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ARTICLE

The Effects of Ground Cover Mowing Height on the Fauna of Ground-dwelling Arthropods in Olive Grove

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ABSTRACT

Ground dwelling insects, spiders, and other arthropods play an important role in agroecosystems as predators and saprophytic organisms. Their presence on the soil surface helps the biological control of pests, enhances organic matter decomposition and promotes biodiversity. Soil disturbance, particularly tilling and mowing has greatly affected the assemblage and abundance of epigeic arthropods. This study aimed to determine the effects of herbaceous vegetation cover mowing height on arthropods abundance and structure in olive orchards. The experimental site was divided into three zones (Z1, Z2, and Z3) regarding mowing heights (0 cm, 10 cm, and 15 cm). This research was done in 2019 from the beginning of May untill the end of September. During this research, 1490 individuals were recorded belonging to 6 classes, 11 orders and 13 families. The number of individuals was higher in the zones Z2 and Z3 comparing with Z1. The highest number of individuals showed woodlices (Isopoda) comprising 67, 5% of all individuals collected. There were significant differences in the number of Carabidae, Bleteliidae and Forficulidae between the zones of research. Unlike Forficulidae, higher heights of mown positively affected the population of Carabidae and Blateliidae.

1. Introduction

The Olive tree (*Olea europaea* L.) is certainly one of the most important crops of the Mediterranean region [5,35]. Thanks to their beneficial effects on human health the consumption and requirement for olive oil are increasing all over the world [5]. According to [3,27] organic olive production has been proposed as sustainable and the option to conventional farming, including all benefits that this type of production brings to the environment, product quality and human health. Moreover, this type of production showed a greater social value than conventional cultivation [36]. The most common practices in soil management associated with organic olive farming are reduction in tillage, therefore vegetation cover is usually controlled by grazing livestock or mowing [30]. Management and disturbance of agricultural soils lead to wind and water erosion but also influence the population and diversity of soil-dwelling arthropods and plants [4,32]. Besides, soil arthropods, earthworms also play an important role as indicators of soil fertility [14]. Less disturbance of ground vegetation may improve better habitat conditions for soil-dwelling and ground-cover natural enemies [20]. Tillage has a direct influence on the abundance of invertebrates by disturbing their habitats, litter layer, and the availability of shelters [46]. Mowing that is a currently

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practiced method in perennial plantations eliminates biomass, removes the source of food and causes animal mortality [11]. Ground cover is usually present in both integrated and organic growth [20], particularly orchards on sloping land [41,47]. The use of cover crops in olive orchards could enhance the soil quality and reduce the risk of erosion [18]. Besides that, cover plants increase soil organic matter, enhance nutrient cycling and improve water infiltrations [41]. Moreover, ground cover promotes biocontrol services, increases the population of beneficial arthropods and minimizes the need for insecticides [35]. Regarding the mowing, one of the negative effects on terestrial arthropods could be the cutting height. Harvesting techniques affect small mammals, amphibians, and invertebrates by killing or damaging their bodies [24]. Some studies [12,33] reported that higher cutting heights are less damaging to field animals. Previous research refers mostly to small mammals and amphibians. Some papers [13,24,25] demonstrated that the model of mowers, as well as cutting height, affect ground beetles fauna. As far as we know there is scarce information about the effect of the height of cutting on arthropod structure and diversity. Although, in the Mediterranean region cover vegetation is usually mowed during the summer period to reduce water and nutrient competition [7]. On the other hand, completely removing ground cover could have negative consequences on olive groves [3]. Olive orchards are inhabited by a different fauna where ants are one of the most abundant groups [7]. In addition to ants, spiders followed by beetles also form an integral part of the arthropod fauna associated with olive groves [52]. There are many ways to protect their population and to maintain their biodiversity in agricultural landscapes. The positive effect of cover crops on the entomophagous insects and spiders has been reported by a group of authors [38,41]. Low-intensity farming and their influence in enhancing the biodiversity of ground-dwelling arthropods as well as in soil conservation. Vegetation cover positively affected soil texture, protected soil from erosion, increased soil biodiversity, particularly arthropod communities. A negative effect of mowing has been reported to some spider communities, particularly less mobile species [9]. Mowing (time and number of treatments) also affects species assemblage [45]. In this research, we hypothesize that lower heights of cutting may negatively affect the number and densities of ground-dwelling arthropods.

2. Materials and Methods

2.1 Site of the Experiment

This research was conducted during 2019 in a 40 years old organic olive grove (43°28'15.8"N, 16°34'48.7"E). The orchard is located in the Central Dalmatia (Croatia – Europe) near the city of Split. The site of research belongs to the Mediterranean climate characterized by warm to hot, dry summers and mild wet winters [26]. Two main olive varieties Oblica and Levantinka were represented in this research. Oblica is the most common variety in Croatia that accounts for about 60% of the total olive varieties. In this grove, Oblica represents 65% until Levantinka represents 35%. Vegetation cover was composed of most weed species dominated by *Avena fatua* L., *Bromus* spp., *Cynodon dactylon* L. (Pers.),., *Hordeum murinum* L., *Senecio vulgaris* L., and *Polygonum* spp . The main olive pests in this area are olive fruit flies (*Batrocera oleae*, Gmelin 1790), olive moth (*Prays oleae*, Bernard 1788) and black scales (*Saisettia oleae*, Olivier 1791). No insecticides and herbicides were used during the period of research.

2.2 Experimental Design, Arthropod Sampling, and Identification

The orchard was divided into three zones, each one occupied by three different heights of grass cutting. The removal of vegetation cover before samplings was performed using a tractor mower. In the first zone (Z1) ground cover was eliminated (0 cm). In the second zone (Z2) grass cutting height was 10 cm, whilist in the third one (Z3) 15 cm withouth biomass removal. Within each zone, five Pitfall traps were placed with a distance of 5 m between each other. Traps consisted of a plastic cup (14 cm high and diameter 9 cm) in which another also plastic cup was put to facilitate their emptying. Plastic cups were filled with a mixed solution (water and 70% ethyl alcohol) and a few drops of detergent. Additionally, above the traps stone roofs were placed to protect them from the litter and precipitations. Sampling was done every fifteen days from early May to early September in 2019. Traps were controlled and emptied 48h after their placement in the soil. All collected arthropods were stored in 70% ethanol plastic vials and placed in the refrigerator (+5 °C) until determination. Identification was performed in the laboratory of the Department of Ecology, Agronomy and Aquaculture using the following keys [15,19,44]. Insects were identified to the family level, whereas all other groups were determined to order level.

2.3 Statistical Analysis

One way ANOVA was used to determine the differences in arthropod community between zones of research. Differences between groups were tested using Tukey's HSD. Arthropod dominance was calculated according to Tischler [50], eudominant (>10%), dominant (5-10%),

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subdominant (2-5%), recedent (1-2%), and subrecedent (<1%). The statistical analyses were performed with software version STATISTICA 8.0 (StatSoftt Inc. 2007).

3. Results

During this research, 1490 arthropod specimens, belonging to 6 classes, 11 orders, and 13 families were collected altogether (Table 1). The highest number of individuals was collected in the zone with a cutting height of 15 cm (557), whereas the lowest number was found on the bare ground (433).

Table 1. Total number of arthropods

Class	Order	Family	Z1	Z2	Z3
Arachnida	Araneae		48	45	44
Chilopoda	Scutigero-morpha		0	7	4
Diplopoda			9	8	5
Malo-costraca	Isopoda		275	341	390
Insecta	Blattodea	Blateliidae	22	26	54
	Dermaptera	Forficuli-dae	20	2	3
	Coleoptera	Carabidae	6	20	14
		Curculion-idae	1	1	0
		Elateridae	0	1	1
		Scarabaei-dae	2	1	0
		Silphidae	0	1	1
		Staphylin-idae	3	1	6
	Diptera	Muscidae	2	4	2
	Hempitera	Miridae	1	0	0
	Hymenop-tera	Formici-dae	42	41	27
	Mantodea	Mantidae	1	0	0
	Orthoptera	Acrididae	1	1	4
Total no. of individuals			**433**	**500**	**557**

Note:Z1 (0 cm), Z2 (10 cm), Z3 (15 cm)

In this research, Isopoda was considered as eudominant with 1006 individuals which is 67,51% of all capture (Table 2). Results showed that dominant groups were Aranea with137 individuals (9,19%) and Hymenoptera (Formicidae) 7,38%, whereas Carabidae (2,68%) was classified subdominant. Forficulidae (1,67%) and Diplopoda (1,47%) considered recedent. All other arthropods were subrecedent with an occurrence of less than 1%.

Table 2. Dominance of arthropods according to Tischler

Class	Order	Family	%	Dominance
Arachnida	Araneae		9,19	Dominant
Chilopoda	Scutigeromor-pha		0,73	Subrecedent
Diplopoda			1,47	Recedent
Malocostraca	Isopoda		67,5	Eudominant
Insecta	Blattodea	Blateliidae	6,84	Dominant
	Dermaptera	Forficulidae	1,67	Recedent
	Coleoptera	Carabidae	2,68	Subdomi-nant
		Curculioni-dae	0,13	Subrecedent
		Elateridae	0,13	Subrecedent
		Scarabaeidae	0,20	Subrecedent
		Silphidae	0,13	Subrecedent
		Staphylini-dae	0,67	Subrecedent
	Diptera	Muscidae	0,53	Subrecedent
	Hempitera	Miridae	0,20	Subrecedent
	Hymenoptera	Formicidae	7,38	Dominant
	Mantodea	Mantidae	0,06	Subrecedent
	Orthoptera	Acrididae	0,26	Subrecedent

Note:Z1 (0 cm), Z2 (10 cm), Z3 (15 cm)

There were differences in the assemblage of arthropods in zones with or without ground cover. Ground cover supported the abundance of woodlice (Isopoda), whereas their number raised from 257 individuals on bare ground to 390 individuals in the zone with cover vegetation (cutting height of 15 cm). Comparing within insects in the zones associated with ground cover the highest abundance showed Carabidae with 34 individuals and Blateliidae with 60 individuals.

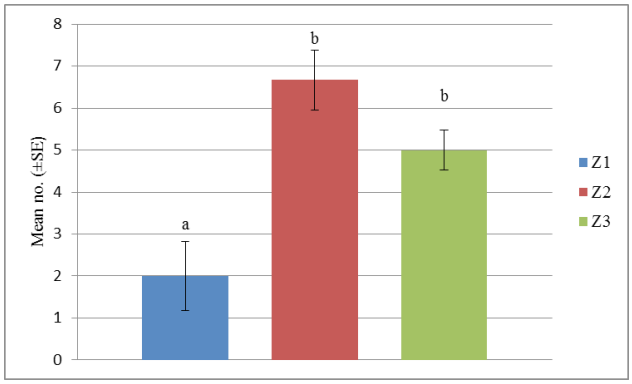

Figure 1. Mean number of Carabidae between zones of research

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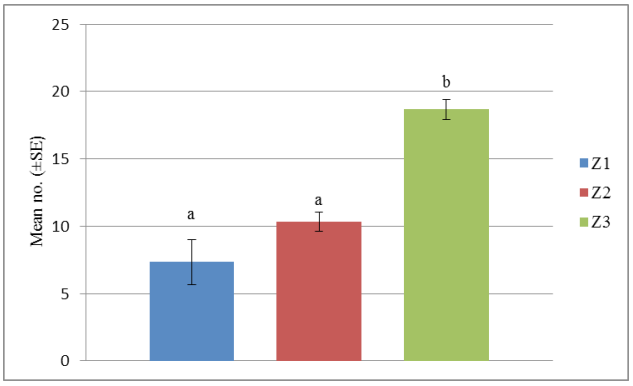

Figure 2. Mean number of Blateliidae between zones of research

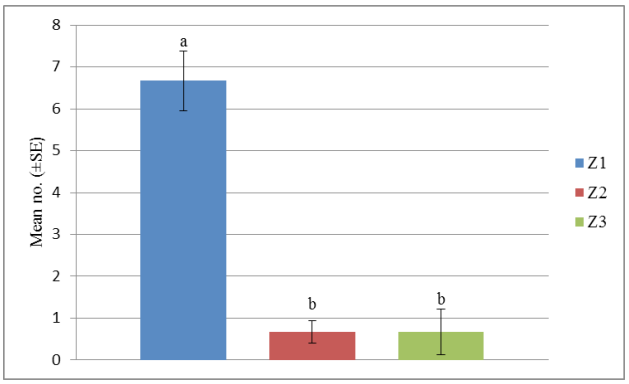

Figure 3. Mean number of Forficulidae between zones of research

There was a significant difference in Carabidae (F=7,947, df=2, *p*=0,021) (Figure 1) and Blateliidae (F=14, 589, df=2, *p*=0,005) abundance between zones (Figure 2). In regard to zones Forficulidae significantly differed (F=27,000, df=2, *p*=0,001) (Figure 3). Within the Z1, Forficulidae dominated. By contrast, spider abundance was similar between zones. Differences were also noticed between months of research.

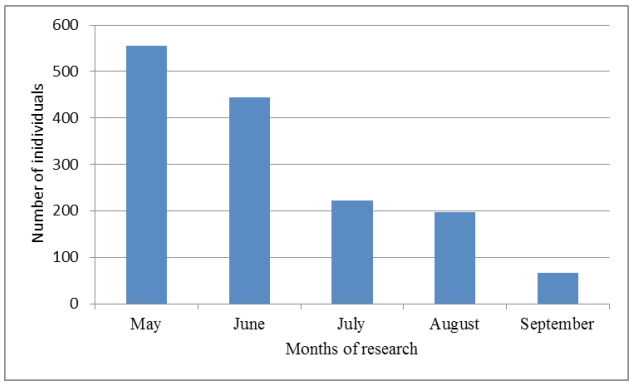

Figure 4. Total number of individuals within months of research

The higher number of individuals was recorded in May and then the population decreased from June to August (Figure 4). According to food preferences, the majority of captured arthropods belonged to saprophytic (isopods) or beneficial organisms (spiders, ants, ground beetles). On the other hand, a very low number of individuals can be considered as olive pests.

4. Discussion

Mowing of ground cover is one of the most common agricultural practices used in soil cover maintenance in organic farming. In the present study how the presence or absence of ground vegetation affected the abundance of some group of ground-dwelling arthropods was shown. Our results demonstrated that captures numerically dominated by Isopoda. Isopoda usually feed on dead plants, half–decomposed leaves and weeds [55]. Saska [43] reported different Isopod species to feed on living plant tissue or seeds. Soil tillage, grass mowing, pesticide application as well as soil acidification affect Isopod diversity and abundance [48]. Besides, these animals prefer minimally tilled or no-tilled soils. Moreover, they act as bioindicators of contaminated or polluted soils, mostly with heavy metals [34]. Comparing the Isopod fauna in vineyards and olive groves in Greece Hadjicharalampous et al. [21] found that olive orchards were the richest in woodlice species. In this research, vegetation was not removed from the soil but left on as a mulch, and possibly increased the number of Isopods. Though there was no significant difference in Isopoda abundance, the highest number was recorded in zone Z3. The results of this study indicate that higher cutting height might benefit the population of this arthropods. Ants are an integral part of the fauna of arthropods offten present in olive groves [23,42]. According to Moris et al. [31] ants are important predators of the olive moth. In their research Santos et al. [42] showed that Formicidae dominated and comprised 56% of all capture. Similar results, a high abundance of ants were reported by Goncalves et al. [17] in integrated farming where cover crops were presented. Ants are one of the most common arthropods in olive groves [7,35] and they play an important role in agroecosystems as they participate in biological control and nutrient cycling [53]. In our research, the number of ants did not differ significantly between zones. Contrary to the findings of previously mentioned authors [42] the number of Hymenoptera in our research reached less than 10%. In their research Carpio et al. [10] reported Formicidae comprised 6,2% of the total captured. According to [35] effect of removing the ground cover on the diversity and composition of ants depends on insect species. Heuss et al. [22] reported mowing as the most harmful land-use practice for ants. But also, authors demonstrated that the effect of

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the mowing regime differs between ant species. Another important familiy associated with olive groves is Carabidae. For instance these insects are natural enemies of the olive fruit fly [37]. Our results demonstrated that ground cover positively affected Carabidae as the higher number was found in zones Z2 and Z3. Vegetation mowing harms the Carabidae assemblage and diversity [51]. Moreover, any kind of mechanical treatment disturbance negatively affects Carabidae in Mediterranean olive groves [37]. The abundance and diversity of Carabidae were related to the frequency of mowing. Authors found that simplified and organic agriculture with reduced mowing rates positively affected Carabidae fauna. Mowing harms ground beetle assemblage in differently managed grasslands [16]. According to Benhadi-Marín et al. [2] spiders are successful natural enemies in olive groves. In this research there were no significant differences in the number of spiders between zones. Cardenas et al. [8] reported that soil management (tillage and mulching) and vegetation type affect the occurence of spiders. In addition, strong influence of soil management on spider families was observed by Mashavakure et al. [28]. For instance, mulching showed a strong positive effect on ground-dwelling spiders. On the other hand, epigeic spider abundannce were insensitive to the implementation of the agri-environmental sheme [39]. Comparing to tillage, mowing has a more favorable effect on arthropods diversity in olive orchards [49]. In our research, the maximum abundance was recorded in May and in June. The number of individuals decreased by the end of the sampling period. For the purpose of making better conditions for invertebrate community Mazalova et al. [29] recommended maintaining the grass strips particularly these associated with perennial grasslands or with natural hedges or trees. Herbicides, mineral fertilizers and removal of vegetation cover could be related to a decline of the abundance and biodiversity of beneficial arthropods [1,54]. Arthropod diversity seems to be positively affected by ground cover. Furthermore, olive orchards with bare ground showed lower values of biodiversity than olive groves with the cover ground [10]. Within the zone (Z1) where the ground cover was not presented the most abundant family was Forficulidae. However, Forficulidae were positively affected by the absence of ground cover in an olive orchard [40]. According to Burnip et al. [6] these insect counts were higher in orchards herbicide treatments comparing to mulched grows. The results of this research could be taken into consideration when mowing of vegetation is planing. Despite the fact that mowing techniques may negatively affect the number and structure of epigeic arthropods this measure is needed as a soil maintance measure in perennial crops, particularly organic groves. Therefore, wherever it is possible at least a part of the groves should be mowed at higher heights in order to enable the comunication between terestrial arthropods and provide them a shelter. Finally, from the results of our research, it is clear that obviously, some arthropod groups react differently with the change of cutting height. For instance, Humbert et al. [25] reported that some tools like the hand-pushed bar mower can kill or cause injuries to caterpillars. Moreover, a tractor-pulled rotary drum killed or injured an average of 37% caterpillars. Using a conditioner that damage reached about 69%. When compared, flail mowers reduced the number of epigeic arthropods by 50% whereas bar or rotary mowing not caused significant damage. Regarding the height of grass cutting on the arthropod abundance, this fact should be taken into consideration when planning the soil maintenance in olive groves. Higher grass cover seems to offer a more complex habitat and better living conditions to the ground-dwelling arthropod fauna. Only one year of research could be the limitation factor of this paper. Hence, further research should be done on this topic for better understanding of the role of mowing height on arthropod abundance.

5. Conclusions

Ground cover as an element of ecological infrastructures present the habitat for arthropods and could increase their population and abundance in agroecosystems. Removing vegetation seems to harm epigeic soil fauna. However further research is required for this subject. In conclusion, the results of our research indicate that a higher height of grass cutting offers better conditions and provides shelter for some group of ground-dwelling arthropods. Furthermore, cover crops favored both some groups of beneficial species (Carabidae, Hymenoptera-Formicidae) and detritivores (Isoptera). In contrast, only Forficulidae are negatively affected by the presence of ground cover. These findings highlight the importance of different mowing heights in the conservation of ground-dwelling fauna. With regard to this research, it is recommended to increase the height of the mowing in order to preserve the arthropod fauna in the olive groves.

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