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The impact of soil management, agroecological zone, and season on ground-dwelling insects in Tunisian olive groves

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Abstract

In Mediterranean agroecosystems, soil management in favor of the intensification of olive groves is one of the major drivers of biodiversity loss. In the present study, we explore the effects of three soil management practices (no tillage, *Faba bean* cover crop and tillage as farmer practice) of olive grove on ground dwelling insects at two seasons (olive flowering and olive ripening) in two agroecological zones (Toukaber and Jammel AEZs). We predict that ground insect orders diversity and abundance increase by the adoption of agroecological soil management practices. We used pitfall traps to sample ground dwelling insects and then compared them at order level. Insects' diversity changed according to AEZ, seasons and practices. No tillage practice showed higher diversity during flowering season for both AEZ. *Faba bean* cover crop soil management allowed the dominance of three orders and tillage was observed to be the soil management practice with low diversity during olive flowering. The results of the present study highlight the beneficial effects of cover crop and no tillage on insects' abundance and provide novel evidence of such soil management practices role with respect to maintaining higher levels of ground dwelling insects' diversity.

Keywords. agroecosystem, biodiversity, intercropping, orchard.

Introduction: Olive production is a major agricultural, environmental and economic driving force for Mediterranean countries. This cultivation frequently follows a conventional agricultural protocol, especially in industrialized, modern olive orchards, which face ecological problems (Kabourakis, 1999, Volakakis et al., 2012). The biodiversity of agroecosystems where intensification takes place is led to impoverishment (Biaggini et al., 2007), while soil arthropod fauna is especially affected (Cotes et al., 2010, Ruano et al., 2004, Santos et al., 2007). Indeed, soil is a vital resource for agricultural productivity and plays a crucial role in sustaining food production systems. Unsustainable soil management practices have led to degradation and loss of this valuable resource, posing significant challenges to global food security and environmental sustainability (Zama and Lungelo, 2023). However, studies have shown a significant global decline in biodiversity. The decline of biodiversity on this scale has encouraged debate concerning the adoption of sustainable soil management practices which emphasize agroecological practices such as minimum tillage, crop rotation, and cover cropping which can help improve soil health and fertility. Therefore, it is essential to investigate how agronomic practices can promote functional biodiversity for both ecological and agronomic purposes.

The main objective of the study was to enhance the functional diversity of ground-dwelling insects in Tunisian olive groves in different agroecological zones (North-West and Central-Est of Tunisia), focusing on the response of the insect abundance linked to the agroecological practices applied as soil management according to two olive phenological stages.

Material and Methods: This work was conducted in 2022 at two organic olive orchards of Tunisia; in the North-West (Toukaber agroecological zone, sub-humid, 36°42'22"N 9°30'38"E, Beja Governorate) and in the Central-Est (Jammel agroecological zone, semi-arid, 35°38'27.5"N 10°41'24.2"E, Governorate of Monastir). Ground dwelling insects were sampled with pitfall traps made of similar white plastic and embedded in the ground so the lip of the trap remained flush with the substrate surface. The traps were set around the olive tree and filled up to one-third full with mono-propylene glycol as a preservative and were covered with a plastic plate held 2 to 5 cm above the trap by nails placed in the corners of the trap; covers are typically used to reduce flooding and the accumulation of leaves and litter in the preservative. Throughout the olive orchards, a total number of 8 pitfall traps were installed for each plot in both sampling periods and locations with three replications in Toukaber and two in Jammel. Trapping periods were implemented at two periods of two weeks each; at flowering season of olive trees (May) and at olive fruit ripening period (August). Insect diversity was studied according to three soil management practices; tillage as farmer´s practice, no tillage, and cover crop using faba bean. Collected samples were transported in plastic bottles to the laboratory, filtered and cleaned of debris and inorganic material and examined by stereomicroscope. Insects were identified on a higher taxonomic level of order. The comparison between different agroecological zones, seasons and soil management practices took into consideration insects order number, insects' abundance, Shannon-Weaver index (H') and Simpson index (D). The data statistical analysis was assessed through the one-way ANOVA followed by an SNK post-hoc test comparisons tests with a significance reported at level $p < 0.01$, $p < 0.05$ and $p < 0.001$.

Results and Discussion

1. Insects' abundance

Hymenoptera, Collembola, and Neuroptera were found in greater numbers in Jammel, a semi-arid region. While Orthoptera, Blatoptera, Zygentoma, and Dermaptera were found in greater numbers in Toukaber, which characterized by a sub-humid climate **(Fig.1)**. Insect community was changed along a climatic gradient including a subhumid and a semiarid. We found that an increase in aridity from sub-humid to semi-arid cause changes in taxonomic diversity especially of Hymenopteran and Collembolan communities. The presence of Hymenoptera in more proportion in Jammel AEZ is related to Formicidae family which are associated to semi-arid climate. While the difference of collembolan communities seems due especially to the soil texture. It was known that the abundance of Collembola in arable soils is closely linked to soil structure and functions (Usher, 1975). Indeed, soils that are too fine or compact may not be suitable for burrowing and inhabiting (Son et al., 2011). Their low abundance in Toukaber region in which the soil is clay and therefore not favorable because they are not able to make their own burrows and are entirely dependent on air-filled pores that are dimensioned to at least their body width. So, they responded with a decline in the number of individuals to a decrease in the volume of coarse soil pores (Larsen et al, 2004).
The abundance of ground-dwelling insects varied with the phenological stage of the olive trees. During flowering, Diptera, Hemiptera, Lepidoptera, Collembola, Neuroptera, Thysanoptra, and Dermaptera were the most abundant orders. However, during fruit ripening, insects belonging to Hymenoptera, Blatoptera, and Zygentoma orders were significantly the most abundant **(Fig.2)**. The seasonal changes influence the distribution and occurrence of some orders in the studied regions. This could be as a result of the temperature, relative humidity and availability of food source. If there are seasonal changes in type of food available, patterns of foraging may change accordingly

(Heatwole and Muir, 1989). This is the case of hymenopteran communities, which represented more by Formicidae family during the fruit ripening season.

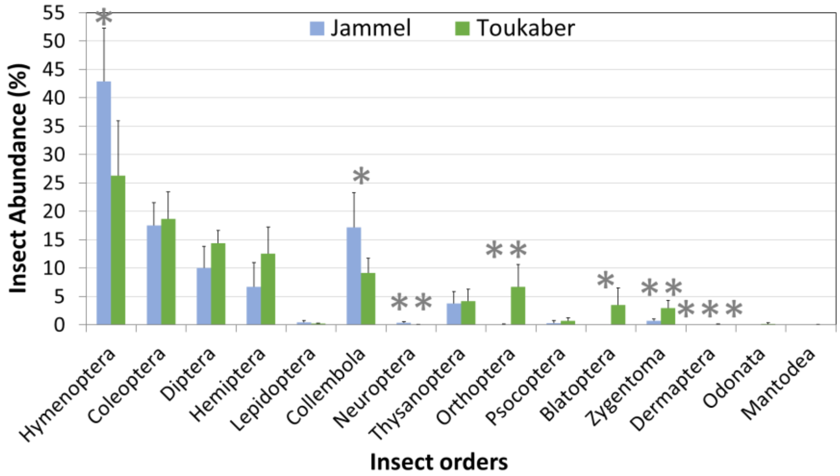

Fig.1. Variation of insect abundance by order between two AEZs: Jammel and Toukaber. Statistical results from one-way ANOVA and SNK post-hoc test *: p<0.5, **: p<0.01, ***: p<0.001

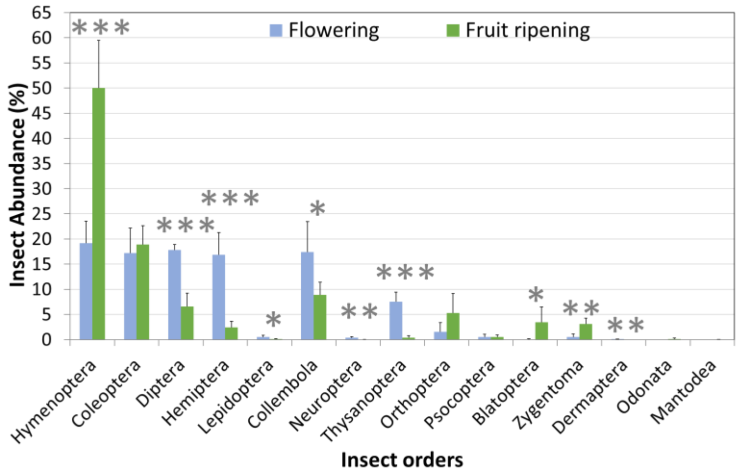

Fig.2. Variation of insect abundance by order between two different phenological stage of the olive tree: flowering and fruit ripening. Statistical results from one-way ANOVA and SNK post-hoc test *: p<0.5, **: p<0.01, ***: p<0.001

2. Insects' diversity

During flowering and fruit ripening, the number of insect orders was higher in Toukaber than in Jammel for both tillage and no tillage practices. However, under the faba bean cover crop practice, both AEZs had the same number of orders at flowering, while Jammel showed the highest order number at fruit ripening **(Fig.3)**.

As shown in **Table 1**, differences were observed between AEZs, phenological stages and practices. The Shannon-Weiner index revealed moderate diversity in all AEZs and practices, with relatively low values. Insect diversity reached higher values under the no-tillage practice during the flowering season for both AEZs. During ripening, the highest diversity was observed under tillage practice for Toukaber, and in the faba bean cover crop for Jammel.

Fig.3. *Number of insect orders collected per AEZ: Toukaber (T) and Jammel (J), per phenological stage: flowering and fruit ripening, and practices. FB: faba bean*

The Simpson index indicated strong overall dominance of some orders across AEZs and practices, with consistently low values. The faba bean cover crop had the lowest Simpson index at flowering, where Collembola dominated in Jammel and Hemiptera in Toukaber. At fruit ripening, the communities with the highest dominance were in Jammel's faba bean cover crop, dominated by Hymenoptera, and in Toukaber's tillage practice, dominated by Collembola.

Table 1. *Biodiversity indexes per AEZ, phenological stage, and practices. T: Tillage, N: No tillage, FB: Faba bean cover crop. Bold: the highest value of Shannon (highest richness) and lowest value of Simpson (highest dominance).*

	Jammel						Toukaber					
	Flowering			Fruit ripening			Flowering			Fruit ripening		
	T	NT	FB	T	NT	FB	T	NT	FB	T	NT	FB
Shannon-Weiner index	1.74	**1.86**	1.51	0.99	0.88	**1.12**	1.74	**1.86**	1.78	**2.05**	1.76	1.16
Simpson index	0.38	0.35	**0.27**	0.46	0.51	**0.42**	0.19	0.19	**0.18**	**0.14**	0.22	0.48

It was known that Insects' abundance would increase as disturbance from tillage decreased (Rowen et al, 2020). In accordance to our expectations, during the flowering season, both AEZs exhibited high insect diversity under the no-tillage practice. However, during fruit ripening season, a high dominance of Collembola was observed under tillage practice for Toukaber AEZ. Tillage can influence insects' communities by disrupting soil structure and directly disturbs their habitat and lifecycles and reduce their populations. In this context, we observed a dominance of Collembola order to the detriment of the others insects' orders. faba bean cover crop was dominated by Hymenopteran insects during fruit ripening in Jammel AEZ. It provides a feeding habitat with substantial amounts of nectar and pollen, thus indirectly providing an ecological service to many pollinators. In general, it offers a rich foraging habitat for several beneficial insects (Koltowski, 1996, Osborne et al., 1997, Nuessly et al., 2004, Manning, 2006). For many beneficial insects and pollinators, faba bean is considered a substitute for the loss of habitat diversity from the environmental impacts of agricultural intensification (Richards, 2001), and several individual ecological insects services.

Conclusion: The abundance and diversity of ground-dwelling insect orders in olive groves varied in both AEZs, phenological stages, and in response to soil management practices. The Shannon index revealed that diversity was highest in No-tillage during flowering, and in either Faba bean cover crop or Tillage treatments during fruit ripening, depending on the AEZ. However, communities exhibited high dominance, as indicated by low Simpson index values. Faba bean harbored communities with the highest dominance, particularly in Jammel, with Hymenoptera, Hemiptera, and Collembola being the dominant orders. These identified orders can provide ecosystem services, such as Collembola contributing to soil structure and health. However, some orders encompass species providing both ecosystem services and disservices. Hymenoptera and Lepidoptera include pollinators, but also some biocontrol agents (Heminoptera) or pests of olive tree (Lepidoptera). Further taxonomic identification at a lower level is essential to better investigate the influence of soil management practices on insect communities at key phenological stages and in both AEZs.

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