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**Exploring the effect of soil management intensity on taxonomic
and functional diversity of ants in Mediterranean olive groves**

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11 **Abstract**

- 12 1. Agricultural intensification is one of the major drivers behind biodiversity loss in
13 Mediterranean agroecosystems. The intensification of olive groves as monoculture
14 in large areas of the southern Spain have had important effects on biodiversity and
15 ecological processes.
- 16 2. We explore the olive grove soil management practices effects on taxonomic and
17 functional diversity of ants, along a gradient of soil management intensity. We
18 predict that both species richness and functional diversity decrease with increasing
19 intensification of olive grove soil management. We used pitfall traps to sample ants
20 in 24 olive groves subject to different soil management regimes in southern Spain,
21 and then compared ant species richness and functional diversity (FD).
- 22 3. Non plowed organic farms showed higher species richness. Plowing was observed
23 to be the soil management practice with the greatest negative effect on ant species
24 richness.
- 25 4. Three functional traits significantly responded to soil management intensity, with
26 tibia length and head width showing a higher FD in organic farms and diet showing
27 a lower FD in plowed farms.
- 28 5. Our results highlight the negative effects of olive grove plowing on ant biodiversity
29 and provide novel evidence of the non plowing organic farming role in maintaining
30 higher levels of ant functional diversity.

31 **Keywords:** Biodiversity, functional traits, management intensity, Mediterranean
32 agroecosystems, olive crops.

33

34 **Introduction**

35 Since the 1950s, industrialization and growing human populations have accelerated several
36 deep changes in ecosystems to satisfy society's rapidly growing and changing demands
37 (Vitousek *et al.*, 1997). In Mediterranean agroecosystems, agricultural intensification is
38 considered a major driver behind ecosystem degradation and biodiversity loss (SNEA,
39 2011). As a general rule, agricultural intensification entails different degrees of landscape
40 simplification and homogenization, leading to a loss in the multifunctionality of
41 agroecosystems and an overall decline in farmland biodiversity (McLaughlin & Mineau,
42 1995; Benton *et al.*, 2003; Medan *et al.*, 2011; Hevia *et al.*, 2015).

43 In Mediterranean Spain, olive groves have been the main agricultural land use for centuries.
44 This crop has changed significantly since the mid 20th century (Sokos *et al.*, 2013), after
45 European Common Agricultural Policy (CAP) subsidies prompted intensification practices
46 such as irrigation, mechanization and chemical inputs (mainly biocides and fertilizers)
47 (Martínez *et al.*, 2008; Marañón *et al.*, 2012). The generalization of these management
48 practices has triggered the spread of olive groves in places such as the Autonomous
49 Community of Andalusia (southern Spain), resulting in a deep landscape transformation
50 (Martínez Sastre *et al.*, 2017). This intensification process peaked from 2005 to 2015, when
51 production increased by more than 20%. Today, olive groves occupy up to 30% of usable
52 agricultural land and 17% of the whole territory of Andalusia, comprising 15% of the
53 world's olive grove area (Junta de Andalucía, 2016). In Sierra Morena and the
54 Guadalquivir Valley (Jaén, Spain), olive groves became a monoculture rather than the
55 previous multifunctional, mosaic like cultural landscape, and this region is currently
56 considered the largest olive monoculture landscape worldwide (Martínez *et al.*, 2008).

The CAP subsidy system made olive cultivation more profitable than other crops and triggered strong changes from traditional practices to agro industrialization. As a result, olives were planted in places where they had never been before (e.g., steep slopes or river beds), replacing other traditional land uses (e.g., holm oak *dehesas*) (García Brenes, 2012). This phenomenon has had several impacts on biodiversity and ecological processes (Martínez *et al.*, 2008; Parras Alcántara *et al.*, 2016), generating significant environmental damage such as soil erosion and loss of natural habitat refuges (García Brenes, 2012). Alternatively, soil conservation and organic farming are currently being fostered by EU policies. Organic olive farming, in particular, is gaining increasing attention in the Autonomous Community of Andalusia, following an increase in consumer demand for organic olive oil (Alonso Mielgo, 2011; MAGRAMA, 2013). Environmental and socioeconomic benefits of organic olive management include erosion control, reduction of pesticide residues, and increase in edaphic organic material (Sánchez, 2004; Cárdenas *et al.*, 2006; Guzmán & Alonso, 2008).

Among other groups of arthropods, ants have been widely used to assess the impacts of soil management practices (Cotes *et al.*, 2011; Redolfi *et al.*, 1999; Santos *et al.*, 2007a; 2007b). Ants are considered a key group because of their huge biomass (Hölldobler & Wilson, 2009) and their important role in terrestrial ecosystem function (Folgarait, 1998). Exclusion experiments in various agroecosystems indicate that species rich ant communities produce positive net effects on yields (Wielgoss *et al.*, 2014, Gras *et al.*, 2016). Although ants are also involved in some disservices (Mody *et al.*, 2011, Wielgoss *et al.*, 2014), they contribute to sustain many ecosystem services (Del Toro *et al.*, 2012; Noriega *et al.*, 2017; Diamé *et al.*, 2018) such as pest control (Offenberg, 2015, Milligan *et al.*, 2016), weed control (Baraibar *et al.*, 2009), and several soil based services (Sanabria *et al.*, 2014).

Moreover, key ecosystem services (e.g., pest control) may be the result of indirect interactions emerging from the self organization of complex, species rich systems rather than simple, direct effects driven by a single ant species (Vandermeer *et al.*, 2012). This finding is consistent with the correlation between diversity and resilience observed in a number of agroecosystems (Del Toro *et al.*, 2012; House *et al.*, 2012), which becomes more evident when functional diversity is considered (Hevia *et al.*, 2013; Sanabria *et al.*, 2014).

There is extensive scientific evidence that olive grove intensification causes a decline in the diversity of ants and other soil arthropods (Cotes *et al.*, 2011; Jerez Valle *et al.*, 2014; Santos *et al.*, 2007a; 2007b; Ruano *et al.*, 2004). However, compared to studies on ant taxonomic diversity, it is noteworthy that there are very few studies investigating the effects of olive grove soil management intensification on any variable measuring ant functional diversity.

In this study, we explore the effects of different olive grove soil management regimes on the species richness and functional diversity of ants, along a gradient of soil management intensification. We predict that both species richness and functional diversity of ant assemblages decrease with increasing intensification in olive grove soil management. Finally, we discuss the implications of achieving more taxonomically and functionally diverse ant communities for olive grove sustainability under the current CAP priorities.

Materials and Methods

Study area

The study site is located in the Autonomous Community of Andalusia (Spain) within the municipalities of Bailén, Linares and Guarromán (see Supporting information, Fig. S1). The area is characterized by a continental Mediterranean climate, with a mean annual precipitation of 470 mm and a mean annual temperature of 16°C. The elevation of the study site ranges from 340 to 420 m.s.l.

Tertiary sedimentary rocks are the dominant lithology, mainly sandstones, clays and loams.

Olive orchards are the main land use, comprising approx. 85% of cultivated lands in the study area.

We selected 24 plots (olive orchard farms) in the study area, grouped into four soil management regimes along a gradient of intensification: (a) non plowed organic farms, (b) integrated farms, (c) conventional fully sprayed farms, and (d) conventional plowed sprayed farms (Fig. 1). Six plots were selected from each soil management regime.

Non-plowed organic farms represent the least intensive soil management regime in our sample, characterized by non use of chemical fertilization or pesticides, and by mechanical or manual elimination of weeds, without any plowing techniques. *Integrated farms* represent the medium level of soil management intensification in our sample, characterized by the use of chemical products for controlling weeds under canopy, but not between tree rows, where weeds are mechanically mowed. Moreover, mulch is added between rows to prevent soil erosion.

The other two soil management regimes represent a higher degree of intensification, including some level of spraying and/or plowing. *Conventional fully-sprayed farms* are characterized by fully spraying the olive orchards with herbicides (usually glyphosate) to control weeds. *Conventional plowed-sprayed farms* are characterized by spraying herbicides under tree canopy and plowing between tree rows.

To avoid other factors that might influence ant diversity, we controlled for the lithology and slope (<5%). All the sampled olive orchards were the *Picual* variety and had a planting pattern between 8 x 8 m and 6 x 7 m. In addition, we selected only rain fed plots, which is the most widespread condition in the study area.

Sampling design and data collection

In each plot, we established an initial random point (at least 20 m from the farm access to avoid border effects). From each initial point, 10 pitfall traps were systematically placed every 10 meters, alternating traps under tree canopy and between tree rows (see Supporting information, Fig. S2; 240 pitfall traps in total). Traps were 2.5 cm in diameter and 5 cm deep, containing a mixture of 70 % ethanol and 30 % monoethylene glycol (Azcárate & Peco, 2012; Hevia *et al.*, 2013), and were left in the field for seven consecutive days. Sampling was concentrated in July, taking advantage of the seasonal activity peak of most Mediterranean ant species (Cros *et al.*, 1997; Gómez *et al.*, 2003; Azcárate & Peco, 2012; Hevia *et al.*, 2013). Despite some limitations (e.g., some ants might not be detected), pitfall traps are considered the most objective, impartial and rapid method to sample ground dwelling ants (Andersen, 1991; Agosti *et al.*, 2000; Nash *et al.*, 2004).

Ants were identified to the species level with a binocular microscope and were then characterized according to four functional traits: eye length, head width, tibia length and diet. These four traits are commonly used in studies on the functional composition of ant communities because of their high correlation with a number of physiological, ecological, and life history traits and their value in understanding ant strategies to obtain resources, their response to environmental conditions and their effects on other components of the ecosystem (Weiser & Kaspari, 2006; Bihn *et al.*, 2010; Silva & Brandão, 2010). To

measure the three quantitative traits (eye length, head width, tibia length), we randomly selected ten individuals per species from the whole sample. The qualitative trait diet was obtained from Azcárate & Peco (2012) and Hevia *et al.* (2013).

Data analysis

Each plot was characterized by species richness per plot, mean species richness per trap, and functional diversity of each functional trait. We calculated functional diversity using the Rao index:

$$Rao = \sum_{i=1}^S \sum_{j=1}^S d_{ij} p_i p_j$$

where d_{ij} is the dissimilarity in trait values between each pair of coexisting species i and j , while p_i and p_j indicate the relative abundances of species i and j , respectively, in the community under consideration (Ricotta & Moretti, 2011).

We analyzed the effect of olive grove soil management on species richness and functional diversity using Generalized Linear Models (GLMs), including the position in the field (under tree canopy vs. between rows) as a within subject factor. Poisson distribution was used for species richness per plot (a count data variable), and Gaussian distribution for the rest of variables. A log link function was used both for species richness per plot and mean species richness per trap, and identity link function for the rest of variables. All data analyses were performed using the statistical package SPSS, version 18.0 (SPSS, 2009).

Results

A total of 6,248 ant workers belonging to 21 species were captured (Table 1). Seventeen species were recorded at non plowed organic farms (of which one was exclusive to this soil management regime), 17 at integrated farms (of which 2 were exclusive to this soil management regime), 17 at conventional fully sprayed farms and 14 at conventional plowed sprayed farms.

Ant species richness

Soil management regime had a significant effect on species richness per plot (Wald's $\chi^2 = 14.56$, d.f. = 3, $P = 0.002$). Species richness in organic farms and integrated farms was significantly higher than in conventional plowed sprayed farms (Wald's $\chi^2 = 14.06$, d.f. = 1, $P < 0.001$; and Wald's $\chi^2 = 4.40$, d.f. = 1, $P = 0.036$; respectively) (Fig. 2; Supporting information, Table S1).

Soil management regime also had a marginal effect on the mean species richness per trap (Wald's $\chi^2 = 6.58$, d.f. = 3, $P = 0.087$), with organic farms showing higher values than conventional sprayed farms (Wald's $\chi^2 = 6.29$, d.f. = 1, $P = 0.012$) (Fig. 3; Supporting information, Table S2).

Functional diversity

Rao index values for head width varied among soil management regimes (Wald's $\chi^2 = 13.14$, d.f. = 3, $P = 0.004$), being significantly higher in non plowed organic farms than in the other three regimes (Fig. 4; Supporting information, Table S3).

Tibia length diversity also varied among soil management regimes (Wald's $\chi^2 = 11.35$, d.f. = 3, $P = 0.010$), being significantly higher in organic farms than in the other three soil management regimes (Fig. 4; Supporting information, Table S4). However, no significant

differences among regimes were found for eye length (Wald's $\chi^2 = 2.24$, d.f. = 3, $P = 0.523$) (Fig. 4; Supporting information, Table S5).

Diet diversity showed significant differences among soil management regimes (Wald's $\chi^2 = 14.61$, d.f. = 3, $P = 0.002$), being lower in conventional plowed sprayed farms than in non plowed organic farms (Wald's $\chi^2 = 9.135$, d.f. = 1, $P = 0.03$). Further, diet diversity was significantly higher in traps under canopy than in traps between rows (Wald's $\chi^2 = 5.846$, d.f. = 1, $P = 0.016$) (Fig. 4; Supporting information, Table S6).

Discussion

Our study shows that ant assemblages respond to olive grove soil management, both in taxonomic and functional terms. However, the effects were more significant between the extremes of the soil management intensification gradient. Non plowed organic and integrated olive groves showed a higher species richness when compared to conventional plowed sprayed farms. Further, three of the four studied functional traits also responded to soil management, with higher FD of tibia length, head width, and diet in organic farms.

How does olive grove intensification affect ant diversity?

Many previous studies have explored the role of soil invertebrates (e.g., nematodes, collembolans, or mites) in forest and agricultural management (Ponge, 2003; Aspetti *et al.*, 2010). However, the highly intensive soil management practices used in conventional olive groves may hinder the presence of many of these organisms. In contrast, ants are able to survive such intensive soil management as herbicide application in olive groves, which may affect the structure and dynamics of other arthropod assemblages (Chong *et al.*, 2010; Ottonetti *et al.*, 2010). Moreover, ants are considered semi sessile organisms (Vandermeer

& Yitbarek, 2012), so they might be expected to be useful for evaluating changes related to soil agricultural practices at the local scale.

Our results show that ant richness values are higher in non plowed organic olive groves and integrated farms than in conventional plowed sprayed farms. In other words, we found that ant richness declined in the more intensive olive grove soil management regime, characterized by the use of mechanical plowing. The plowing techniques may partially or totally destroy the nests of ants that live in soil. Although the changes in the composition of ant communities caused by plowing are not necessarily permanent, it is important to note that these changes can generate negative effects on several ecosystem functions and services (e.g., biological control, soil erosion prevention) (Perfecto & Castiñeiras, 1998).

On the other hand, herbicide spraying techniques eliminate the wild plant cover between olive rows, thereby decreasing soil organic matter (Vance, 2000) and the biological populations in soil (García *et al.*, 2005) and increasing the effects of raindrop impact (Folorunso *et al.*, 1992). However, our results suggest that the exclusive use of spraying techniques in olive groves soil does not imply a significant reduction in ant richness values compared with the non spraying soil management regimes. These results may be because most ant species detected are minimally dependent on resources provided by the wild plants that are eliminated with fumigation techniques. Moreover, it seems that the effects of plowing occur in a shorter period than herbicide application (Campos *et al.*, 1996). Thus, further studies of the real effect of herbicide application on ants would be better carried out by using long term designs.

What do ant functional traits tell us?

Our findings suggest that functional diversity in ant communities decreases slightly with increasing intensification of olive grove soil management. More specifically, three traits significantly responded to soil management regime. FD in the diet showed a significant reduction in the conventional plowed sprayed farms compared to non plowed organic farms. This is consistent with the fact that all the soil practices applied in this regime, particularly plowing, imply a strong simplification of the system, which inevitably limits the range of available trophic resources for ants.

At the opposite extreme of intensification, non plowed organic farms showed a higher FD in tibia length (a proxy for leg length) and head width. Longer legs allow a higher speed and improve the ability to carry loads over longer distances and are consequently more useful in open and planar habitats, where moving in straighter lines is particularly advantageous (Kaspari & Weiser, 1999; Parr *et al.*, 2003; Pearce Duvet *et al.*, 2011). Conversely, shorter legs reduce the cross sectional area of worker ants and allow more maneuverability in highly rugose or interstitial habitats (Sarty *et al.*, 2006, Gibb & Parr, 2010). All the sampled olive groves were essentially open and planar environments, suitable for long legged ants. However, soil conservation techniques (used particularly in integrated and non plowed organic farms) produce a greater small scale complexity, which probably allows higher FD in leg length.

On the other hand, FD in head width (proxy of body size in ants) also showed higher values in organic farms. Body size is considered a key trait, since it is correlated with a large number of physiological, behavioral, ecological and life history traits (e.g., ingestion, respiration, age, longevity, prey size, colony size; Weiser & Kaspari, 2006; Bihn *et al.*, 2010; Moretti *et al.*, 2017). Having a wide range of body sizes, some ant species could benefit from their potential capacity to collect some hard to find resources (da Costa

268 Milanez *et al.*, 2017). Although it is not easy to determine the detailed mechanisms
269 explaining the higher FD in head width observed in organic farms, our results probably
270 reflect the higher environmental complexity, with the consequent increase in the number of
271 niche options offered by non plowed organic farms. Ultimately, the reduced soil
272 management of organic farms may provide the ant community with a greater range of ways
273 of getting resources and interacting with the system. Body size is a trait that primarily
274 responds to large scale factors, such as climate (Reymond *et al.*, 2013), although it is also
275 linked to the preference for simple vs. complex environments, similar to the trait of leg
276 length (Kaspari & Weiser, 1999; Gibb & Parr, 2010). Our observations suggest that micro
277 scale factors mainly act on leg length (as explained above) and body size.

278 By contrast, we did not find differences in the FD of eye length, suggesting that factors
279 affecting eye size would operate in the same way in the four soil management regimes
280 tested. Eye size is linked to behavioral traits such as foraging period (Weiser & Kaspari,
281 2006), but it is unlikely that soil management affects the adequacy of showing diurnal,
282 crepuscular or nocturnal habits. Furthermore, eye size also differs between arboreal,
283 ground level and hypogaeic ants (Weiser & Kaspari, 2006; Silva & Brandão, 2010; Blaimer
284 *et al.*, 2015). Considering that our experimental design was intended to explore the effects
285 of soil management only on ground dwelling ants, a potential effect on eye size, mediated
286 by a differential impact of management on the different layers of the system, cannot be
287 ruled out.

288 Finally, FD analyses can also be discussed in terms of their effects on agroecosystem
289 resilience. Previous studies have shown that communities with high FD may respond better
290 to disturbances, enhancing the resilience of the system (Hevia *et al.*, 2017). The fact that

non plowed organic systems showed higher values of FD in three of the traits evaluated might have positive implications for olive grove resilience in the face of global change.

Implications for olive grove management under the Common Agricultural Policy

The EU Common Agricultural Policy (CAP) for olive products (mainly olives and olive oil) has historically promoted intensification in most regions (Duarte *et al.*, 2008). Therefore, intensive olive monocultures have replaced traditional olive orchards in the most productive areas, while the less profitable areas tended to be abandoned (Stoate *et al.*, 2009; Martínez Sastre *et al.*, 2017). This scenario of intensification vs. abandonment of olive groves has been dominant in recent decades in southern Spain, giving rise to undesirable consequences such as a reduction of biodiversity and a loss of landscape values (Siebert, 2004; Stürck *et al.*, 2015). Our results highlight that some management practices of conventional olive farming systems, such as plowing, negatively affect ant species richness and functional diversity. In contrast, the effects of herbicide spraying on ant richness were not conclusive.

Recent reforms in the CAP have identified sustainability as one of the key priorities (Pe'er *et al.*, 2014). To achieve this overarching goal, the CAP is intended to promote all those practices that reduce soil erosion or enhance plant and animal biodiversity, ensuring long term provision of ecosystem services in European agroecosystems (European Commission, 2013). In the case of Mediterranean olive groves, the reduction and prevention of soil erosion has become a major sustainability challenge (Rodríguez Entrena & Arriaza, 2013; Gómez *et al.*, 2014). Recent policies to promote more environmentally sensitive farming practices have resulted in a wide interest in integrated protection (Boller *et al.*, 2004) and organic farming (Guillou & Scharpé, 2000).

Organic farming is usually associated with reduced management intensity, contributing to higher biodiversity of a wide range of taxa (including birds, mammals, and invertebrates) compared with more conventional and intensive practices in agroecosystems (Bengtsson *et al.*, 2005; Hole *et al.*, 2005; Schmidt *et al.*, 2005). Our results are consistent with these previous findings, as most biodiversity variables analyzed (both taxonomic and functional) showed higher values in organic farms. However, being mechanical plowing so harmful for ant diversity, it is noteworthy that this practice is not yet regulated in organic farming systems. Although our analysis did not include any organic farms that used plowing to control weeds between tree rows, we have evidence that some organic farms in our study area use this technique regularly. In those cases, it would be expected that the benefits of organic farming on ant diversity would be counteracted by plowing.

Integrated farms can be considered the second least intensive management in our study area. Soil conservation practices applied in these farms aim to reduce the negative effects of plowing on soils and the harmful consequences of biocides on biodiversity as an alternative to highly intensive systems of olive grove management (Parra López *et al.*, 2008). Previous studies have shown that integrated management practices are beneficial for erosion control (Parra López *et al.*, 2007) and have a positive effect on ant abundance (Ruano *et al.*, 2004). Our results are consistent with these findings, showing higher ant species richness in integrated farms than in conventional plowed farms.

In summary, to better balance olive production with biodiversity conservation under the current CAP priorities, our results highlight the negative effects of olive grove plowing on ant taxonomic and functional diversity. Further, our results provide novel evidence of the importance of non plowing organic farming in maintaining higher levels of ant functional

338 diversity, which potentially increases the resilience of olive grove systems in the face of
339 global change.

340

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586 **Table caption**

587 **Table 1.** Species of ants identified in the four soil management regimes, sorted by field
588 zone.

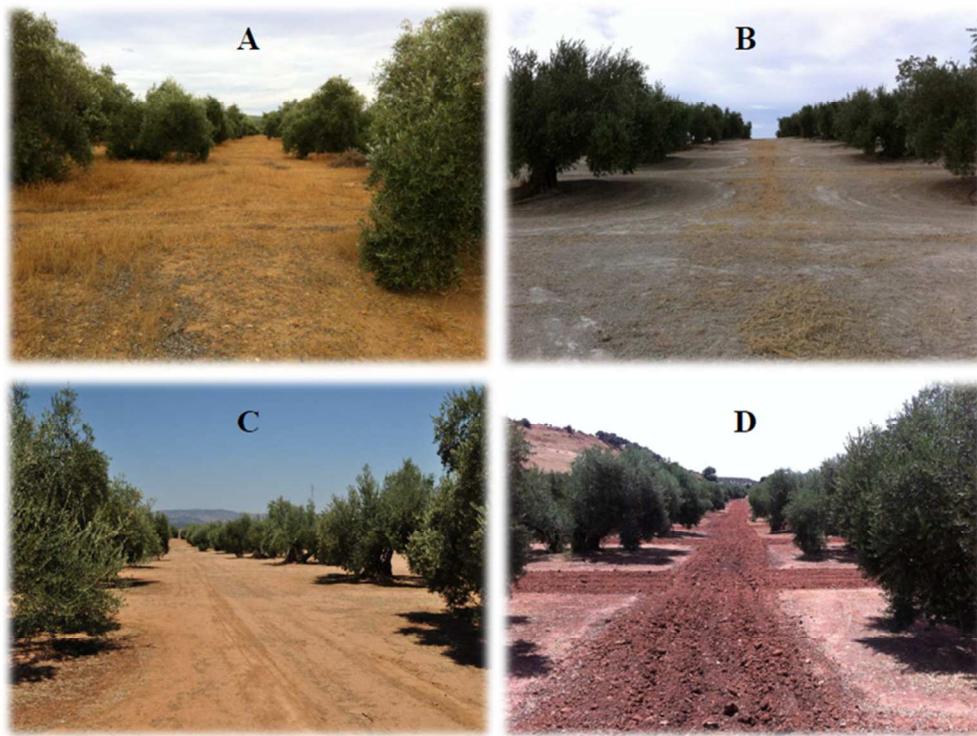
589

590 Table 1

Species	Non plowed organic farms		Integrated farms		Conventional fully sprayed farms		Conventional plowed sprayed farms	
	Between Rows	Under canopy	Between Rows	Under Canopy	Between Rows	Under canopy	Between Rows	Under canopy
<i>Aphaenogaster gibbosa</i> (Latreille, 1798)	X	X	X	X	X	X	X	X
<i>Aphaenogaster ibérica</i> (Emery, 1908)	X	X	X	X	X	X	X	X
<i>Aphaenogaster senilis</i> (Mayr, 1853)	X	X	X	X	X	X	X	X
<i>Camponotus barbaricus</i> (Emery, 1905)	X	X	X	X	X	X	X	X
<i>Camponotus foreli</i> (Emery, 1881)	X	X	X	X	X	X	X	X
<i>Camponotus micans</i> (Nylander, 1856)			X					
<i>Cardiocondyla batesii</i> (Forel, 1894)			X	X	X	X	X	
<i>Cataglyphis hispanica</i> (Emery, 1906)	X	X			X	X		
<i>Cataglyphis ibérica</i> (Emery, 1906)	X	X						
<i>Cataglyphis rosenhaueri</i> (Santschi, 1925)	X	X	X	X	X	X	X	X
<i>Crematogaster auberti</i> (Emery, 1869)	X	X	X	X	X	X		
<i>Iberoformica subrufa</i> (Roger, 1859)					X	X	X	X
<i>Messor barbarus</i> (Linnaeus, 1767)	X	X	X	X	X	X	X	X

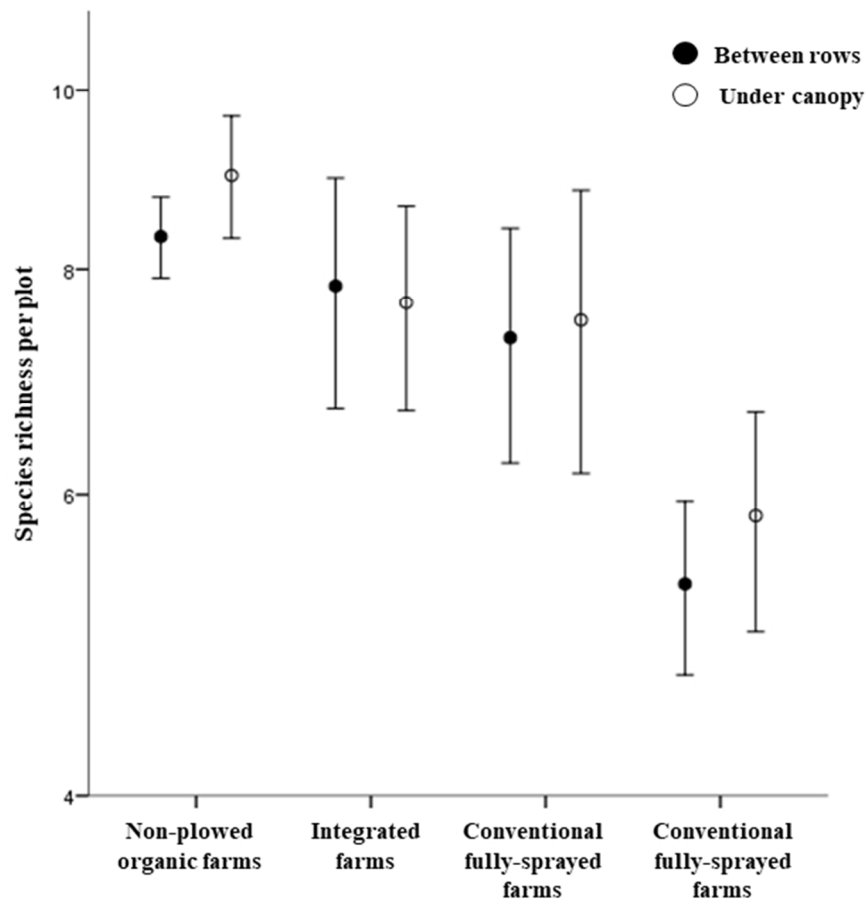
<i>Messor bouvieri</i> (Bondroit, 1918)			X					
<i>Pheidole pallidula</i> (Nylander, 1849)	X	X	X	X	X	X	X	X
<i>Plagiolepis pygmaea</i> (Latreille, 1798)		X		X	X	X	X	X
<i>Tapinoma erraticum</i> (Latreille, 1798)		X	X	X	X	X	X	X
<i>Tapinoma gr. nigerrimum</i> *	X	X	X	X	X	X	X	X
<i>Goniomma Hispanicum</i> (André, 1883)		X						
<i>Tetramorium forte</i> (Forel, 1904)	X	X		X		X		
<i>Tetramorium semilaeve</i> (André, 1883)	X	X	X	X	X	X	X	X
Total	14	17	15	15	16	17	14	13

591 * Seifert *et al.* (2017) considered this ant species as a complex of 4 ant species.



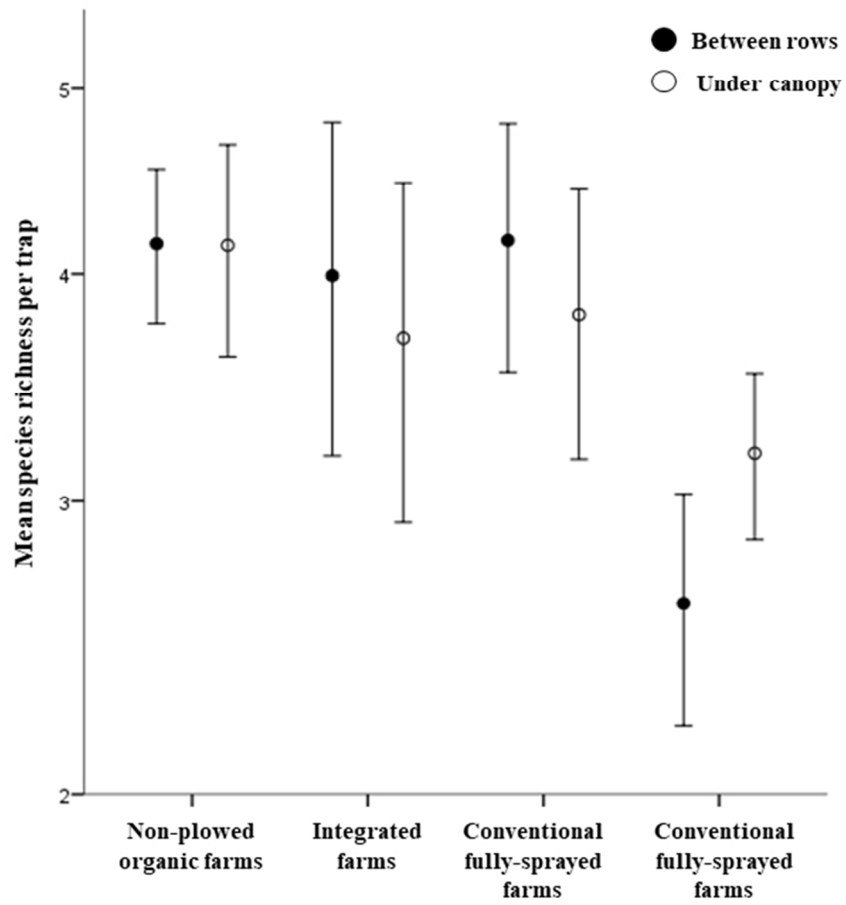
Pictures illustrating the four dominant olive grove management types: (A) Organic farming, (B) Soil conservation farming, (C) Conventional farming, and (D) Plowed conventional farming.

254x190mm (96 x 96 DPI)



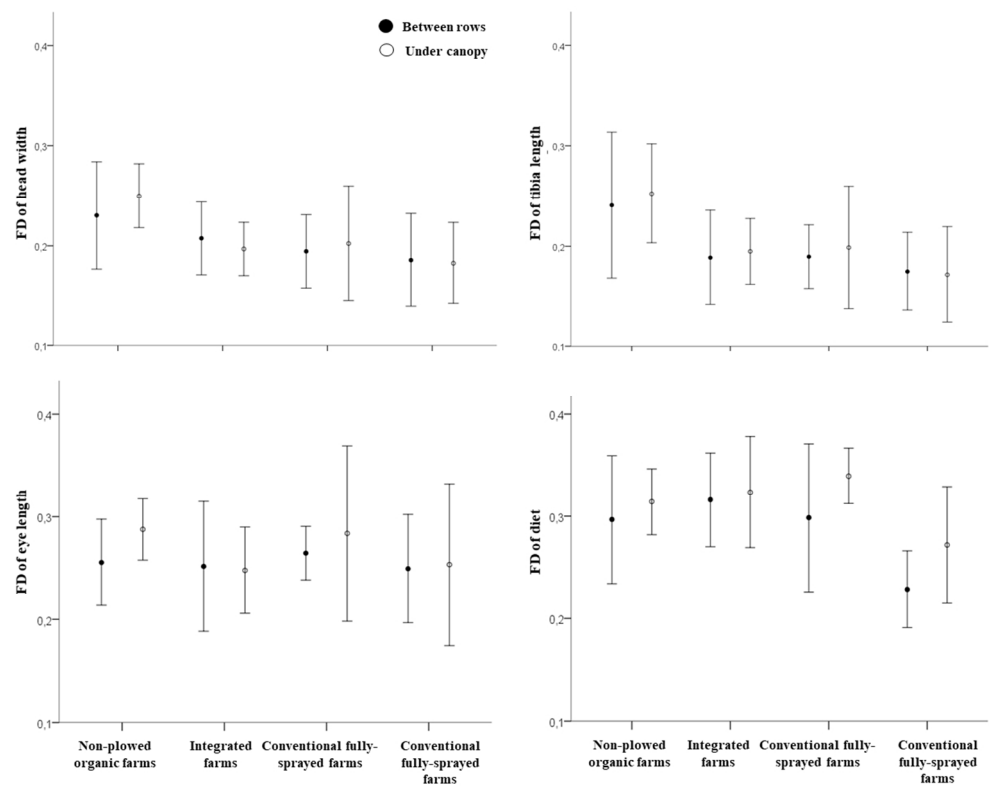
Ant species richness per plot for each olive grove management type. Values are mean \pm standard deviation (y-axis in logarithmic scale).

187x175mm (96 x 96 DPI)



Ant richness per trap on the four management types. Values are mean \pm standard deviation (y-axis in logarithmic scale).

187x175mm (96 x 96 DPI)



Mean \pm standard deviation of the RAO index for quantitative traits (tibia length, eye length and head width) and diet.

328x260mm (96 x 96 DPI)