Trapping methodologies for functional canopy arthropod diversity in olive agroecosystem

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Abstract. The value of a diverse and balanced community of canopy arthropods is undeniable in terms of pest management and overall agroecosystem functionality. However, a suitable monitoring methodology for them has not been well defined, especially in perennial crops. Field sampling conducted in Crete, Greece during autumn and spring was done in order to look into two types of trapping methodologies, yellow sticky traps (YST) and transparent sticky traps (TST) in organically managed olive orchard. The caught arthropods were organized in functional groups and compared on this basis. Although the differences between the diversity indices were not statistically significant, some differences came up between the total abundance and abundance of certain orders. The YST had a much higher abundance of arthropods while in absolute numbers, the TST present a more diverse and even canopy arthropod community. The agroecological approach seems to be useful and practical in terms of characterization of the properties of the YST and TST. Using the TST as a low cost, less labour demanding, replicable and easily set trapping methodology is suitable for estimation of the biodiversity of the canopy arthropods. This suggested that further research set on this approach can help in assessment and recommendation for further practices in perennial crops in order to reach a more stable and productive agroecosystem from ecological, social and economical aspect.

Keywords. Agroecology - Monitoring - Coloured sticky traps.

Méthodologies de piégeage pour une diversité fonctionnelle d'arthropodes de canopée dans un agroécosystème d'olivie

Résumé. *La valeur d'une communauté diverse et équilibrée d'arthropodes de canopée est un atout majeur pour une bonne gestion d'insectes et un agroécosystème fonctionnel. Cependant, une méthode adéquate de monitorage pour les communautés d'arthropodes n'est pas encore établie, surtout dans les espèces pérennes. Dans un champ cultivé biologiquement, un échantillonnage en plein champ a eu lieu en Crète, Grèce pendant le printemps et l'automne afin de comparer deux types de pièges à colle, le premier est un piège jaune (YST) et le deuxième est transparent (TST). Les arthropodes captivés ont été classifiés en groupes fonctionnels et comparés sur cette base. Bien que les différences entre les indices de diversité n'étaient pas statistiquement significatives, quelques différences ont été observées entre l'abondance totale et l'abondance de certains ordres. Les YST présentaient plus d'arthropodes, alors qu'en nombre absolu les TST avaient une communauté d'arthropodes plus diverse et régulière. Par conséquent, l'approche agroécologique semble être utile et pratique en termes de caractérisation des propriétés des deux méthodes de piégeage (YST et TST). Avoir recourt aux pièges transparents (TST) comme méthode à coût minime, nécessitant peu de labour, reproductible, et facilement établie, peut être considérée comme méthode convenable pour l'estimation de la biodiversité des arthropodes de canopée. Des travaux d'optimisations pour cette méthode sont donc nécessaires afin qu'elle puisse devenir un atout dans les travaux de monitorage d'agro-biodiversité, dans le but ultime d'assurer un agroécosystème plus stable, productif tant à l'échelle économique qu'aux échelles écologiques et sociales*.

Mots-clés. *Agroécologie - Monitorage - Piège adhésif coloré.*

I - Introduction

For millenniums, the Mediterranean region has been exposed to anthropogenic activities which have resulted in a region with an especially high level of biodiversity, combined with natural ecosystems' evolution (Sokos *et al.*, 2013). The olive biocenosis is a valuable and inseparable part of the Mediterranean landscape, culture and lifestyle. The perennial olive agroecosystem is considered to be especially rich and generally more stable than other agricultural system with a close resemblance to the natural Mediterranean ecosystems (Loumou and Giourga, 2003) and optimization of the management could lead towars higher ecosystem stability and resilience (Landis, 2017) as well food security (Thrupp, 2000).

In the Mediterranean countries there is an increasing interest in effective and sustainable measures against pest species and prevention of pest outbreaks (Picchi *et al.*, 2017). Therefore, a site-specific agroecological approach that predominantly relies on local characteristics of the working area with the surroundings, and focuses on better understanding of pre-determined functional group(s) in a targeted context (Bárberi, 2013) is suitable for studies focusing on the control of main pests and even further, the comparison of biodiversity monitoring methodologies. Functional biodiversity has shown to be an important tool in terms of biodiversity, as it expresses the contribution to agroecosystem services and functioning (Laureto *et al.*, 2015; Gkisakis *et al.,* 2018). Indeed, the olive orchards benefit from the numerous functional services provided by arthropods since they are more specialized, adapted to specific plants and habitats and perform crucial services in the ecosystem they inhabit (Pimentel *et al.*, 1992) due to their abundance and diversity (Loumou and Giourga, 2003). Additionally, the integrated and organic olive orchards exhibit a higher arthropod abundance that conventionally managed orchards (Santos *et al.*, 2007; Picchi *et al.*, 2017; Gkisakis *et al.*, 2018). Therefore, a suitable trapping methodology of olive canopy arthropods, selected according to the scope of the study, is crucial in order to obtain comparable data (Basset *et al.*, 1996). For biodiversity assessments, the aim is to yield a more various and abundant sample regardless of the number of replications (Basset *et al.*, 1996; Ozanne, 2005; Missa *et al.*, 2009; Yi *et al.*, 2012) and preserve (most of) the individuals in condition suitable for identification (Yi *et al.*, 2012). A passive sampling methodology as the sticky traps that relies on the movement of the arthropods towards the traps (Gullan and Cranston, 2005) can provide satisfactory results with smaller investment, since they are cheap, can be used in large numbers and suitable for replication (Basset *et al.*, 1996; Young, 2005).

The objective of this study was to compare the arthropod community trapped by yellow and transparent sticky traps by following an agroecological approach and differentiation of functional groups of arthropods and define the characteristics of both trapping methodologies.

II - Materials and methods

1. Study site and trapping methodology

The trapping of canopy arthropods was conducted in an organic olive orchard located in the region of Chania, north-west part of Crete, Greece (Figure 1-A). Two trapping periods were planned over the course of two seasons, one in autumn and one in spring, each lasting five weeks. Throughout the olive orchards, a total number of 10 trapping sites were chosen for trapping in both sampling periods. The traps were set centrally, in the olive tree canopy at a suitable position without obstructions from by branches or leaves (Figure 1-B). Two types of traps were regularly set and replaced: commercially available yellow sticky trapst (YST) and lab-produced transparent sticky traps (TST) as a novel and appropriate approach (Gkisakis *et al.*, 2018).

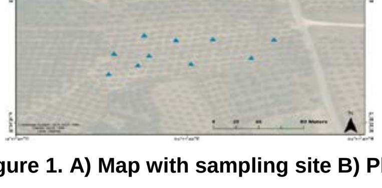
A)  B) 

Figure 1. A) Map with sampling site B) Photo of both traps set on field.

2. Data analysis

The arthropods were identified on a higher taxonomic level of order, suitable for efficient biodiversity assessment (Cotes *et al.*, 2011) and classified in two functional groups, those with positive functionality (biological pest control group - BPC) and those with negative functionality (main olive pests). Due to their importance in the olive agroecosystem, relevant arthropods were identified to the level of species/family. The comparison between the YST and TST took into consideration (1) Specific taxa abundance, (2) Total catches, (3) Abundance of functional arthropod groups, (4) Richness of taxa - S, (5) Shannon-Weaver index – H', (6) Pielou's index - J and (7) Reverse Simpson index – 1-D. The data normality was assessed through the non-parametric Mann-Whitney test with a significance reported at level $p < 0.05$ and $p < 0.001$.

III - Results and discussion

1. Arthropod abundance and diversity

In total, 43,302 arthropods were caught, out of which the YST captured 33,489 individuals while the TST captured 9,813 individuals. The 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 4 species - *Bactrocera Oleae, Psytallia Concolor, Margaronia Unionalis,* and *Prays Oleae*.

The groups with positive functionality, biological pest control group (BPC) took into account the taxa of canopy arthropod fauna that are considered to be predators and parasites of the main olive pests. A total number of 4761 arthropods or 10.99% of the total catches, considered as BPC, were captured and identified during both sampling seasons. The YST caught 70.47% (3355 individuals) of the arthropods belonging to this group while the TST caught 29.53% (1406 individuals). This group took into account the abundance of fam. *Syrphidae* and fam. *Asilidae* from order *Diptera;* sp*. Psytallia concolor* and fam. *Ichneumonidae* from order *Hymenoptera;* fam. *Chrysopidae* and fam. *Hemerobiidae* from order *Neuroptera* and order *Araneae.* Most abundant of these were *Asilidae* during the autumn sampling and *Ichneumonidae* during the spring sampling.

A separate group of the main pests of the olive tree that is characterized with negative functionality was assembled and included sp*. Bactrocera oleae*, sp. *Prays oleae* and sp. *Margaronia unionalis*. However, during the sampling only individuals of *B. Oleae* were caught. Out of the total catches, 251 individuals (0.58% of the arthropods monitored) belonged to this group. The YST caught a total of 223 individuals (88.84%) while TST caught 28 pests (11.16%). In terms of this functional group, there was a considerable difference between autumn and spring sampling, with a total of 238 *B. Oleae* caught during the autumn and only 13 caught during the spring. This is due to the biological cycle and population dynamics of *B. Oleae* which in early autumn reaches is activity peak as adult (Therios, 2009) and it has already been seen in previous studies (Gkisakis *et al.*, 2018).

The arthropod abundance difference in terms of the total, BPC and pest abundance is shown in the figure below (Figure 2).

The abundance of arthropods belonging to different orders on the YST and TST varied, leading to a different ranking of the taxa in terms of the trapping methodology (Table 1). With the YST the most dominant taxa captured was *Diptera* (61.2%), followed by *Thysanoptera* (16.2%), *Hymenoptera* (13.7%), *Hemipt./Homoptera* (3.8%) and *Psocoptera* (2.2%). The remaining five of the identified ten orders were present in abundance < 1%. With the TST, *Diptera* was also the dominant order (51.8%), followed by *Hymenoptera* (16.8%), *Thysanoptera* (14.3%), *Psocoptera* (2.4%) and *Coleoptera* (1.4%) with the remaining five orders present in abundance

≤ 1%. Using the same methodology, Gkisakis (2018) had a similar ranking of the orders present in the olive tree canopy captured by transparent traps.

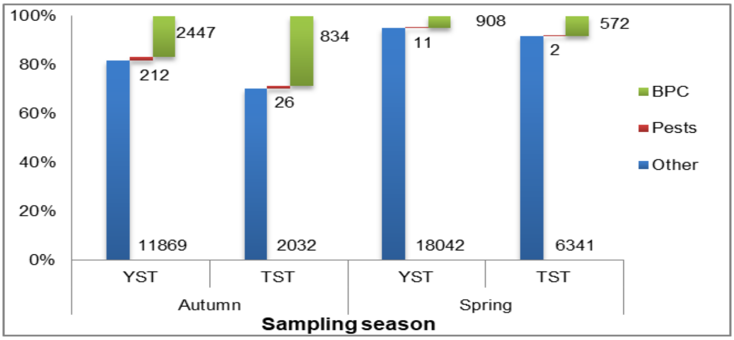


Figure 2. Total, BPC and pest abundance throughout the two sampling seasons.
BPC, biological pest control; YST, yellow sticky trap; TST, transparent sticky trap.

Table 1. Ranking and abundance of arthropods in terms of trapping methodology.

YELLOW STICKY TRAPS			TRANSPARENT STICKY TRAPS		
Orders	**Abundance**	**Ranking**	**Orders**	**Abundance**	**Ranking**
Diptera	20,480	**1**	Diptera	5086	**1**
Thysanoptera	5416	**2**	Hymenoptera	2703	**2**
Hymenoptera	4586	**3**	Thysanoptera	791	**3**
Hemipt./Homoptera	1289	**4**	Psocoptera	293	**4**
Psocoptera	746	**5**	Coleoptera	291	**5**
Coleoptera	304	6	Hemipt./Homoptera	268	6
Araneae	255	7	Araneae	178	7
Neuroptera	176	8	Hemipt./Heteroptera	88	8
Hemipt./Heteroptera	157	9	Neuroptera	71	9
Lepidoptera	80	10	Lepidoptera	44	10
TOTAL	**33,489**		**TOTAL**	**9,813**	

2. Statistical analysis

In the univariate data analysis there was a statistically significant difference between the two types of trapping methodologies in terms of the total abundance which is much higher for the YST than TST. In terms of specific arthropod groups, a difference in noticeable for the abundance of *Diptera* and *Homoptera* ($p < 0, 01$) as well as for *P.Concolor* and *Thysanoptera* ($p < 0, 05$) (Table 2). *Diptera* are naturally attracted to yellow traps (Bekker *et al.*, 2017) and the general high abundance of *Diptera* is correlated with the high abundance of *Asilidae* which could be due to swarm behaviour of this arthropods, generally associated with availability of specific prey groups (Neill, 2011). The natural attraction of *Homoptera* towards yellow as seen before in a study with yellow pan traps (Petacchi and Minnocci, 1994) also explains the statistically significant difference between the YST and TST. Even though many hymenopterans are biased towards the yellow traps (Gullan and Cranston, 2005) other studies suggest that *P.Concolor* does not have a colour preference (Benelli and Canale, 2012) and it is generally present in the olive orchards. Arthropods belonging to the order *Thysanoptera* have been also reported as an abundant group present in the olive (Gharbi *et al.*, 2012) but research suggests that these arthropods have no specific preference towards yellow colour (Kirk, 1984; Gillespie and Vernon, 1990).

Table 2. Comparison of accumulative abundance, richness and biodiversity indices.

Taxa	YST	TST	Taxa	YST	TST	Abun./Ind.	YST	TST
Ord. Araneae	255	178	Ord. Lepidoptera	80	44	Total	33489**	293
Ord. Diptera	20480**	5086	sp. *M. Unionalis*	0	0	Pests	5416	791
fam. *Syrphidae*	2	4	sp. *P. Oleae*	0	0	BPC	304	291
fam. *Asilidae*	2573	920	Ord. Neuroptera	176	71	J	0,506	0,559
sp. *B Oleae*	223	28	fam. *Chrysopidae*	12	8	H'	1,152	1,275
Ord. Hemipt./Heteroptera	157	88	fam. *Hemerobiidae*	9	2	1-D	0,556	0,586
Ord. Hemipt./Homoptera	1289**	268	Ord. Psocoptera	746	293			
Ord. Hymenoptera	4586	2703	Ord. Thysanoptera	5416*	791			
sp. *P. Concolor*	26*	6	Ord. Coleoptera	304	291			
fam. I*chneumonidae*	478	288						

** $p < 0.05$, ** $p<0.001$: level of significance applied for comparison of trapping methodologies using Mann-Whitney test; YST, yellow sticky traps; TST, transparent sticky traps; BPC, biological pest control; S, richness of taxa; J, Pielou's index; H', Shannon-Weaver index; 1-D, Reverse Simpson index.*

Overall, the data analysis suggests that the YST captured statistically more significant number of arthropod and therefore have a higher abundance. In terms of diversity, there is no statistically significant difference between the two trapping methodologies based on the biodiversity indices taken into consideration. However, in absolute numbers even though the YST have a higher abundance, the TST captured a more diverse and even canopy arthropod community (Table 3).

IV - Conclusions

Following an agroecological approach has shown to be a practical and adaptable way to obtain information regarding the functioning of a well-established perennial agroecosystem as the olive crop. Using two trapping methodologies for canopy arthropods over a period of two sampling seasons comparable data was gathered. The YST have shown to be highly attractive for the canopy arthropods that inhabit the olive orchards and they gathered a more abundant sample. On the other hand, the TST had a lower abundance and, though statistically insignificant, in terms of raw data higher evenness and diversity of the canopy arthropod community. This suggests that the TST, as a novel approach, are suitable as a passive, unbiased, low demanding trapping methodology which can be easily replicated and adapted for different study sites. As such, it becomes a significant part of an assessment regarding the functioning of valuable agroecosystems and its inclusion in further research can provide recommendations for agricultural optimization.

Table 3. Arthropod abundance and biodiversity indice values over both sampling periods.

SEASON	AUTUMN									
	Week 1		Week 2		Week 3		Week 4		Week 5	
TRAPS	YST	TST	YST	TST	YST	TST	YST	TST	YST	TST
Total	3997	377	2669	354	698	134	3168	744	3996	1289
S	9	10	10	8	10	10	10	10	10	10
J	0.39	0.63	0.53	0.46	0.66	0.71	0.47	0.52	0.22	0.28
H'	0.87	1.45	1.23	0.95	1.52	1.64	1.07	1.20	0.50	0.65
1-D	0.38	0.63	0.61	0.41	0.72	0.73	0.51	0.57	0.20	0.28
SEASON	SPRING									
	Week 6		Week 7		Week 8		Week 9		Week 10	
TRAPS	YST	TST	YST	TST	YST	TST	YST	TST	YST	TST
Total	5666	1335	2646	969	3824	1520	2597	1276	4228	1818
S	10	10	10	10	10	10	10	10	8	10
J	0.46	0.6	0.53	0.58	0.57	0.56	0.59	0.59	0.66	0.66
H'	1.06	1.37	1.23	1.33	1.3	1.28	1.36	1.35	1.37	1.52
1-D	0.54	0.64	0.6	0.62	0.67	0.63	0.67	0.65	0.68	0.72

YST, yellow sticky traps; TST, transparent sticky traps; BPC, biological pest control; S, richness of taxa; J, Pielou's index; H', Shannon-Weaver index; 1-D, Reverse Simpson index.

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