Commagene Journal of Biology

Tusun & Bozdoğan (2020) *Comm. J. Biol.* 4(2): 100-103.
DOI: 10.31594/commagene.783479

e-ISSN 2602-456X

Research Article / Araştırma Makalesi

Effects of Soil Substrate on the Ecological Features of the Sand Pit-building Antlions *Myrmeleon formicarius* Linnaeus, 1767 (Neuroptera: Myrmeleontidae) Larvae in the Amanos Mountains of Turkey

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Received: 21.08.2020 **Accepted:** 30.09.2020 **Published online:** 14.10.2020 **Issue published:** 31.12.2020

Abstract: The hunting behavior of antlion larvae is unique in the insect world and the soil characteristics may strongly affect their microhabitat selection. Therefore, the substrate type of sand pit construction is expected to have an important role in their traps. Different types of soil substrates can be inhabited by *Myrmeleon formicarius* Linnaeus, 1767 larvae. This study was conducted during 2018-2019 June-August in the Amanos Mountains of Turkey to examine the relationship between the microhabitat preference of larvae of *M. formicarius.* In this study, five substrate types were determined as particularly according to their habitat preference. In this study, the preference of fine-grained soils is found more adaptive because the pits are constructed in these substrates are more functional for longer periods and they are much more successful in trapping their prey than the coarse-grained soil pits. Furthermore, it was found that there is a direct relationship between the pit size and substrate particle structure. Therefore, the detection and selection of microhabitats under more convenient ecological conditions, which increase capture success and elucidate the hunting strategy, may be carried out during strong soil substrate selection for *Myrmeleon* Linnaeus species. It was concluded that there is no strong relationship between the soil substrate type, pH, and trap diameter.

Keywords: Neuroptera, *Myrmeleon*, sand pit building, ecology.

Toprak Substratının Amanos Dağları'nda Kumul Yuva Yapan *Myrmeleon formicarius* Linnaeus, 1767 (Neuroptera: Myrmeleontidae) Larvasının Ekolojik Özelikleri Etkisi

Öz: Karıncaaslanı larvalarının avlanma davranışı böcekler dünyasında eşsiz bir yere sahiptir ve toprak karakterizasyonu bu canlıların microhabitat seçimlerinde güçlü bir etkiye sahip olabilmektedir. Bu nedenle, konik-kumul tuzağın substrat yapısının tuzak inşasında önemli bir rolü vardır. *Myrmeleon formicarius* Linnaeus, 1767, farklı toprak substratlarında konuşlanabilmektedir. Bu çalışma, 2018-2019 Haziran-Ağustos ayları arasında, *M. formicarius* larvasının türünün toprak substratı ile microhabitat seçimi arasındaki ilişkiyi göstermek üzere Amanos Dağları'nda yürütülmüştür. Çalışma kapsamında habitat tercihlerine göre 5 substrat tipi tanımlanmıştır. Çalışmada, larvalarının yuva yapımında iyi elenmiş toprak partiküllerini tercih ettiği saptanmıştır. Zira bu tip topraklarda, kalın-kaba partiküllü topraklara oranla avlanma başarıları daha yüksek ve daha fonksiyonel olmaktadır. Dahası, yuva yarıçapı ile partikül yapısı arasında direkt bir ilişki bulunmaktadır. Bu nedenle *Myrmeleon* Linnaeus cins için uygun ekolojik koşullar altında avlanma başarı ve stratejisinde toprak türü seçimi önemli olabilmektedir. Çalışma sonucunda, toprak substrat tipi ve pH ile yuva yarıçapı arasında herhangi bir ilişkinin olmadığı saptanmıştır.

Anahtar kelimeler: Neuroptera, *Myrmeleon,* kumul yuva yapımı, ekoloji.

1. Introduction

The use of traps to aid the capture of prey was observed in a wide range of animal groups including insects (Alcock, 1972; Hansell, 1984). The ecological and ethological aspects of animal capture have received a great deal of attention (Griffiths, 1980). As an important function of the trap is to improve the catch efficiency, animals must design traps in such a way to maximize the probability of capturing their prey (Lucas, 1989). Most animal traps are made from self-secreting silk; therefore, antlions are rare among trap builders because they use only materials found in the environment (Franks, Worley, Falkenberg, Sendova-Franks, & Christensen, 2019).

The inverted conical pits are built by antlion larvae on the sand surface for capturing their prey (Devetak, Mencinger-Vračko, Špernjak, & Devetak, 2007). Antlion larvae (Neuroptera: Myrmeleontidae) are predators of small arthropods that are sitting and waiting after digging pits in loose soil in order to capture their prays to fall into funnel-shaped traps. After a victim falls into the pit, the larva attempts to capture it and inserts its mandibles. They tend to position their pits far enough from those of other antlions in mostly dry, shaded, and sandy areas in order to ensure that an optimal number of prey fall in. These larvae are commonly known as antlions since the most common arthropod in the pit traps is ants (Devetak et al., 2007). Antlion larvae can be discriminated in different particle sizes of different soil substrates (Farji-Brener, 2003; Levente, 2006; Devetak, 2008; Hollis, Cogswell, Snyder, Guillette, & Nowbahari, 2011; Devetak, Novak, & Janžekovič, 2012; Devetak, Podlesnik, Klokocovnik, & Janzekovic, 2013; Krivokhatsky, Shapoval, & Shapoval, 2014; Devetak & Arnett, 2015). Many ecologists have claimed that predation and climate have important effects on the

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population (Price, 1997). It is known that abiotic and biotic variables may interact, affecting populations through indirect effects. Several studies have shown that abiotic factors, such as soil moisture, litterfall abundance, temperature, rainfall, and soil compactness, may restrict the habitat available to antlions (Farji-Brener, 2003). Considering the hunting behavior of antlion larvae, microhabitat selection may be strongly influenced by soil characteristics (Gotelli, 1993). However, the construction of a pit in a suitable environment - where temperature, space between other pits, sand particle size, rainfall amount, and light-dark cycle are optimal - rather than an area where there are many preys is more important for antlions (Arnett & Gotelli, 2001).

The spatial distribution of the antlion larvae has been reported as strongly influenced by abiotic environmental factors such as physical disturbance and degree of soil dryness (Matsura, Yamaga, & Itoh, 2005). All living things require minimum amounts of certain essential elements with known biological roles and functions to maintain optimal health and productivity.

Soil can be ecological crossroad in terms of disposing of undesirable materials but also it is a transmitter of many contaminant chemicals as metals to surface–groundwater for living organisms (Giannakopoulou, Gasparatos, Haidouti, & Massas, 2012).

The presence of adequate amounts of minerals such as K, Ca, Mg, and Fe in the soil is partly dependent on the soil type and conditions.

The present study aims to investigate the soil substrate preferences of the pit- building antlion larvae *M. formicarius* that live in the Amanos Mountains of Turkey.

2. Material and Methods

2.1. Study Area

The Amanos Mountains draw attention because of its extraordinary natural heritage. These Mountains are located in the Mediterranean Region and they are one of the most intact areas of Turkey. This chain of mountains has very important natural areas with its flora, fauna diversity, and its sensitive ecosystems (Aytaç & Semenderoğlu, 2012). It has got 1580 plant taxa and 251 of which are endemic for Turkey (Baba & Doğan, 2018). It also contains so many plant taxa according to Mediterranean, Euro-Siberian, Irano-Turanian, and Cosmopolitan phytogeographical regions (Türkmen & Düzenli, 1998). In terms of genetic resources, mountain ecosystems have numerous important species, and, particularly, the mountains of Turkey have many endemic herbaceous species of the Anatolian Region (Türkmen, 2018).

2.2. Method

This study was carried out between June and August 2018 on the Amanos Mountains of Turkey. We collected soil samples around the zones to experimentally assess the relationship between the microhabitat preference of larvae and soil substrate types. To determine the direct and indirect effects of soil structure on the abundance of *M. formicarius*, we randomly established 8 plots as localities. All specimens were identified in the species level by Dr. Ali Satar at Dicle University in accordance with Badano and Pantaleoni (2014).

We classified them into four groups in terms of the locality types as in Figure 1. After sieving dry substrate samples, the collected substrate particle sizes were determined according to Devetak, Špernjak, and Janžekovič (2005). The mean annual rainfall was 1600–2100 mm and the mean annual temperature was 27°C in the survey area. Soil structure was classified based on its percentage of soil particles with different sizes (<2 mm to >5 mm). Each larva was put on the substrate with large particles. At each locality, the area of dense antlion pits was circumscribed and measured (Fig. 2). Pitfall trapping was conducted on 10 dates (6th,10th, 16th, 20th, and 28th June 2018 and 10th,12th,18th, 22nd, and 26th August 2019) at each of the 8 study plots. Soil samples were collected in a depth of approximately 0-25 cm. These were dried at 110°C, ground to pass through a 200-mesh sieve, and transferred to polyethylene bottles. The dried samples were ground to fine powder; then, the powdered samples were sieved using a standard set of sieves to diameter. Every powdered sample was shacked using an electric shaker to make sure that the sample was homogenized (El-Taher & Abdelhalim, 2014). The pH values of the soil samples were determined in a soil/water (1:2.5) suspension with a digital pH-meter.

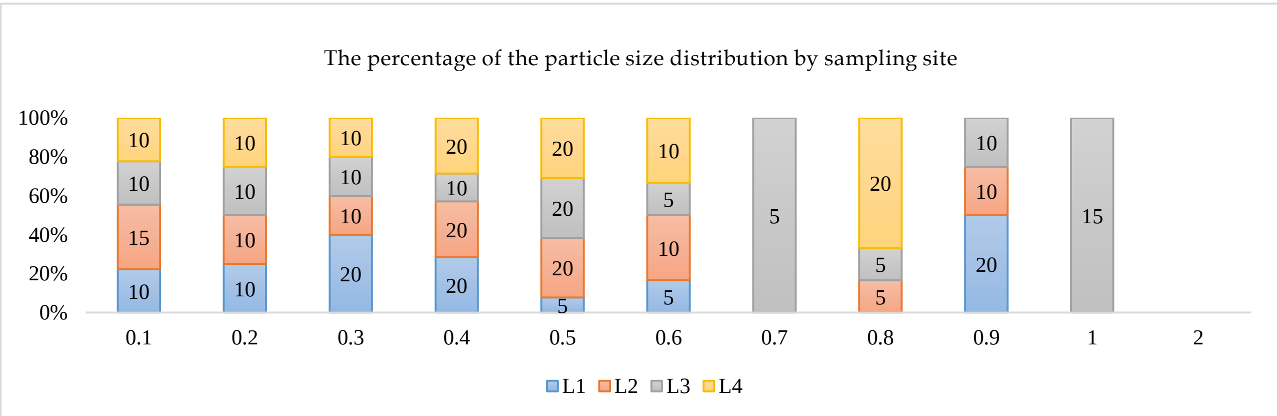

Figure 1. Particle size distribution in the different habitat types in the Amanos Mountains. L1: Locality type 1, L2: Locality type 2, L3: Locality type 3, L4: Locality type 4

Figure 2. Different soil substrate in survey areas

3. Results

In this study, 8 locality types listed below were observed and examined. Eight sand traps have been examined in each locality labeled as Loc A, B, C, D, E, F, G, H in Table 1. The distances to the nearest ant nest have been measured as min. 2900 and max. 12450 mm in the survey area. Four north and just one southwest direction pit trap showed in Table 2 were observed. Therefore, no soil particle size was bigger than 1.0 mm. Al, Si, K, Fe, Mn, Cu, Se, and Ni elements have been observed in normal levels symbolized as N. pH levels ranged from 4.2 to 6.1 in the different soil substrates.

4. Discussion

It was hypothesized by Devetak et al. (2012) that antlions larvae may be distinguished as their substrate type choice. Furthermore, pit diameter, pit depth, and pit angle of *Euroleon nostras* were determined to decrease significantly with substrate density. The effects of substrate density on site selection and pit characteristics were thoroughly investigated for the first time in their study. They concluded that antlions occupy places with different substrate densities varying from 121 to 1562 g/l in natural habitats. Furthermore, they stated that the higher was the substrate density, the lower were the pit diameter, pit depth, and pit angle when *E. nostras* larvae were forced to construct a pit in each of the eight-substrate densities (i.e., no-choice experiment).

Devetak et al. (2007) emphasized that the number of pits and the pit diameter depend on substrates with certain particle sizes. The most convenient substrate for capturing prey and forming pit is sand having a particle size of 0.23-0.54 mm.

Devetak and Arnett (2015) revealed that the composition of substrates in natural habitats and the effect of substrate particle size on-site selection are important for sand-dwelling antlion and wormlion larvae.

Heinrich and Heinrich (1984) observed the entrances of ant nests in the midst of patches of sand and they implied that there is a strong relationship between the antlions' sands and the locations of an ant nest.

Luna (1988) stated that organic soil fertility practices can provide supplies of secondary and trace elements, occasionally lacking in conventional farming systems that rely primarily on artificial sources of N, P, and K. Besides nutrient concentrations, optimum fertilization, which provides a proper balance of elements, can stimulate resistance to insect attack.

Table 1. The relationship between the soil substrate type, pH and trap diameter

Number of Locality Type	Type of Soil Substrate	pH	Trap diameter (mm)	Soil Elements Al	Si	K	Fe	Mn	Cu	Se	Ni
LocA	Fine gravel	5.4	8-17	N	L	N	N	N	N	L	L
LocB	Dark Brown Forest Soil	5.1	9-14	N	L	I	I	I	N	L	L
LocC	Laterite	4.4	11-18	N	L	L	N	N	N	L	I
LocD	Topsoil	4.2	7-15	N	N	N	I	N	N	N	I
LocE	Laterite	5.0	11-19	N	I	N	I	N	N	N	N
LocF	Humic	6.1	6-14	L	I	N	N	N	L	I	L
LocG	Silt	5.5	10-15	N	I	N	N	N	L	L	L
LocH	Loamy sand	5.9	21-26	I	N	N	N	L	I	L	L

L: Low, N: Normal, I: Intense, Loc: Localit

Table 2. Distance to the nearest ant nest (mm) in the survey area.

Distance to the nearest ant nest (mm)	The direction of Ant nest to the trap	Number of Locality
3000	North	L1 (Pit Trap Loc1B)
5400	North	L2 (Pit Trap Loc2D)
2900	South	L3 (Pit Trap Loc3H)
3850	East	L4 (Pit Trap Loc4C)
6000	Southwest	L3 (Pit Trap Loc3E)
6500	North	L1 (Pit Trap Loc1F)
12450	North	L4 (Pit Trap Loc4G)
12000	Northeast	L2 (Pit Trap Loc2A)

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