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Ground foraging ants (Hymenoptera: Formicidae) in Argane (*Argania spinosa*, L) ecosystem: Response to grazing impact

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ABSTRACT

Grazing is one of the important activities practiced by local farmers in the argane ecosystem. Agdal is the traditional management system linked to grazing management in this ecosystem. This work focused on grazing and Agdal impact on ground foraging ant community. Ant sampling using pitfall traps was occurred in three selected sites during two periods. Species richness, abundance and ant diversity per sample unit were compared between site 1 which is an open rangeland and two sites (2 and 3) where a seasonal defense for grazing and harvesting is applied (Agdal). Ants workers captured were belonging to 14 species, 10 genera and 3 subfamilies. *Monomorium salomonis obscuriceps* (Santschi, 1921) and *Pheidole pallidula* (Nylander, 1849) were the two predominated species during November-January period samples. They contribute to more than 50 % of dissimilarity between ant communities. A negative impact of overgrazing on diversity parameters was reported in site 1. Significant decrease of species richness, abundance and ant diversity per sample unit was observed during both sample periods in overgrazed site (site1) compared to the other sites where Agdal management system is applied.

Key words: Agdal, *Argania spinosa*, Biodiversity, Formicidae, *Pheidole pallidula*, *Temnothorax tameriensis*, *Tapinoma magnum*

INTRODUCTION

Ants are important components of terrestrial ecosystems in terms of biomass and diversity, playing a crucial role in their function (Hölldobler & Wilson, 1990). They live in various environments with diverse feeding habits and in association with other species, in particular, plants and insects (Hölldobler & Wilson, 1990). Ants are important ecologically because of their actions at many trophic levels in the ecosystem - as predators as prey, as detritivores, mutualists, and herbivores (Alonso, 2000). Ant communities appear to be perfect candidates as bioindicators (Majer, 1983; Nash *et al.,* 2004). According to Andersen & Majer (2004) ants monitoring has been successfully applied to a wide range of other land-use situations. They were used to monitoring ecosystem restoration following mining (Andersen, 1997), forest management (Arnan *et al.,*2009), conservation assessment (Hevia *et al.,* 2013) and grazing impacts (Bestelmeyer & Wiens, 1996; Nash *et al.,* 1999; Nash *et al.,* 2004; Hoffmann, 2010). In Morocco more than 85 % of land is classified as rangeland, which includes forests, steppes, high meadows, and Saharan lands. As a result of intensive grazing without proper management, the state of Morocco realized that millions of hectares of rangeland are being degraded, especially in the northeastern area, the *Argania spinosa* ecosystem, and the sub-Saharan and Saharan area (Nash *et al.,* 2014). Souss -valley and its surrounding mountains constitute an exceptional area, where *Argania spinosa* is exclusively endemic (Blérot & Mhirit, 1999). The argane forest has been declared as Biosphere Reserve in 1998. Argane tree has a major role in the ecology, economy, and social relations of the local communities (Ait Aabd *et al.,* 2013; Belyazid, 2000). Local farmers still practice traditional management system in Biosphere Reserve Arganeraie. The agro-sylvo-pastoral system in RBA is based on four major productions: billy goat, barley, wood and argane oil (Bourbouze & El Aïch, 2005). People from the argane region have developed a particular management system to protect fruits during maturation (Bourbouze & El Aïch, 2005). In the argane grove, a seasonal defense for grazing and harvesting is traditionally applied, called Agdal (Bourbouze & El Aïch, 2005). We hypothesis that this traditional management system practice (Agdal) has a positive impact on ants which are an important component of argane ecosystem, they represents the most specious and

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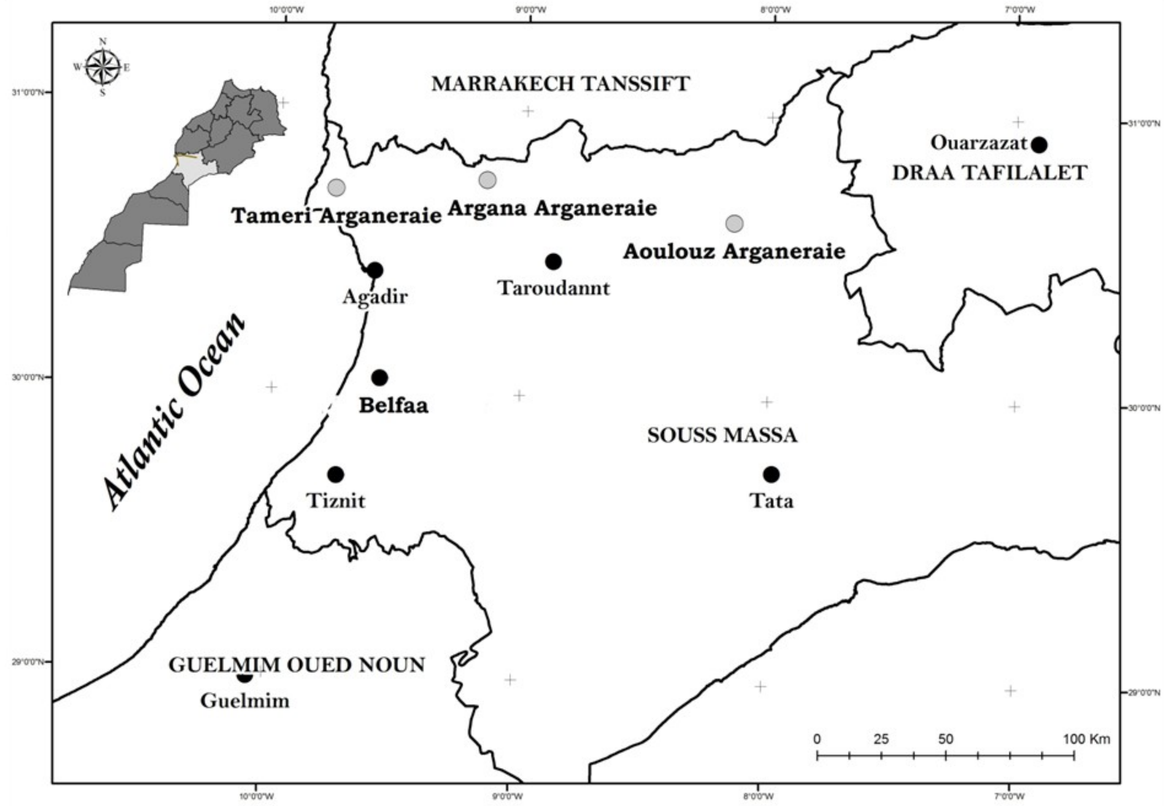

Figure 1. Map of the study sites (Grey spots)

abundant family, it represents more than 50% of total ground foraging arthropods (Ajerrar et *al.,* 2015; Ajerrar *et al.,* 2017). To confirm this hypothesis we suggest to compare ants species richness, abundance, and Shannon diversity between an overgrazing site and two sites where Agdal management system was applied.

MATERIALS AND METHODS

Study sites

This work has been conducted in three Argane ecosystem sites in Souss valley located in south-west of Morocco. The three study sites belong to the argane forest ecosystem. The first site (site 1) is located in Argana (30.7519869N, -9.1529756W), in the north-west of Taroudant, this site is an open rangeland without any management system; cattle's frequent daily this area. The second site (Site 2) is located in Aoulouz (30.62352N, -8.14542W) in Taroudant. The third site (Site 3) is located in Tameri (30.70672N, -9.76643W) in the north of Agadir (Figure 1, Table 1). Site 2 and Site 3 are managed plots for barley crops in the shade of argane trees and for argane fruits production. Barley cropping usually starts on first autumnal rain, and harvesting during late spring. The Agdal management system is applied in these two sites; farmers cannot harvest the argane fruits and bring their cattle until after a specific date which everyone knows.

Sampling

Ant sampling was carried out using pitfall traps, the predominant method for studying ant communities in rangelands and arid area (Agosti & Alonso, 2000; Read & Andersen, 2000; Nash *et al.,* 2004; Hoffmann, 2010). Pitfall traps measures are 16 cm in height and 9 cm in diameter (Gonçalves & Pereira, 2012; Assis *et al.,* 2018). In each site, twelve argane trees were selected separated from each other by 10 to 15 m. At each tree four pitfall traps were installed on four cardinal directions at about 80 cm from the trunk. Ant sampling was occurred during January 2016 to November 2016. Traps were carefully installed with minimal soil and litter disturbance. The traps were filled to 1/3th with salted water (10g/L) mixed with drops of natural soap. The traps were removed to laboratory 24 hours after installation. In the laboratory, ants were separated from other soil fauna and rinsed with tap water to remove plant debris and the rest of the soil; then conserved in ethanol 70%. Ant identifications was made to species and genus level using stereomicroscope and appropriate keys and catalogs (Bolton, 1994; Cagniant, 1996a; Cagniant, 1996b; Cagniant, 1997; Cagniant & Espadaler, 1997; Cagniant & Espadaler, 1998; Cagniant, 2006; Cagniant, 2009; Borowiec, 2014) in the laboratory of entomology, integrated crop production unit, at National Institute of Agronomic Research (INRA). Doubted specimens were identified by Dr. Henri Cagniant (ex-professor of University Paul Sabatier Toulouse). Voucher specimens are available at INRA Entomology laboratory (Agadir, Morocco).

Data analysis

Due to ant seasonality activity in argane ecosystem proved by El keroumi *et al.* (2012) samples were pooled into two periods; (November-January) and (April-

Table 1. Study sites characteristics

Sites	Locality	Altitude (m)	Climate	Types of Soil	Average Trees density (Ha)	Aver-age tree hight (m)	Main Associate plants	Anthropogenic activity/ management system
Site 1	Argana	775	Arid	Laomy with weak litter layer	50	5	*Rhus pen-taphylla, Ziziphus lotus, Launaea arbo-rescens*	open rangeland without proper management
Site 2	Aoulouz	784	Arid	Laomy with weak litter layer	80	7	*Ziziphus lotus, Launaea arbo-rescens*	Barley crops, Grazing/ Agdal
Site 3	Tameri	86	Arid	laomy with relative dense litter layer	100	5	*Olea europaea, Genista sp, Drimia sp, Euphorbia offi-cinarum, Ononis natrix.*	Barley crops, Grazing/ Agdal

August). Software package Paste 3 (Hammer *et al.,* 2001) was used to compute ant richness (S), ant species abundance (N), and Shannon diversity index (H). To avoid overvalue abundance of species forming trails, abundance classes was assigned according to Read & Andersen (2000); 1=1 ant, 2=2-5 ants, 3=6-20 ants, 4=21 -50 ants, 5=51-200 ants and 6>200 ants. Ant data recorded were analyzed by ANOSIM and SIMPER (Bray-curtis index, 9999 permutation) test. The main objectives of this analysis were to assess dissimilarity on ant community between the three sites among the two sampling periods and species percentage contribution on dissimilarity. The number of total expected ant species in each study site among the two periods was computed by Estimate S (Colwell, 2006) based on the number of rare species and 100 time randomization. The mean and SD of species ant richness were computed for the 12 samples units in each site. The expected richness function Mao Tau and 95% CI curve was estimated from 100 randomizations. The obtained data of ant diversity (abundance, richness, Shannon index) were subjected to ANOVA one way at $p<0.05$. Newman-Keuls post hoc test at 95% confidence limit was used to compare mean value. To avoid impact of seasonality, data obtained from each study site was compared during each period.

RESULTS

Ant fauna

Sampling effort yielded a total of 12.664 ant workers in the three sites during the two samples periods. Ants workers captured are belonging to 14 species, 10 genera and 3 subfamilies. Myrmicinae (9 species) and Formicinae (4 species) were the most speciose subfamily whereas Dolichoderinae represented only by one species. Up to 67 % of total ants were captured during April-August period however less than 33% were captured during November-January period. *Monomorium salomonis obscuriceps* was the most abundant species in both sites 1 and 3 however *Pheidole pallidula* was the most abundant species in site 2. Ant species per sample unit (tree) varied from 0 species in site 1 for only one sample unit to 9 species in site 3. The expected ant richness curves obtained from 100 randomization of samples order tend to decrease with adding samples, therefore sampling effort was sufficient (expected ant richness were similar to observed richness in almost all samples in the three studied sites) (Figure 2). Ant communities of the three studied sites were different with some overlap during November-January period, where ant community of site 2 and 3 shows a low dissimilarity ($R=0.28$; $P=0.0002$), however a relatively high dissimilarity of ant community was reported between site 1 and 3 ($R=0.44$; $P=0.0001$). During April-August period, ant community of the three studied sites was different to highly different without overlap, thus, the highest dissimilarity were reported between site 2 and site 3 ($R=0.96$; $P=0.0001$), as well as between site 2 and site 1 ($R=0.7$; $P=0.0001$) (Table 2). *Monomorium salomonis obscuriceps* and *Pheidole pallidula* contribute to more than 50 % of dissimilarity between ant communities during November-January period. However, a similar dissimilarity percentage contribution of several ant species was shown during April-August period, nevertheless, the high contributed dissimilarity percentage was computed for *Aphaenogaster praedo* Emery, 1908 (15.20 %) and for *Pheidole pallidula* (14.36 %) (Table 3).

ANOVA one way ($p=0.05$) analysis of mean species richness, Shannon diversity and mean species abundance computed per sample unit (tree) showed a significant difference comparing mean computed in each site and during the tow sampling periods. Mean species richness (November-January: $F= 16.95$, df. 33, $P<0.00001$; April-August: $F=16.53$, df. 33, $P<0.0001$). Low species richness was recorded in overgrazed site (site1) whatever the sampling periods compared to managed sites (site 2 and 3). Therefore, Newman-Keuls post hoc test (at 95% limit of confidence) showed a significant difference between site 1 and the two other sites (Figure 3). Low abundance was recorded in site 1 during both periods;

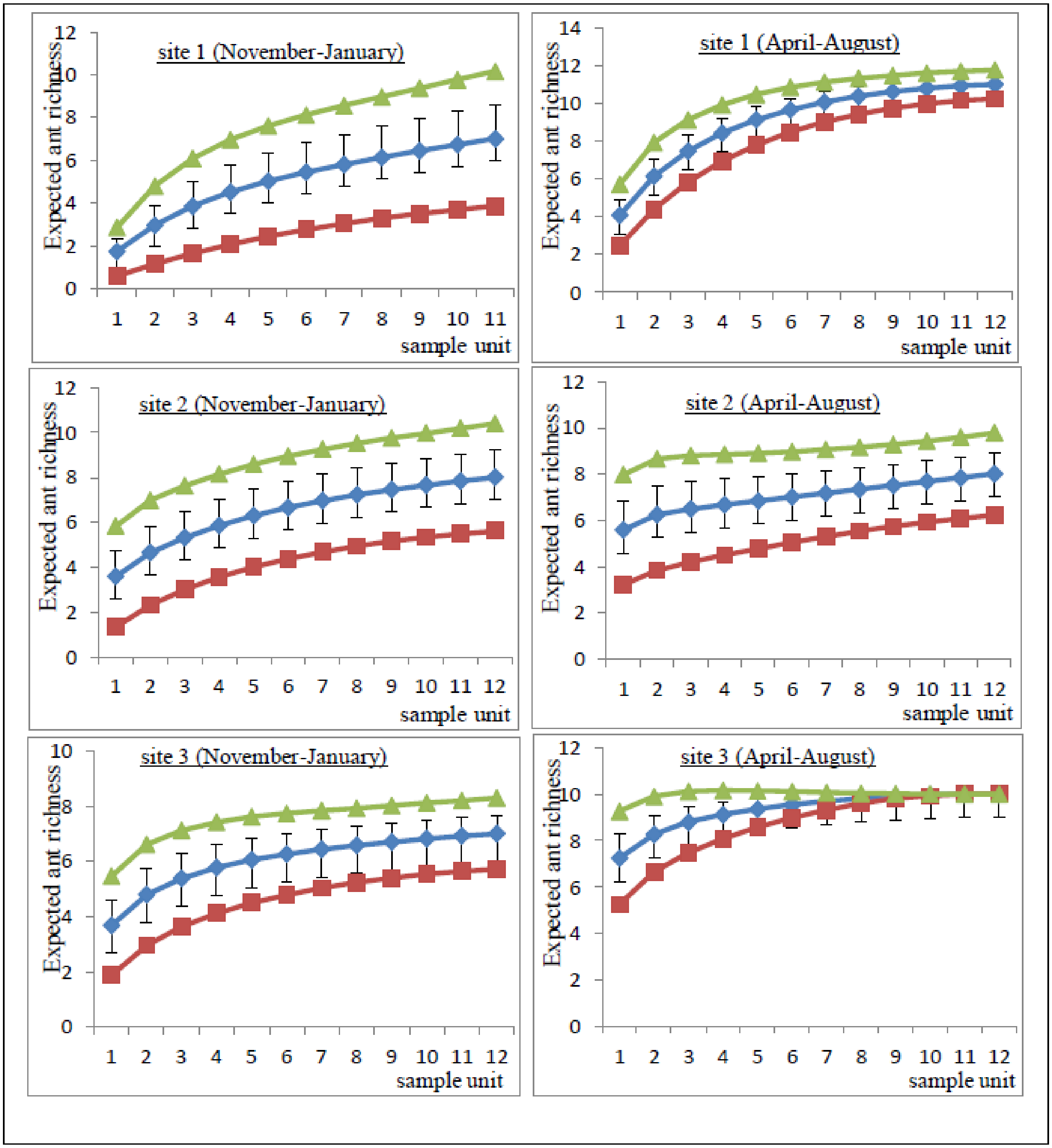

Figure 2. Expected ant richness (mean ± SD) function Mao Tau computed among two periods at each study site.

November-January (2.41±1.6) and April-August (9.42±4), however, a higher abundance was recorded in site 3 during April-August (23.58± 4.6). A high and similar abundance value was recorded in both sites 2 and 3 during Autumn-January. Significant difference among the three sites was reported comparing mean abundance (Autumn-January: F= 28.32, df. 33, P<0.000001; April-August: F=41.55, df. 33, P<0.0001) (Figure 3). Low ant diversity was reported during November-January period in three studied sites; however relative increase was shown during April-August period. Significant difference between site1 and the other sites were reported comparing Shannon diversity index (Autumn-January: F= 21.82, df. 33, P<0.00001; April-August: F=17.51, df. 33, P<0.00001). The lowest value of Shannon diversity index was recorded in site 1 (0.39±0.3) during November -January, while a significant increasing was observed during April-August (1.22±0.40) in the same site (Figure 3).

DISCUSSION

Ant ground foraging below argane trees in Souss valley were composed of 14 species. *Temnothorax tamriensis* was the new ant species reported in Morocco (Ajerrar *et al.,* 2018). All captured species are native and no invasive species has been captured. Low ant richness reported in this study was reported elsewhere (Cerdá *et al.,* 2009; El Keroumi *et al.,* 2012; Gonçalves & Pereira, 2012; Barech *et al,* 2018). Diversity parameters computed in

Table 2. Similarity computed among seasons of ant communities between study sites. ANOSIM R values and their corresponding P (between brackets).

Sites	November-January		April -August	
	site 2	site 3	site 2	site 3
Site 1	0.3496 (0.0001)	0.4469 (0.0001)	0.5184 (0.0001)	0.7 (0.0001)
Site 2		0.2822 (0.0002)		0.9672 (0.0001)

Table 3. average dissimilarity and contribution percentage computed by SIMPER of ant species among study sites during each period.

	November-January		April-August	
Taxon	Av. dissim	Contrib. %	Av. dissim	Contrib. %
Monomorium salomonis obscuriceps	20.28	29.59	6.18	10.54
Pheidole pallidula	16.07	23.44	8.43	14.36
Aphaenogaster praedo	12.29	17.93	8.92	15.20
Messor marocanus	6.27	9.14	5.02	8.56
Tapinoma magnum	4.01	5.85	6.33	10.79
Tetramorium semilaeve depressum	2.97	4.33	3.98	6.78
Camponotus brullei	1.89	2.76	3.73	6.35
Cataglyphis albicans vaucheri	1.83	2.66	5.39	9.18
Camponotus erigens	1.50	2.19	6.03	10.28
Temnothorax sp1	0.83	1.21	0.38	0.64
Temnothorax tameriensis	0.61	0.90	2.08	3.54
Temnothorax sp2	0.00	0.00	0.33	0.57
Cataglyphis viatica	0.00	0.00	0.38	0.65
Crematogaster scutellaris algirica	0.00	0.00	1.51	2.57

(Av. dissim= average dissimilarity; Contrib.%= % of contribution)

each site were different between the two sampling periods. Indeed, a high value was computed during warm and dry season (April-August), however, lower values were computed during wet and cold season (November-April). The same finding was reported by El Keroumi *et al.* (2012) study and within the same site the difference may be explained by the seasonality pattern of ground ant foraging activity under argane tree. The obtained results show a significant impact of overgrazing on ant diversity, species richness and abundance per sample unit. Similar studies conducted in arid climate elsewhere reported the negative impact of grazing on ant richness (Nash *et al.,* 2001), richness and relative abundance of some species (Bestelmeyer & Wiens, 2001), abundance (Debinski *et al.,* 2011) and species diversity (Abensperg-Traun *et al.,* 1996). Moreover, grazing impact on ant is worldwide proved in different ecosystems (Hoffmann, 2010). The site 1 located in Argana arganeraie which is overgrazed without any management system shows a significant decrease in abundance, richness and diversity per sample unit compared to the other two sites where traditional management is applied. This significant decrease of the three studied diversity parameters recorded in the site 1 could be explained by alteration of the vegetal cover due to intensive grazing. According to Andersen (1995), grazing disturbance acts indirectly through change in vegetation structure, food supplies and competitive interactions. In addition, the ripe and ripening argane fruits are known as suitable environment for insect's development and are heavily infected mainly by Mediterranean fruit fly *Ceratitis capitata* (Debouzie & Mazih, 1999). The fact that these fruits are consumed by livestock for its pulp (Bourbouze & El Aïch, 2005) before emergence of insect's larva may reduce ant's food resource availibility and impacts negatively their population size and diversity. According to El Keroumi *et al.* (2010), 96% of *C. capitata* larva were captured by ants under argane trees in Essouira argane forest.

Based on different ant studies conducted in Mediterranean ecosystems and our field observations, the ant species associated to arganeraie ecosystem can be classified into three main groups according to feeding behavior: generalist/omnivorous species, seed feeder, and insect, honeydew and nectar feeder. Therefore, four species (*P. pallidula, T. semilaeve, M. salomonis, A. praedo*) are belonging to to generalist feeders. However, *M. maroccanus* is only a seed / generalist feeder. Three species are belonging to insectivore/animal feeder (*C. albicans*, *C. viatica* and *C. scutellaris*). In addition, *T. magnum* was shown to visit Argane trees for Aphid's honeydew and argane flower nectar (Ajerrar *et al*., 2020). Pheidole P. pallidula and T. semilaeve are two omnivorous ant that collect animal and plant remains in similar proportion and that rarely climb the plants to collect liquid food

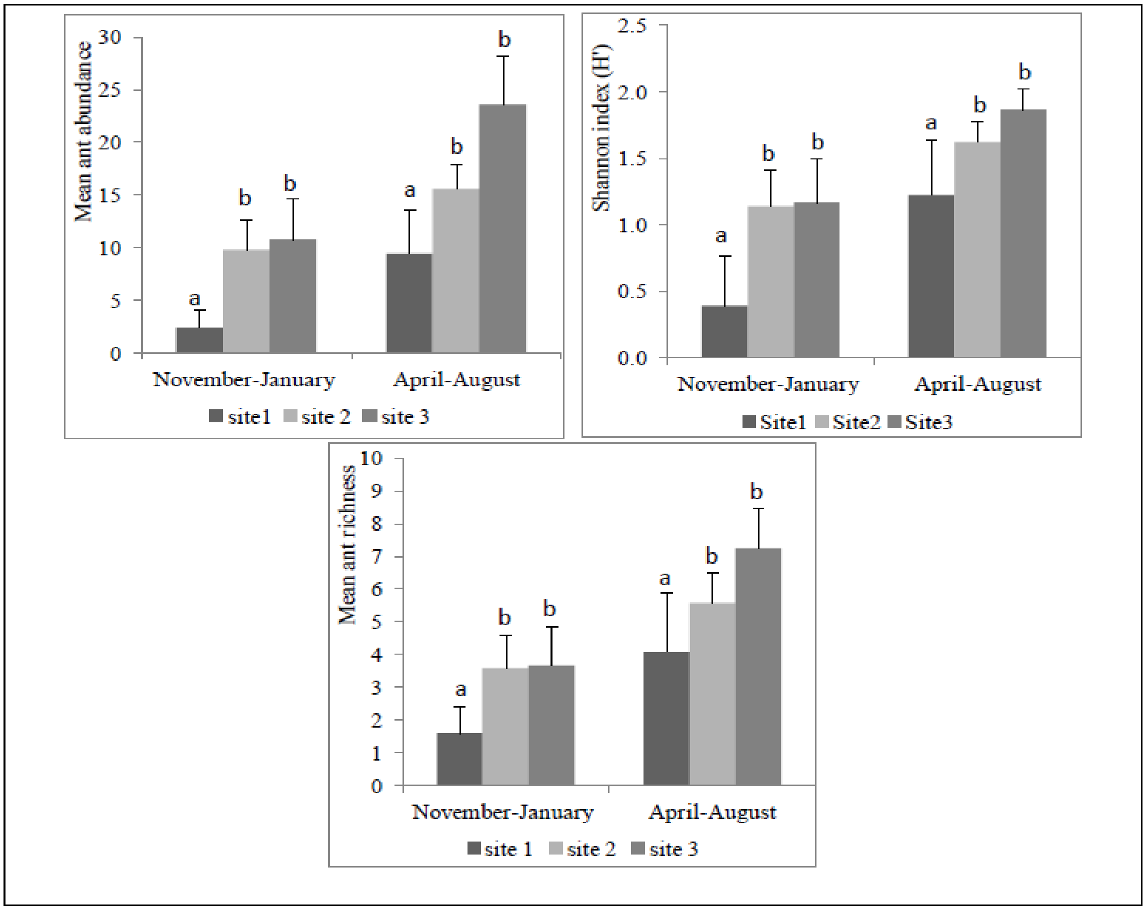

Figure.3. Ant species richness, ant abundance and Shannon's diversity index (mean values ± SD) computed during the two sampling periods at each study site. The letters on the graphs denote the significant differences (Newman-keuls post hoc test at 95% limit confidence).

(Retana *et al*., 1992). *M. salomonis* and *A. praedo* were observed to prey in *C. capitata* larva and plant (per obs). In contrast, Segev & Ziv (2012) study state that *M. salomonis* is a generalist seed-feeder. According to Santini *et al*. (2011) *C. scutellaris* is a common ant widely distributed in both natural and managed ecosystems throughout the Mediterranean area, it occupied a high rank of dominance that has a high ability to discover and to monopolize food sources (Santini *et al*., 2007).

CONCLUSION

Despite the resilience of ant communities in arid area to disturbance noted elsewhere (Nash *et al.,* 1998; Whitford *et al.,* 1999) overgrazing occurred in open rangeland of argane ecosystem impact negatively richness, abundance and diversity of ants. In the other hand, Agdal management system adopted by local farmers either in their own orchards or in collective ones shows the importance of this traditional management to preserve ant communities in argane ecosystem.

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