming is a complex design system that goes beyond the principles of organic farming and creates a sustainable human environment [18, 19]. In addition, it is important to emphasize that it is not just a farming alternative, but a nature-centered approach: based on ethical and design principles focused on conserving the Earth and nature.

By organic - also known as biological, ecological - farming we mean a complex farming alternative, which enables the production of healthy food under environmentally friendly, strict conditions and controlled conditions. It seeks to protect natural habitats, use resources within the system, and maintain ecological balance. Conventional farming is a profit-oriented, intensive form of agriculture, which relies primarily on the use of synthetic pesticides and fertilizers, and often uses monoculture on large fields.

2.2.Methods

Pollinators were assessed by visual sampling method similar to Bihaly et al. [11]. We carried out field surveys in three months in 2020 – in May, July and August. We went to the farms on consecutive days to have the similar weather conditions. Sampling duration was 0,5 hour at each time, 1 person for the 30 minutes, always visiting the sites slowly, in different order. Sampling was done throughout the whole site on a pre-defined line to assess possible occurrence of pollinators on weed flora, but mostly concentrated on the flowering cultures, we never sampled the same place twice to avoid double counting. If pollinators in one group was so abundant that it was hard to count than we registered 100 individuals (it happened mostly in case of honey bees). We always started with the description of cloudiness, temperature, wind strength, and any other relevant information. We also recorded cultivated crops and main weed species and the flowering plants. During our field work we recorded the most important factor affecting the results, namely that which crops, or plants were most attractive to pollinators. Plants grown in plastic tunnels were not included in the analysis or surveys. Each pollinator was registered in 14 different taxonomic categories. The main categories were bees (Apidae), butterflies (Lepidoptera), hoverflies (Syrphidae), and other pollinators (beetles, bugs, wasps). The "other bee species" included wild bees other than bumble bees, such as Megachile or Osmia species, and other pollinators were Vespidea and mostly beetles (Cetoniinae, Cantharidae).

All collected taxonomic group presence-absence and abundance data were divided into functional group categories and were registered in matrices. In our calculations, Apis mellifera and Bombus species abundance data were united in Apidae group as like other taxonomic groups. We calculated taxonomic group number and Shannon diversity by all collected presence-absence and abundance data of taxonomic groups (families and species) on field. Residuals of every relationships between different categorical (type of farms) and numeric factor (pollinator taxonomic group numbers and abundances) variables were checked for normality with Shapiro-Wilk normality test. TukeyHSD test was used for normally distributed residuals and in cases of non-normally distributed residuals, Kruskal-Dunn's posthoc test was applied to determine significant differences ($p<0.05$) between different type of farms. Every calculation were made in R 3.5.1. programming environment [21] by the 'PMCMR', 'PMCMRplus' and the 'vegan' packages.

3. Results

3.1. Abundance of pollinators

A total of 2972 pollinators were registered, of wich 84% were bees, 4% butterflies, 8% hoverflies, 4% were other pollinators; the distribution of registered pollinators by sampling date and farms is shown in the Appendix (Table 2). We did not find significant differences in May and July sampling in the abundance of pollinators, although permaculture farms had the highest average, while conventional had lowest. According to our analysis, the total number of pollinators were significantly higher in August in the permaculture and organic farms compared to the convetional (Figure 2a). Within that Apidae species (Figure 2b) and honey bees (Figure 2c) were significantly higher both in permaculture and organic farms compared to the conventional farms.

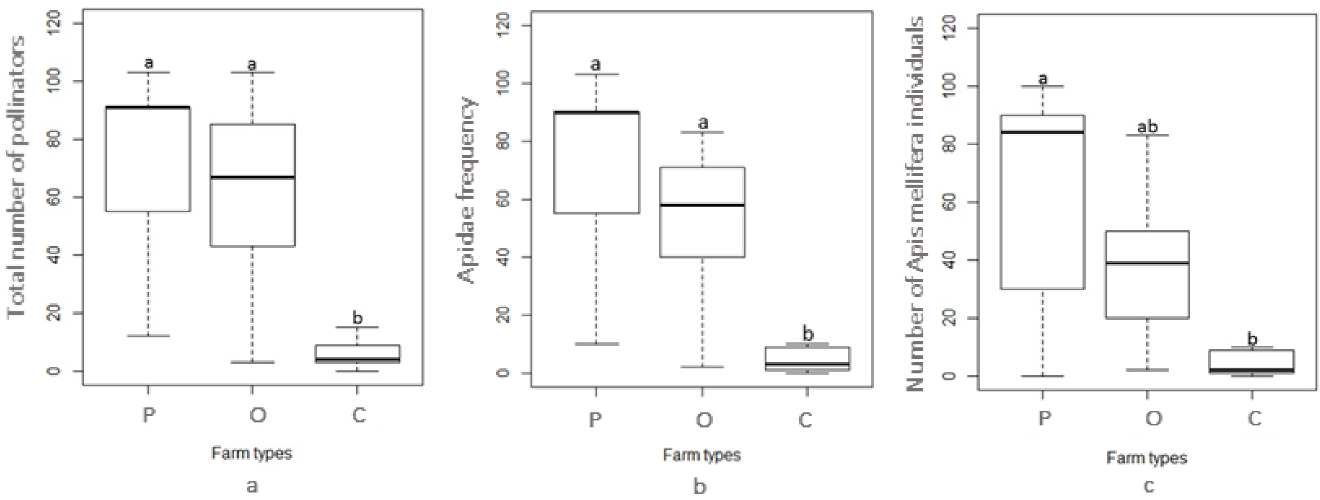

Figure 2. Total number of pollinators (a), frequency of Apidae pollinators (b), and number of Apis mellifera individuals (c) in the three studied farming system (P= permaculture, O= organic, C= conventional farms, n=5) in August, 2020.

3.2. Diversity of pollinators

We did not find significant difference in the pollinator taxonomic group number nor in Shannon diversity in the three farming systems in neither of sampling times, figure 3 shows the results in August, 2020 (Figure 3 ab).

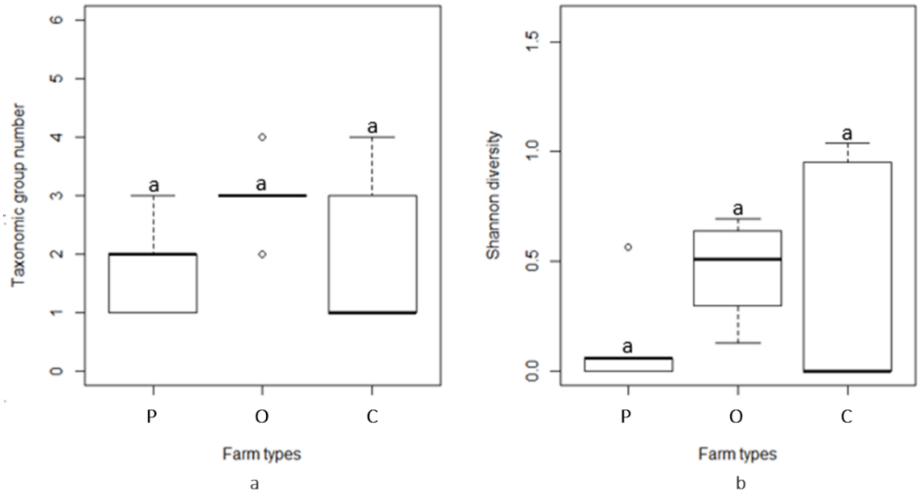

Figure 3. Pollinator taxonomic group number (a) and Shannon diversity (b) in the three studied farming system (P= permaculture, O= organic, C= conventional farms, n=5) in August, 2020.

Shannon diversity index average was highest in permaculture farms in May, while in the organic farms in July and August, 2020. Both in July and August permaculture farms had lowest average. Average taxon number values showed the same trend (Table 1.)

Table 1. Average Shannon diversity and taxon number of pollinators in the three studied farming systems with standard deviations during samplings in 2020 may, july and august (n=5). P=Permaculture farms, O=Organic farms, C=Conventional farms.

Sampling date	May	May	May	July	July	July	August	August	August
Farming system	P	O	C	P	O	C	P	O	C
Taxon number (MEAN ± SD)	4.40 ± 1.14	4.00 ± 1.22	2.40 ± 1.34	4.00 ± 1.22	4.20 ± 0.84	3.20 ± 1.10	1.80 ± 0.84	3.00 ± 0.71	2.00 ± 1.41
Shannon diversity (MEAN ± SD)	0.85 ± 0.47	0.70 ± 0.32	0.58 ± 0.54	0.55 ± 0.28	0.68 ± 0.26	0.65 ± 0.28	0.14 ± 0.24	0.45 ± 0.24	0.40 ± 0.55

4. Discussion

Our results show that the abundance of some pollinator taxonomic groups was highest in case of permaculture farms and in some cases even significant differences were found (e.g. Apidae and Total number of pollinators taxonomic groups). On the other hand regarding taxonomic group Shannon diversity of the pollinator communities, we could not detect any significant difference between the farming types. However it is important to further investigate factors that could influence the results (flower resources for pollinators, environment and habitats on and around the farms, landscape heterogeneity, farm management like used plant protection agents etc.) [22-26] . In our pilot study, we have found similar patterns in 2019 with only three farms, although we have expected greater differences in the diversity of pollinators [27] which is in line with what we explored in the biodiversity theme during sustainability assessment of permaculture farms comapered to organic and conventional farms [28]. Pollinatior communities and biodiversity were richer and more abundant with agrienvironment management schemes in a previous study [29]. In an other study, the authors found that organic farming should be mainly in mosaic landscapes to provide biodiversity, where the yield differences are lower between conventional and organic crops [30, 31]. Besides environmental factors, sampling method and circumstances of sampling (weather, time of sampling during the day etc.) could also potentially influence the results, moreover the relatively low sample size (15 farms, 5-5 farm from each farm type) is also an issue for the statistical analysis and our analyes showed that with a greater sample size and a more robust database we could have probably found more significant statistical results.

5. Conclusions

Based on the pollinator abundance data we suggest that permaculture farms could provide favorable conditions for pollinators, specially for Apidae taxon. We emphasize that besides measuring ecological indicators and conditions we have to investigate the attitude of farmers as it determines farm management decisions. We plan to expand our research into this direction and also link our field research with ecosystem service delivery of the farm.

Acknowledgments: We would like to thank for participating farmers for the opportunity to conduct this research in their farms. Supported by the ÚNKP-20-2-I New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund.

Author Contributions: Alfréd Szilágyi and Miklós Sárospataki conceived and designed the experiments; Alfréd Szilágyi and Fanni Mészáros performed the experiments; Alfréd Szilágyi and Róbert Kun analyzed the data; Alfréd Szilágyi, Fanni Mészáros, Miklós Sárospataki and Róbert Kun wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

P: permaculture farm; O: organic farm; C: conventional farm; SD: standard deviation

Appendix

Table 2. Registered number of pollinators during samplings in May, July and August, 2020. P=Permaculture farms, O=Organic farms, C=Conventional farms.

Sampling date	Farm	Apis mellifera	Bombus terrestris	Bombus lapidaris	Bombus pascuorum	Other bees	Sphingidae	Papiolionidae	Pieridae	Lycanidae	Satyridae	Nymphalidae	Other lepidopterans	Syrphidae	Other pollinators
May	**P1**	41	7	1	0	11	0	0	2	0	0	0	0	11	8
May	**P2**	1	0	0	0	6	0	0	0	4	0	1	0	9	5
May	**P3**	100	100	100	0	43	0	0	1	1	0	1	0	26	12
May	**P4**	66	0	0	0	20	0	0	0	0	0	0	0	5	4
May	**P5**	4	0	0	0	0	0	0	0	0	1	0	0	4	1
May	**O1**	17	1	8	0	21	0	0	0	1	0	0	1	9	13

May	**O2**	6	0	0	0	16	0	0	0	1	0	0	0	2	11
May	**O3**	60	0	1	0	7	0	0	0	0	0	6	0	13	2
May	**O4**	19	0	0	0	4	0	0	0	0	0	1	0	0	0
May	**O5**	36	31	0	0	13	0	0	0	4	0	4	0	1	8
May	**C1**	0	0	0	0	2	0	0	0	0	0	0	0	1	2
May	**C2**	0	0	0	0	1	0	0	0	0	0	0	0	0	0
May	**C3**	2	0	0	0	10	0	0	0	0	2	0	0	5	1
May	**C4**	0	0	0	0	1	0	0	0	0	0	0	0	0	0
May	**C5**	10	5	0	1	40	0	0	0	0	0	0	0	26	6
July	**P1**	6	0	0	0	54	0	0	0	0	1	0	0	5	7
July	**P2**	19	50	5	0	11	0	0	1	0	0	0	0	0	0
July	**P3**	100	30	12	0	43	0	0	4	10	0	0	0	9	7
July	**P4**	15	14	0	0	14	0	0	1	0	2	0	0	15	0
July	**P5**	40	2	0	0	5	0	0	3	0	1	0	0	3	3
July	**O1**	100	4	0	0	34	0	0	1	0	0	0	1	26	13
July	**O2**	2	1	0	0	11	0	0	0	0	0	0	0	3	2
July	**O3**	100	4	0	0	15	0	0	0	0	1	0	0	3	2
July	**O4**	23	1	0	0	7	0	0	2	0	0	0	0	3	3
July	**O5**	12	0	0	0	18	0	0	1	3	0	0	0	8	1
July	**C1**	100	23	1	0	52	0	0	1	0	0	0	0	19	1
July	**C2**	25	0	0	0	27	0	0	0	0	0	0	0	10	0
July	**C3**	3	0	0	0	19	0	0	0	0	0	0	0	11	0
July	**C4**	19	9	0	0	8	0	0	1	0	0	0	0	10	1
July	**C5**	7	3	1	0	3	0	0	2	0	0	0	0	4	3
August	**P1**	0	0	0	0	10	0	0	1	1	0	0	0	0	0
August	**P2**	90	0	0	0	0	0	0	1	0	0	0	0	0	0
August	**P3**	30	0	0	0	25	0	0	0	0	0	0	0	0	0
August	**P4**	84	0	0	0	6	0	0	0	0	0	1	0	0	0
August	**P5**	100	3	0	0	0	0	0	0	0	0	0	0	0	0
August	**O1**	83	0	0	0	0	0	0	1	0	0	0	0	0	1
August	**O2**	50	20	1	0	0	0	0	30	0	2	0	0	0	0
August	**O3**	39	0	0	0	19	0	0	2	0	1	0	0	0	6
August	**O4**	2	0	0	0	0	0	0	0	0	1	0	0	0	0
August	**O5**	20	0	0	0	20	0	0	2	0	0	1	0	0	0
August	**C1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	**C2**	9	0	0	0	0	0	0	0	0	0	0	0	0	0
August	**C3**	2	0	0	0	1	0	0	0	0	0	0	0	0	0
August	**C4**	10	0	0	0	0	0	1	3	0	0	0	0	0	1
August	**C5**	1	0	0	0	0	0	0	2	0	0	0	0	0	1

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