

AGROBIODIVERSITY IN A CHANGING CLIMATE: EFFECT OF HERBIVORE-INDUCED PLANT VOLATILES ON FUNCTIONAL CANOPY ARTHROPODS IN THE OLIVE AGROECOSYSTEM

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Abstract

Changing climate is expected to have the global effect on natural ecosystems, including Mediterranean basin, which among other issues is estimated to endure the loss of biodiversity. The consequences of such reduced biodiversity can directly affect major ecosystem functions and services, including biological pest control. Considering the importance of the above, a study was conducted in order to monitor the diversity of olive canopy arthropods in the presence of herbivore-induced plant volatiles (HIPVs), using transparent sticky traps (TST). Monitoring confirmed high diversity and abundance of arthropods, including those providing the function of biological pest control against important olive pests. No significant differences appeared between traps with HIPVs and control. Further research is needed in order to identify modes of HIPVs effectiveness in the enhancement of the activity of fundamental arthropods, followed by biodiversity conservation and enhancement efforts, to provide resilience and pest control services in the aspect of climate changes.

Keywords: climate change; functional biodiversity; arthropods; olive; agroecosystem;

1. Introduction

This century is facing the biggest challenges related to environmental changes caused by altered climate conditions. Both natural and agricultural ecosystems are main indicators of negative climate impacts, since every alteration in temperature or carbon dioxide concentration is causing inevitable consequences on their functioning [13]. Ecosystems are supporting complex interactions between species and their environment, f.i. biotic and abiotic factors, and due to ecosystem functioning, we are enabled to benefit by using its goods and services. However, the understanding of interactions within ecosystems is crucial, and the ways these interactions are affected even by minor changes in the climate [15]. The increase of global average temperature has multiple consequences on the ecosystems worldwide and while it is expected to improve crop productivity in some areas, it will be followed by severe shocks and stresses, such as droughts and floods, in others [13]. It is expected that in the altered climate conditions Mediterranean ecosystems will experience, among others, a large loss of biodiversity, due to their sensitivity to all drivers of biodiversity change [16]. One of the highest concerns about climate change is its detrimental effect on the agricultural sector, including the effect on pest populations [18]. Several studies have shown that unstable climate conditions may lead to increased pest activity, and consequently to crop losses. In such conditions, solutions other than increased pesticide use should be applied, as their effects on natural resources, biodiversity, and human health are known, besides their contribution to climate change effects [12].

1.1 Climate changes and arthropod species

Global warming and temperature extremes possess a crucial role in shaping life traits of beneficial insects and their interactions with habitat and pest organisms [8]. Climate instability is affecting ecosystem functioning at all

trophic levels, as well as species distribution and community composition [18]. These changes put in jeopardy the interactions between plants, pests, and their predators, which are the result of a long evolution process [8]. Global climate changes have a potential to disrupt the life cycle of pest and predator species, also as the nature of their interactions [18] which resulted in growing research focused on effects of altered climate on the environment and biodiversity. Scientists expect that climate change could cause shifts in life cycle development of arthropods, as well as spatial and temporal overlaps caused by their migration towards more favorable conditions [17]. Indeed, small temperature changes can disturb the whole population dynamics and destroy the most important ecosystem services of biological pest control. It becomes therefore important to study interactions and functionality changes of insect populations, among other reasons, due to climate changes as main cause of alterations between host and parasitoid relations [8]. More research is necessary in the field of evolutionary responses not only for predators but also prey species which usually reproduce faster and might have greater potential to adapt to new environmental conditions [17].

1.2 Climate changes and HIPVs

HIPVs are one of the most important communicating pathways within ecosystems. The release of these volatiles is the feature of several families and they are involved in interactions between plants and pests, pests and their predators, and between plants themselves [4]. Besides attracting beneficial organisms, HIPVs can alleviate pest damages by repelling pests from feeding, females from oviposition or by triggering defense genes of the plant that will induce priming. The composition, synthesis, and emission of HIPVs in natural ecosystems are dependent on various biotic and abiotic factors [2]. Still, the effect of abiotic factors on emission of HIPVs is not well known, even though it is documented that the constitutive emission of plant volatiles is affected by factors including temperature, CO₂ concentration, ozone, light intensity, water and nutrient availability. Therefore it is likely that same factors influence the production of HIPVs, since the same biosynthetic pathways are involved. Considering that abiotic changes affect a whole range of metabolic processes within the plant, the negative effects on primary metabolism will also affect the secondary metabolism, potentially affecting the production of HIPVs [1].

Olive fruits are producing more than 100 volatile compounds, identified by gas chromatography and mass spectrometry. Studies confirmed increased amount of certain volatiles after infestation of the fruits, as well as production of new HIPVs which varies according to the cultivar. Additionally, it is demonstrated that healthy fruits also produce volatiles useful in attraction of beneficial arthropods including *Psytalia concolor* [6]. However, Becker et al. [1] confirmed that abiotic conditions can potentially interfere with the interactions between plants and parasitic hymenoptera since the changes in atmosphere and climate are affecting the emission of HIPVs.

The question arises if beneficial arthropods will be able to interpret the altered airborne signals, caused by abiotic changes? In order to avoid high variability of HIPVs emission by plants in unstable environment, the increased use of HIPVs synthetic blends in integrated pest management have been recorded over the past years. Numerous compounds which were successfully tested in field conditions are listed, including methyl salicylate (MeSA), methyl jasmonate, indol, geraniol, octyl aldehyde and many more [1].

Considering the above, aim of this study is to provide the evaluation of diversity of tree canopy arthropods in the olive ecosystem and effectiveness of a HIPVs-based attractant commercially available (MagiPal®), as the results may provide better insight into functional biodiversity and potential of HIPVs in biological pest control management.

2. Materials and Methods

2.1 Study site and trapping methodology

This study was conducted in the olive orchard located in Georgioupolis, Rethymnon, northwest Crete (35° 20' N, 24° 17' E). 10 pairs of trees, located in the orchard center, were selected for evaluation of the effectiveness of commercially available attractant for beneficial arthropods. Tree selection was done on the criterion of eliminating external variation produced, i.e. by canopy volume, abiotic conditions or vegetation. Each pair included one tree with attached MagiPal® lure, in the center of the canopy, next to a transparent sticky trap, used in previous studies [5, 7], while another tree served as control, without attractant. Sampling period included a period of 5 weeks during the autumn of 2018 (September to October). Traps were collected weekly using thin, transparent plastic membranes for transportation and further manipulation purposes. Identification of arthropods was conducted in laboratory conditions by using a stereomicroscope (Novex AP Euromax®, Holland).

2.2 Data analysis

Arthropod taxa were classified in 10 orders - *Araneae*, *Diptera*, *Hemiptera/Heteroptera*, *Hemiptera/Homoptera*, *Hymenoptera*, *Lepidoptera*, *Neuroptera*, *Psocoptera*, *Thysanoptera* and *Coleoptera*; 5 families - *Syrphidae*, *Asilidae*, *Ichenumonidae*, *Chrysopidae* and *Hemerobiidae*; and 2 species - *Bactrocera Olea* and *P. Concolor*. After taxonomization, the arthropods were classified in groups with positive (beneficials / Biological Pest Control - BPC) or negative (pests) functionality.

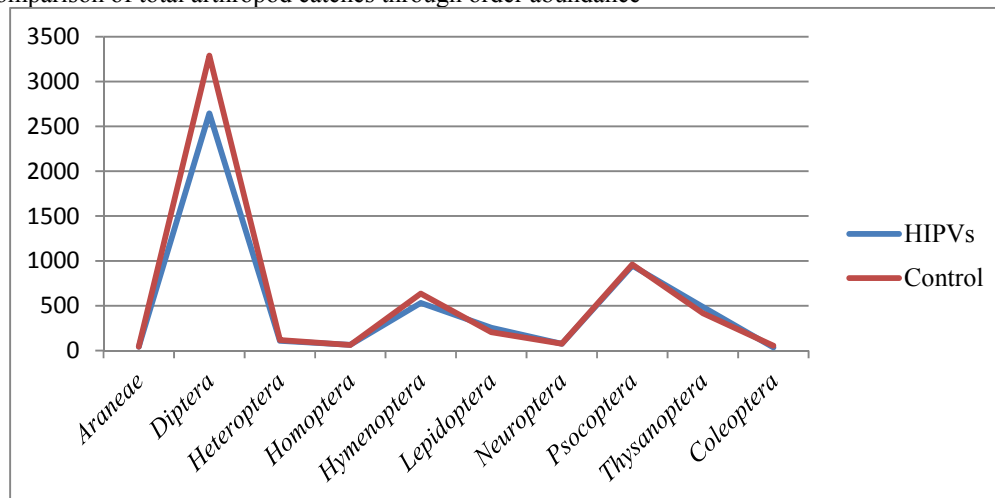
The effect of HIPVs on arthropods community took into consideration: Specific taxa abundance; Total catches; Abundance of functional arthropod groups; Richness of taxa (S); Shannon-Weaver index (H'); Pielou's index (J) and Reverse Simpson index (1-D). The data normality was assessed through the non-parametric Mann-Whitney test.

3. Results and discussion

3.1 Arthropod abundance and diversity

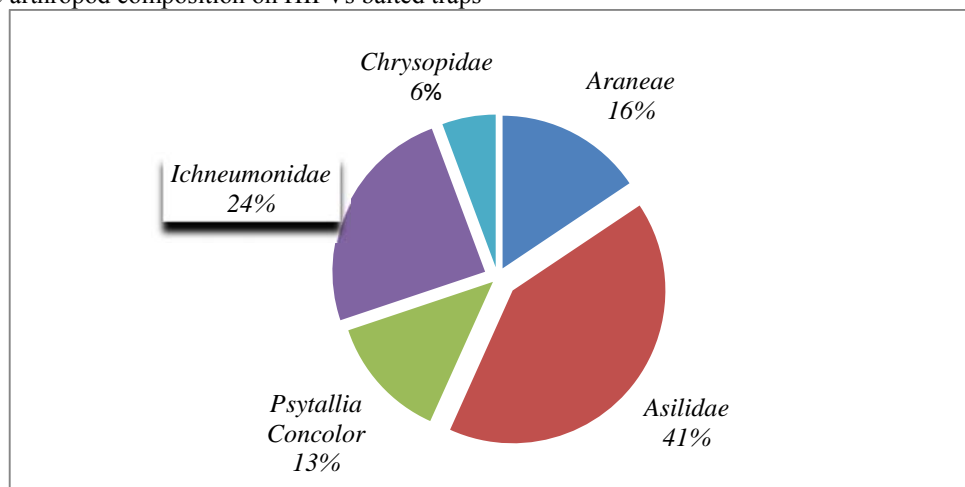
In total, 11,063 arthropods were caught, out of which the traps with used attractant captured 5,195 individuals while the control traps captured 5,868. The total arthropod abundance in HIPVs, as well as control traps is shown in the graph below (Figure 1). Based on the total numbers counted, the following five orders were most abundant during the five week sampling: *Diptera* (54%), *Psocoptera* (17%), *Hymenoptera* (11%), *Thysanoptera* (8%), and *Lepidoptera* (4%). The ranking of taxa according to the abundance of arthropods did not differ between traps with HIPVs and control traps, except for *Coleoptera* which was the least abundant in the presence of HIPV, while in the case of control traps that was *Araneae*. Similar ranking of the most abundant taxa of arthropods in olive groves captured by TST was confirmed in other studies [7, 5].

Fig. 1 Comparison of total arthropod catches through order abundance



BPC group took into account the taxa of canopy arthropod fauna considered to be predators and parasites of the main olive pests included *Syrphidae* and *Asilidae* of order *Diptera*; sp. *P. concolor* and fam. *Ichneumonidae* (order *Hymenoptera*); fam. *Chrysopidae* and fam. *Hemerobiidae* (order *Neuroptera*) and order *Araneae* (Figure 2). The group counted in total 586 individuals, or 5.29% of the total catches, out of which 282 (48.12%) were captured on HIPVs baited traps, while 304 (51.88%) were found on control traps.

Fig. 2 BPC arthropod composition on HIPVs baited traps



The abundance of arthropods belonging to BPC group, captured with HIPVs, compared with number of total catches from this group is *Asilidae* 51%, *Araneae* 49%, *P. Concolor* 49%, *Ichneumonidae* 44% and *Chrysopidae* 43 %.

The group with the negative functionality included the abundance of *B. oleae*, while *Margaronia Unionalis* and *Prays Oleae*, also considered as key pests of olive orchards, were not captured during this study. Total number of captured olive pests was 10, of which 2 were captured in HIPVs attracted traps, while 8 in the control traps.

Population dynamics of *B. Oleae* is reaching the activity peak as an adult in autumn, which was confirmed in studies by Gkisakis [7] and Dimitrova [5].

3.2 Statistical analysis

The univariate data analysis and Mann-Whitney test confirmed not significant difference between the groups with and without HIPVs lures. The difference was not significant in the case of specific functional groups, individual arthropod species and biodiversity indices (Table 1).

Table 1. Arthropod abundance and biodiversity indices values

	Week 1		Week 2		Week 3		Week 4		Week 5	
	HIPVs	Control	HIPVs	Control	HIPVs	Control	HIPVs	Control	HIPVs	Control
Total	1092	1276	897	821	1352	1664	711	882	1143	1225
Pests	1	4	0	0	0	0	0	2	1	2
BPC	109	103	37	27	52	59	34	73	50	42
S	10	10	10	10	10	10	10	10	10	10
J	0.70	0.68	0.68	0.62	0.59	0.53	0.57	0.58	0.61	0.54
H'	1.62	1.56	1.57	1.42	1.36	1.22	1.31	1.33	1.40	1.25
1-D	0.77	0.76	0.73	0.64	0.59	0.52	0.56	0.58	0.62	0.56

BPC, biological pest control; S, richness of taxa; J, Pielou's index; H', Shannon-Weaver index; 1-D, Reverse Simpson index;

The positive effect of synthetic blends containing MeSA in attraction of arthropod species effective in pest suppression has been confirmed in *Chrysopidae* species [10], *Coleoptera* species [3], parasitic *Hymenoptera* and predaceous *Heteroptera* [11]. However, the studies have also recorded weak attraction of beneficial arthropods to HIPVs blends containing MeSA [11]. Even though MeSA is considered as important part of volatile blends for attraction of beneficial arthropods, research has shown its effectiveness in field conditions only within a narrow range [3]. Since the majority of research related to arthropod response to HIPVs, including natural enemies has been conducted in laboratory conditions [10], the spatial scale efficacy of HIPVs blends is still not clear, as well as underlying effects of HIPVs on arthropod species [3].

The highest abundance of *Diptera* species in olive agroecosystems is related with the prey availability and it was confirmed in previous studies [5, 7].

The key pest in olive groves, *B. oleae* is considered as the most damaging pest of olive groves in the Mediterranean area with the potential to develop up to five generations per year [14]. The low abundance of *B. oleae* might be related with life cycle and harvesting period of Koroneiki variety, as well as lower attraction towards transparent than colored sticky traps [5]. *P. concolor* is larval endoparasitoid of numerous tephritid flies of different crops, including olive groves [6]. *P. concolor* was introduced to Greece from Tunisia during the last century, and today it represents the most abundant parasitoid of *B. oleae* in Crete [19]. The effectiveness of *P. concolor* in different regions depends on its ability to adapt on changing climate conditions and the availability of food for adult individuals in such environment [19]. Females use numerous stimuli for location of the host, with the ability to distinguish infested from healthy olive fruit, suggesting that olive fruit infested with larvae is important for host location and acts like short-range kairomone [6]. The same abundance of *P. concolor* in HIPVs attracted traps and control traps might indicate better response to volatile blend originating from olive fruits, than bait itself.

Although the effectiveness of biological control agents against key olive pests varies in different studies, this method is considered as safe for the environment and economically effective [9], and it has been practiced in Europe

over the decades [19]. The high abundance of arthropods crucial in BPC combined with growing knowledge related to HIPVs can provide their further use and establishing as a part of integrated pest management in olive agroecosystems.

4. Conclusion

Although the results of our study were limited in a short period, they delivered a useful insight of beneficial and pest canopy arthropods of the olive agroecosystem and the basis for further research in the area. Preserving and enhancing biodiversity in agricultural ecosystems has an emerging importance in order to ensure their functioning and better resilience under changing climate conditions. As arthropods possess different tolerances and thermal optimums and as temperature means increase, followed by extreme conditions, it is expected that diverse arthropods assemblages will ensure more reliable ecosystem services. Temperature change, followed by wind and altered rates of precipitation are estimated to affect natural enemy efficiency, and since their sensitivity to climate change is unknown, defining the strategies for their attraction and preservation within agricultural systems has crucial importance. Studies focused on HIPVs can provide knowledge necessary for advanced alternative measures in pest control which might be crucial in close future.

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