



Intraspecific trait variability of herbaceous plants in organic and conventional olive plantations in a desertification-prone region

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Abstract Olive crops cover a substantial area of agricultural land, particularly in dry areas with a high desertification risk, where their understory represent an important room for plant communities. Their management is therefore essential for the maintenance of the complex functions and services the vegetation provides in these agroecosystems. In southern Italy (Apulia), we selected conventionally managed and organic olive plots. The organic plots had never been ploughed for more than ten years. We compared soil properties, the species and functional trait composition of the plant community in the understory, and intraspecific trait variability (ITV) of five dominant species as an indicator of the stress source for plants. Under the organic management, the plant community

had a higher cover, with strong dominance of *Avena fatua*, and was overall dominated by species with a higher specific leaf area, and the soil had a higher C content, which reduced the level of desertification. ITV generally showed lower environmental stress for plants in organic plots. They had higher stature, higher SLA, lower leaf area, and lower leaf mass, but – unexpectedly – they also had a higher leaf dry matter content (LDMC). Absence of ploughing of the olive plots supported the formation of an understory with high cover, where traits suitable for between-plant competition rather were more common than those for drought stress. This also promoted soil formation through carbon accumulation. Organic farming therefore seems to be a suitable option for lowering the desertification risk of olive cultures/plantations.

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Introduction

Olives are the main European woody crop and cover large areas of agricultural land, however their management is often unsustainable threatening the plant communities the olives host in its understory and the ecosystem services they provide (Kairis 2013). Agriculture implies radical land-use changes, which

impact on biogeochemical cycles, freshwater use, biosphere integrity, and climate (Rockstrom et al. 2009; Campbell et al. 2017). This is even amplified in the Mediterranean climate (Cramer et al. 2020). Some regions of southern Europe are affected by aridification (Colantoni et al. 2014) and are considered to be at a strong desertification risk (Cramer et al. 2020). Appropriate management of olive plantations has therefore great importance to maintain ecosystem services, especially in this type of artificial landscape where natural vegetation has been severely reduced.

Conventional agriculture uses fertilizers, herbicides and pesticides to increase yields. It also includes frequent ploughing, to reduce competition with weeds and fire risk, but it also promotes mineralisation due to faster decomposition of soil organic matter (Kairis 2013). This in turn may however promote the desertification of the landscape (Grilli et al. 2021). Many observers claim that using a high input of energy and resources we can produce more food using less land, so that more space and natural habitat remain intact for flora and fauna (Ritchie 2024). Others argue that organic agriculture (and other forms of agroecological practices) offers more sustainable solutions for planetary crises (Altieri 1996). Organic agriculture seems to better preserve biodiversity, minimising water pollution and enhancing soil quality (Reganold 2016). However, other works show that conventional agriculture reduces eutrophication and the acidification potential, concluding that some crops perform better in organic while others in conventional agriculture (Clark and Tilman 2017; Tuomisto et al., 2012).

Herbaceous plants have a bio-indicator potential and can be used to investigate agroecosystem functioning (Taffetani and Rismondo 2009; Cano-Ortiz et al. 2020). Functional traits can be used as a proxy to assess how plants respond to organic and conventional olive plantation management and its effects on drought (aridification). They reflect the *effect* of the organism on the environment (“effect traits”), or the environmental *response* on the species (“response traits”; Garnier, Navas, Grigulis 2016). Traits linked with plant physiology, like plant height, specific leaf area (SLA), and leaf dry matter content (LDMC), are useful to study plant responses to environmental change, such as drought stress (Garnier, Navas, Grigulis 2016). LDMC is often used as a proxy to assess drought stress in plants because increased dry matter of leaves is correlated with better drought tolerance

(Garnier, Navas, Grigulis 2016; Majekova 2021), but it can also be used as an effect trait. For example, LDMC reflects the litter decomposition rate, which gives indirect insight into the soil condition (Lavorel et al. 2013) and therefore into the nutrient cycling rate of the ecosystem. A proper functional trait set-up may also improve those conditions through their effect on soil carbon sequestration. Soil organic carbon (SOC) is the key parameter of the soil environment, and organic matter produced by plants in appropriate quality and quantity may fill carbon pools depleted by tillage (Castellano et al. 2015).

A plant’s habitat quality can also be evaluated looking directly at the soil environment. The better soils have the capacity to retain water and nutrients, the more they can withstand harsh weather and climatic conditions. Mediterranean soils are threatened by several factors, especially high erosion rates. Grilli et al. (2021) have proposed SOC as a fundamental indicator of soil degradation and identified a threshold of 2% below which soils seriously begin to deteriorate. Carbon (C) is the main constitutive element (almost 60%) of soil organic matter (SOM) and is strongly related to all other basic soil parameters like total nitrogen (TN), phosphorous (P), pH, etc. Moreover, organic matter considerably affects the soil water holding capacity, and SOC is related to the water available to plants (Grilli et al. 2021; Brady and Weil 2017), which are obviously crucial factors in desertification-prone regions (Lal 2020). Given these threats, assessing which system is better in maintaining good soil conditions is crucial for Mediterranean olive plantations.

We selected five functional traits – plant vegetative height, specific leaf area (SLA), leaf dry matter content (LDMC), leaf area, and leaf mass to investigate how spontaneously growing herbaceous plants of the olive understory respond to agricultural management (response traits) but also as a proxy to investigate the soil environment (effect traits). Dominance of the traits in the community can be assessed through community-weighted mean (CWM) computation. This approach is based on the idea that dominant individuals perform the main ecological functions in a community (“mass ratio hypothesis”; Grime, 2002; Garnier et al., 2016; de Bello et al. 2021). Other approaches focus on entire communities or single species, studying its intraspecific trait variability (ITV). In this case, physiological traits should reflect

rapid adaptations of species to environmental stress through phenotypic responses (de Bello et al. 2021). This approach has been recommended to study aridity in Mediterranean drylands (Nunes et al. 2017).

In this study we hypothesise that conventionally (intensively) managed olive plantations have higher desertification risk and expose the herbaceous plants in the understory to higher environmental stress caused primarily by drought. We assume that organic (lower-intensive) management provides a better habitat, therefore we expect reduced drought stress and better soil conditions. The purpose of this study was to test this assumptions by combination of the measurement of soil properties with measurement of plant responses indicated by their functional traits on both intraspecific and interspecific level.

Methods

Study site

This study was conducted in Apulia, a semi-arid Mediterranean region in south eastern Italy. The plots were located at Castellana Grotte, Bari Province [40°54'17.3"N 17°11'59.9"E] on the Le Murge hills at 300 m a.s.l. The mean annual temperature is 16 °C and the precipitation is 596 mm/year (*a-pulia*=no rain). Soils are alkaline and are considered as “low quality soils” (Ladisa et al. 2010). Apulia is the main region of olive production in Italy and among the most important in Europe. Conventional systems are used in the majority of the region (84%) (Ciervo 2020). Olive trees fertilisation seems to have been more popular some decades ago, at least at this location (according to the organic farm owner), while great use is made of pesticides and disk ploughing (especially glyphosate; Ciervo 2016, 2020). Currently the practice in this region is fertilization by N in the amount of 60–120 kg/ha and P in the amount of 30–60 kg/ha (Xiloyannis et al., 2000; Proietti et al. 2015). Irrigation is not applied. Organic production does not allow the use of chemical compounds (with some exceptions). Ploughing is considered an intensive practice, but is not regulated by organic certification standards. However, agricultural paradigms based on ecological principles tend to restrict its use (Altieri 1999). Nevertheless, maintaining soil-covering plants (cover crops or spontaneous vegetation)

remains rare in this region. It needs to be reminded that ploughing is part of the traditional management in this region. This approach is partially justified to prevent fire spread during summer (dry season). The olive understory is dominated by annual plants with common occurrence of geophytes.

Only one farm was reference for organic management, whereas conventional plots were chosen as close as possible in surrounding plantations. At the organic farm, the soil has not been ploughed for at least ten years. Vegetation cover was maintained all year round and mown sporadically, once or twice a year by a mowing machinery. No kind of fertiliser is added directly to the soil, except for chopping and mulching of olive pruning residues every 3–4 years. Irrigation was not applied. The study site is located in the so-called buffer zone of the Xylella bacteria expansion. Olive plantations are considered highly prone to desertification in this locality (Caliandro and Stelluti 2005). The site can therefore be considered as an optimum spot to study how different types of agricultural management respond to desertification constraints.

Sampling

We set up six pairs of organic and conventional plots (Figure S1). The study was conducted from 4 March to 4 April 2023. Sampling was conducted during early morning or late afternoon in most cases. We initially conducted phytosociological relevés to investigate the flora and species composition of all plots. In each relevé 5 m×5 m in size, we visually estimated the percentage cover of individual species and the total vegetation cover. This was also a preliminary step for the selection of dominant species present in the landscape, which we used for functional trait measurements.

The five selected species were: one grass, *Avena fatua*, and four forbs, *Calendula arvensis*, *Glebionis segetum*, *Erodium malacoides*, and *Medicago orbicularis*. All those species are annual plants as the annual plants form majority of the vegetation cover. They were extirpated rather than cut above the collar to reduce water loss by transpiration. In each plot, the eight best developed individuals were sampled, which resulted in a total of 440 plant individuals sampled. Individuals were water-saturated by sealing them into plastic bags containing water. This procedure was

suggested to avoid transpiration (Perez-Harguindeguy et al. 2013). Samples were then stored into a fridge at 4 °C no later than one hour after sampling. Measurements of traits were carried out after 12 h (Perez-Harguindeguy et al. 2013). For the measurements of leaf traits only healthy undamaged leaves were selected (two leaves for *Avena fatua*; five leaves for all other species). Wet weight was measured with a portable KERN-TAB balance (accuracy 0.001 g; calibrated before every session). Leaves were dried at 20 °C for at least 36 h and stored. Dry weight was measured during the last week of March for all samples. Scanning (for SLA and LDMC measurements) was conducted with a portable IRIScan Book scanner. Area calculations were conducted with the ImageJ software (Schneider et al. 2012). To assess functional trait composition of the whole community, plant height, SLA, and LDMC were excerpted from the TRY database for all species recorded in the relevés (Kattge et al. 2020). Based on species composition of the community, the community-weighted mean (CWM) of these traits was computed. Leaf area and leaf mass were not available for the whole community and were excluded for community-level analysis.

In each plot, we took soil samples composed of five sub-samples, collected at random spots (in the same 5 m × 5 m quadrat). Every sub-sample was taken at 0–10 cm depth. Soil samples were dried at 20 °C for 24 h and sieved through a 2-mm sieve. pH and conductivity were measured in deionised water (sample to liquid ratio of 1:5). Total soil carbon (SOC) and total soil nitrogen were measured with a CN analyser (NC 2100 Soil Analyzer, ThermoQuest Italia S.p.A.). Available phosphorus was extracted with Mehlich III extractant (Mehlich 1984) and then quantified with a flame spectrophotometer. For a summary of soil properties, see Table S1 (supplementary materials).

Statistical analyses

Multivariate data on plant species community composition were initially assessed with Detrended Correspondence Analysis, which showed a relatively short gradient (1.6 SD). Plant species community composition was therefore analysed with the linear ordination method of Redundancy Analysis (RDA), as recommended by Šmilauer and Lepš (2014). The management type (organic vs conventional) was used as explanatory variable. Identity

of plot pair was used as covariate. Significance was tested with the Monte Carlo permutation test with 999 permutations. Only plots within the pairs were permuted. RDA analysis was conducted in the Canoco 5 software (ter Braak and Šmilauer 2012). We used version R 4.1.1 for all univariate analysis (R Core Team 2022). Measured functional traits were analysed with Analysis of Variance (ANOVA), where management type, species identity, and their interaction were used as fixed effect explanatory variables. Identity of plot pair was used as random effect variable. To disentangle the species-specific responses to management, five species measured for functional traits were analysed separately with similar ANOVA, where management type was used as fixed effect explanatory variable and identity of plot pair as random effect variable. Accordingly, total community cover, number of species, CWM of database traits, and soil properties were analysed with ANOVA, where management type was used as fixed effect explanatory variable, while identity of plot pair was used as random effect variable. All ANOVAs were conducted using the *aov* function. The normality of the residuals was tested by Shapiro–Wilk test and the homoscedasticity was tested by Bartlett test. Both of these assumptions of ANOVA were found as fulfilled for all tests.

Results

Plant species composition significantly differed between organic and conventional plots as indicated by RDA ($F=4.2$, $p=0.042$, explained variability 29.33%; Fig. 1). Most of the species were associated with conventional management. This includes also *Glebionis segetum* and *Calendula arvensis* (which were selected for trait measurements). Poaceae species appeared more abundant in organic management, especially *Avena fatua*. The number of species did not differ between the management types. Organic plots hosted on average, 11.7 ± 2.9 (SD) species and conventional plots 11.8 ± 2.7 ($F=0.02$, $p=0.903$; ANOVA). Total cover was significantly higher in organic than in conventional plots ($F=35.1$, $p=0.002$; ANOVA). Organic plots had an average cover of $78\% \pm 10\%$ (SD), while conventional plots $43\% \pm 14\%$ ($F=35.1$, $p=0.002$; ANOVA).

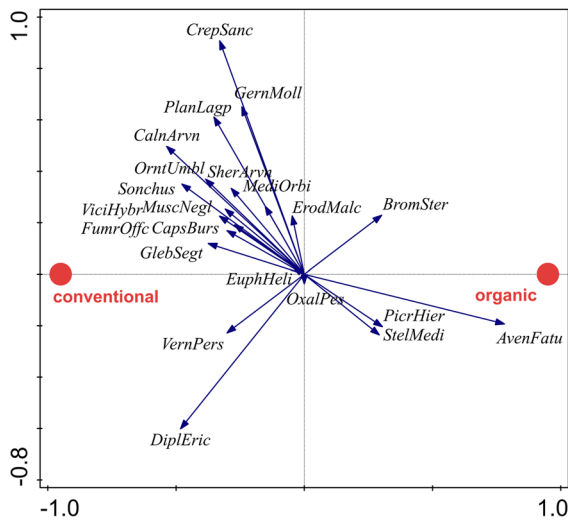


Fig. 1 Ordination diagram of RDA testing the effect of management on community composition. Focus was scaled on interspecies correlations. Abbreviations are: AvenFatu—*Avena fatua*, CalnArvn—*Calendula arvensis*, GlebSegt—*Glebionis segetum*, MediOrbi—*Medicago orbicularis*, ErodMalc—*Erodium malacoides*, MuscNegl—*Muscari neglectum*, GernMoll—*Geranium molle*, SherArvn—*Sherardia arvensis*, CrepSanc—*Crepis sancta*, DiplEric—*Diplotaxis eruroides*, ViciHybr—*Vicia hybrida*, EuphHeli—*Euphorbia helioscopia*, StelMedi—*Stellaria media*, OrntUmbL—*Ornithogalum umbellatum*, Sonchus—*Sonchus* spp., CapsBurs—*Capsella bursa-pastoris*, FumrOffc—*Fumaria officinalis*, PicrHier—*Picris hieracioides*, OxalPes—*Oxalis pes-caprae*, PlanLagp—*Plantago lagopus*, VernPers—*Veronica persica*, BromSter—*Bromus sterilis*

Table 1 Results of ANOVA (F and p-values) testing the effect of management, species identity and their interaction on functional traits measured on plant individuals

	Management		Species		Management × Species		
	F		p	F	p	F	p
Height	106		$< 10^{-3}$	123	$< 10^{-3}$	4.3	0.001
LDMC	9.7		0.001	220	$< 10^{-3}$	5.6	$< 10^{-3}$
SLA	11.1		$< 10^{-3}$	11.2	$< 10^{-3}$	5.5	$< 10^{-3}$
Leaf area	10.6		0.001	506	$< 10^{-3}$	2.0	0.099
Leaf mass	15.7		$< 10^{-3}$	419	$< 10^{-3}$	4.2	0.002

Table 2 Results of ANOVA (F and p-values) testing the effect of management on functional traits of each species separately

	Height		LDMC		SLA		Leaf area		Leaf mass	
	F	p	F	p	F	p	F	p	F	p
<i>A. fatua</i>	12.2	$< 10^{-3}$	32.3	$< 10^{-3}$	0.15	0.701	0.05	0.829	0.012	0.914
<i>C. arvensis</i>	44.4	$< 10^{-3}$	13.5	$< 10^{-3}$	0.97	0.329	0.37	0.543	0.027	0.871
<i>G. segetum</i>	52.5	$< 10^{-3}$	0.82	0.37	4.5	0.038	11.7	0.001	15.61	$< 10^{-3}$
<i>M. orbicularis</i>	13.7	$< 10^{-3}$	10.0	0.002	18.7	$< 10^{-3}$	7.3	0.008	21.52	$< 10^{-3}$
<i>E. malacoides</i>	22.4	$< 10^{-3}$	0.65	0.423	1.6	0.214	2.1	0.149	3.192	0.051

At intraspecific level, all traits significantly differed between species and they were also significantly affected by management. All traits were affected by management, but in a species-specific manner. ANOVA was highly significant for all management, species and their interaction. The only exception was the interaction of management and species for leaf area (Table 1). ANOVA for each species separately showed that plant height significantly differed with management in all species (Table 2). The other traits did not differ between the two management types for all species. Solely *Medicago orbicularis* revealed significant results for all traits. However, all traits responded in *Glebionis segetum*, except for LDMC (Fig. 2). Pairwise correlation of individual traits is shown in Fig. 3.

Analysis of CWM of database traits partially confirmed the results on ITV showing a higher plant height, LDMC and SLA in organic plots. However, the ANOVA test produced significant results for SLA only, while it was marginally significant for plant height, and non-significant for LDMC (Table 3, Fig. 4).

Levels of SOC were higher in organic plots, as expected (Table 4; Fig. 5). Similarly, also the total soil nitrogen content of organic plots was higher. Levels of phosphorous (PO_4) and pH did not differ between management types. Electrical conductivity was on

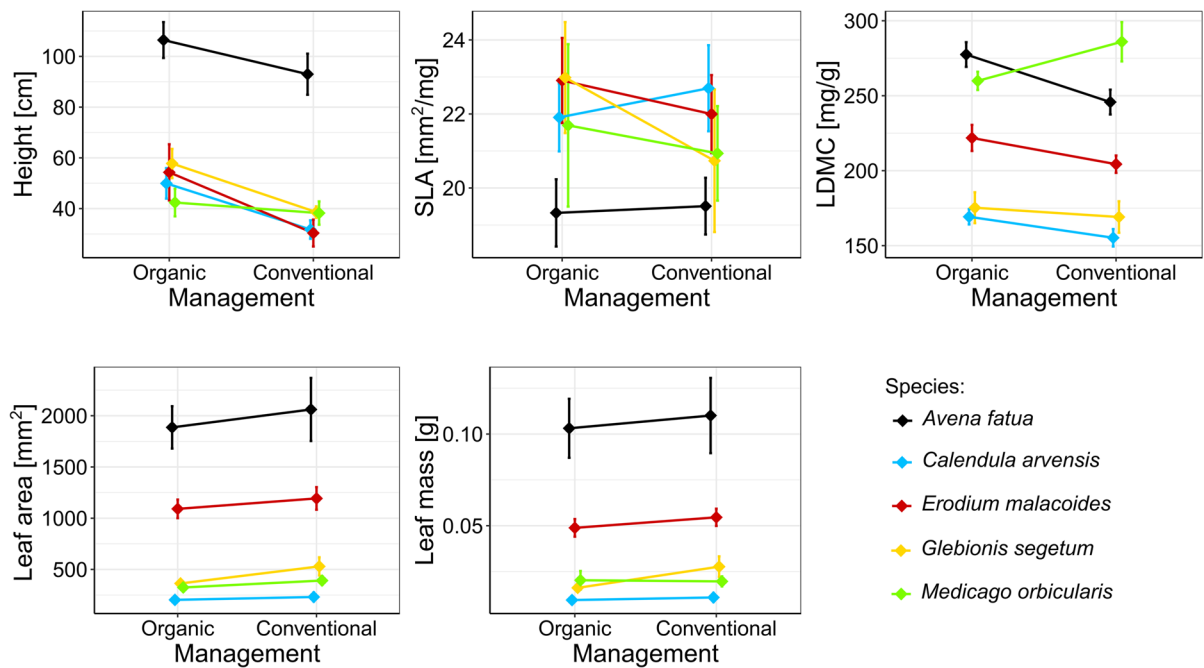


Fig. 2 Plant functional traits of individual measured species in organic and conventionally managed plots. Mean $\pm$ 95% confidence interval is shown

average higher in organic plots, but management had a marginally significant effect only (Table 4; Fig. 5).

Discussion

We found several differences between conventional and organic management types. Species composition significantly differed, similarly to functional trait composition (indicated by CWM) even though significantly only for one trait. Intraspecific trait variability significantly differed for individual species and management. Trait values generally revealed lower environmental stress for plants in organic plots, although the results were partially mixed. All species grew taller in organic plots, as expected. Despite the SLA and LDMC were negatively correlated, in average both of these traits had unexpectedly, higher values under organic management. Soil carbon levels were higher in organic plots indicating reduced drought stress and desertification risk.

In organic plots, plants were limited rather by intense competition, while more by abiotic stress in conventionally managed plots. Taller plants, found

in organically managed plots, are associated with increased competition in plant communities, similarly to the higher SLA, which is associated with faster growth due to enhanced photosynthesis (Westoby 1998). This is generally linked with better soil and habitat conditions, which do not limit interspecific competition of plants for nutrients but favour competition for light, pushing plants to grow taller. The denser vegetation cover found in organic plots confirms this idea, which is further supported by leaf area and leaf mass, since taller plants with smaller leaves indicate that plants invest in height to compete for light rather than in maintenance of photosynthesis (Perez-Harguindeguy et al. 2013). On the contrary, smaller plants are often associated with increased aridity (Nogueira et al. 2018). Decreased precipitation acts as a strong stress on plants, especially in the Mediterranean climate. In these conditions, a smaller size decreases the risk of cavitation and embolism (Nunes et al. 2017), reducing the surface for water transpiration. SLA is considered a key trait to study drought response, since it is linked to the plant water strategy. SLA tends to decrease with reduced water availability (Poorter et al. 2009). Plants

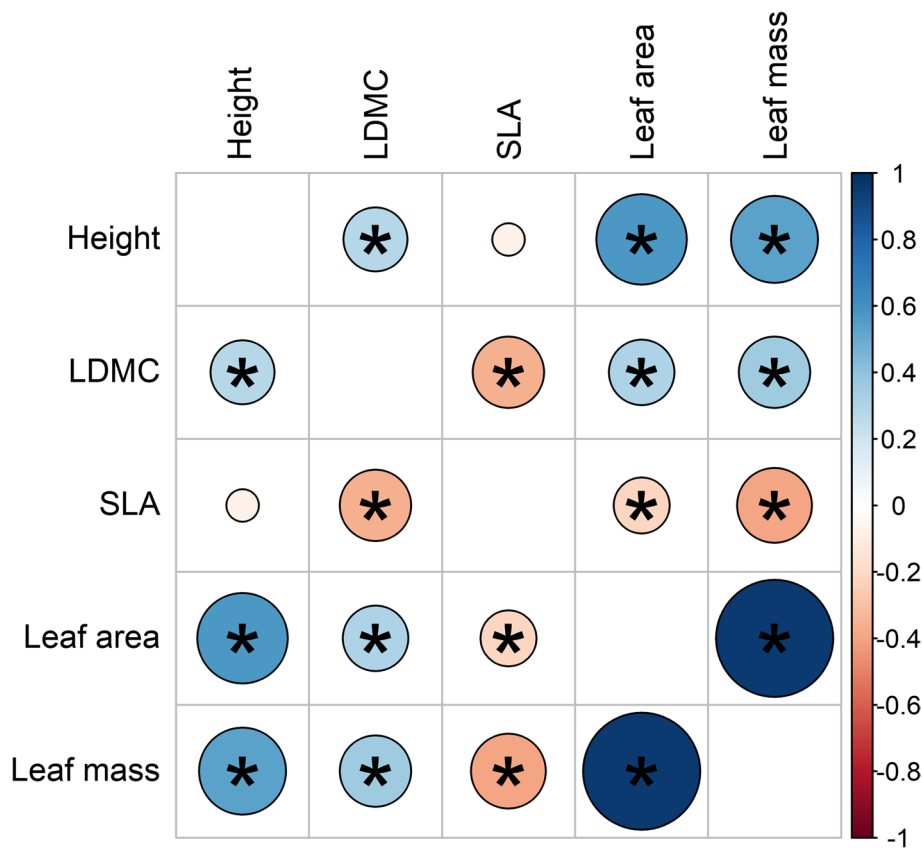


Fig. 3 Correlation matrix of individual traits measured on plant individuals. Shown is correlation coefficient (R). Positive R is depicted with blue colours and negative R with red col-

ours according to legend on the right. Significant correlations ($p < 0.05$) are marked with asterisk

Table 3 Results of ANOVA testing the effect of management on CWM of database traits

	F	p
Plant height	5.47	0.06
SLA	8.98	0.03
LDMC	3.16	0.1

in the Mediterranean environment tend to reduce SLA to increase water use efficiency (Wright, 2004; Ackerly 2004). Some studies of CWM have found a reduced SLA with increased aridity (Ackerly, 2004; Costa Saura 2016), which is coherent with our results (Fig. 4). In our study, two out of five species had an increased SLA in organic plots (the others did not significantly respond), which should indicate better soil water availability. Soil analysis has provided

further validation of this idea. Soil wetness was not directly measured, but higher SOC levels are linked to an increased capacity of storing water in the soil, which is clearly linked with reduced drought stress (Brady and Weil 2017; Grilli et al. 2021). On average, soil organic carbon was found to be almost one percent higher in organic plots, which strongly supports our hypothesis, since the addition of just one percent point significantly enhances soil water holding capacity (140,000–170,000 l per hectare; Lal 2020).

Higher LDMC values are generally interpreted as a plant's response to increased drought stress (Majekova et al. 2021) or to a nutrient-poor habitat (Garnier et al. 2007). Usually, LDMC and SLA are considered to respond in opposite ways (Wright et al. 2004). Apparently, this did not happen, although pairwise correlation of traits showed a negative relationship between these two traits. Some species responded by

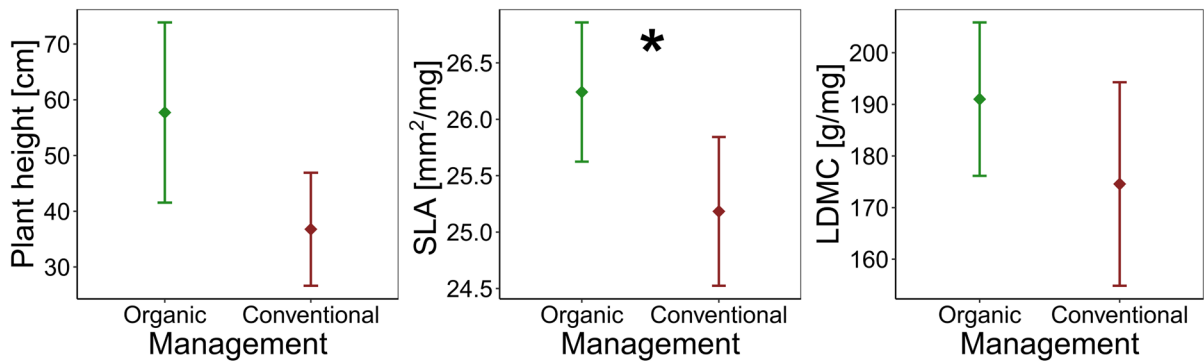


Fig. 4 Community-weighted means of plant functional traits in organic and conventionally managed plots. Mean $\pm$ 95% confidence interval is shown. Significant difference ($p < 0.05$) is marked with an asterisk

Table 4 Results of ANOVA testing the effect of management on soil properties

	F	p
C	28.94	0.002
N	11.89	0.018
P	1.126	0.337
pH	0.574	0.483
Electrical conductivity	4.854	0.078

changes in SLA, while others in LDMC. *Medicago orbicularis* was the only species responding to all traits and the only one expected to respond like that which further supports our hypothesis. *Avena fatua* and *Calendula arvensis* increased their LDMC values in organic plots, contradicting that hypothesis. Nevertheless, this probably contributed to the overall mean across species causing congruent response of LDMC and SLA. *Avena fatua* responded by increasing its LDMC in organic plots. This result is unexpected and deserves attention, since this species was dominant in the organic plots. It was the tallest and most abundant plant in both management types (even more abundant and taller in organic plots). It is therefore likely that the increase in LDMC of *A. fatua* was a response to direct sunlight exposure (de Bello et al. 2021). Other species, being shaded by *A. fatua*, needed to compete more intensively for light and adjust their traits for that. Since its leaves had a higher LDMC in organic plots, the decomposition rate would probably be lower due to its lower palatability for soil organisms (Costa-Saura et al., 2016). This has further consequences for the soil, because

low decomposition rates stimulate high carbon accumulation (Kardol and Wardle 2010). These results are akin to what was found by Garnier et al. (2007) in a study investigating grassland species along a gradient of decreased management intensity in different climate types (Mediterranean included). Plants were found to be taller and have a higher LDMC at lower intensity sites, and soils were found to have a higher SOC and total nitrogen. The authors suggest that the plants adopted a resource-conservation strategy. Targetti et al. (2013), studying ITV in Mediterranean grasslands in the Italian Apennine Mountains, found lower LDMC levels of three grass species as a response to grazing. This confirms the link between increased management intensity (manure fertilisation) and reduced LDMC, although LDMC was found to be higher than expected in some very high intensity plots. Investigating ITV in Mediterranean grasslands under extreme drought manipulation, Jung et al. (2014) found a general tendency for increased LDMC with drought, but five out of thirteen species responding in opposite directions. The authors suggested a species-specific response to drought.

Considering the type of management carried out in organic plots in our research, we can argue that the vegetation had probably been mown too sporadically (low disturbance) to allow fast nutrient cycling of the residues. When plants remain too long in the field, they tend to accumulate lignin in tissues with age. Absence of animal grazing and low rate of mowing result in a larger availability of organic matter and soil carbon accumulation (Targetti et al., 2013). This effect seems to be stronger in organic plots where the cover of plants is higher and even disturbance by ploughing is absent.

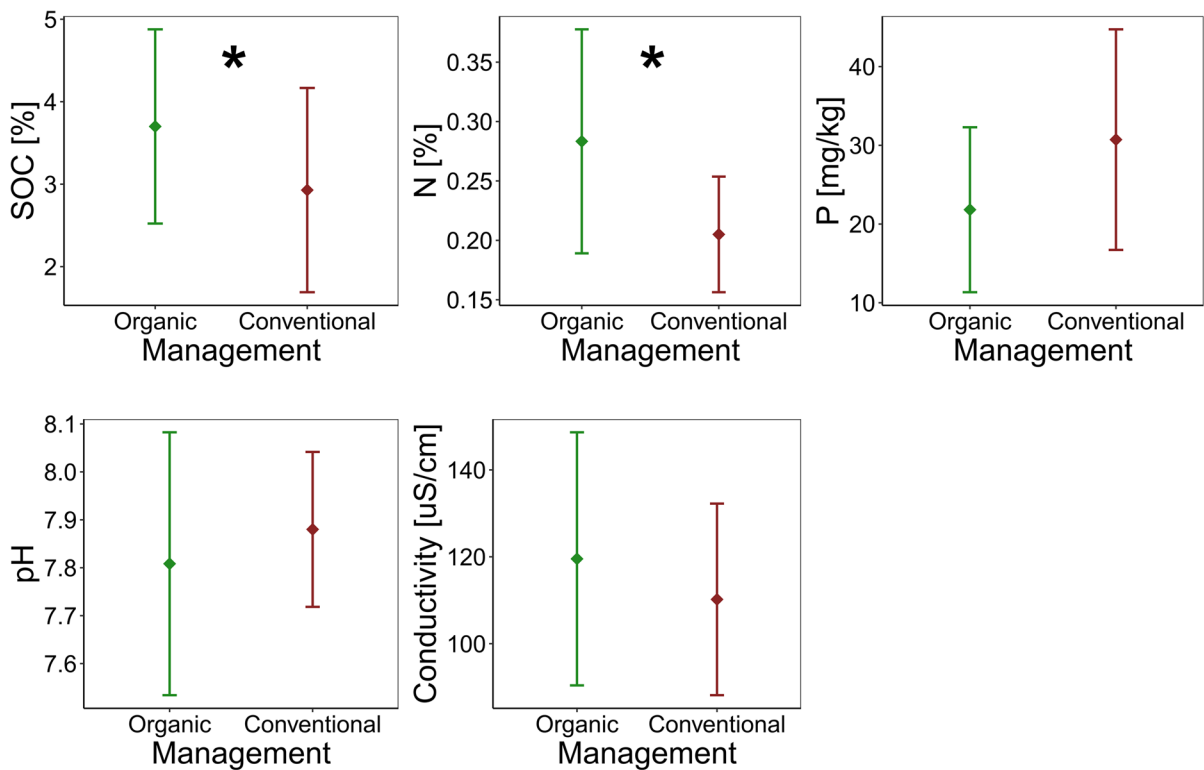


Fig. 5 Soil properties measured in organic and conventionally managed plots. Mean $\pm$ 95% confidence interval is shown. Significant differences ($p < 0.05$) are marked with an asterisk

There is consensus on the idea that fertilisation is associated with increased SLA (Nogueira et al. 2018; Carmona et al. 2019). In our study, no indications sustain the idea that conventional management provides a nutrient-rich habitat, but rather the opposite (since SLA values were found to be higher in organic plots).

The most distinct result concerns SOC levels, which strongly supports the idea that organic management supports carbon sequestration, differently from conventional management. Synthetic fertilizers applied in conventional plots are unable to produce humus in the soil and the elevated LDMC values in the organic plots allow us to argue for reduced soil carbon loss. When leaf dry matter increases, it reduces palatability and therefore lower activity of soil fauna. Following, also microorganism activity is reduced. This is the opposite of what happens in more intensive systems, where fast-growing plants (low LDMC, high nutrient content) provide more palatable organic matter, which results in enhanced mineralisation and soil carbon loss (de Bello et al. 2021).

Nevertheless, we should consider that SOC levels were above the 2% desertification threshold in both organic and conventional plots. Higher total nitrogen (TN) levels were found in organic plots, although this itself is not a guaranty of improved fertility, since total nitrogen is not an available form of nitrogen for plants (Brady and Weil 2017). Phosphorous levels were found to be higher in the conventional plots, although non-significant.

Conclusions

Our results indicate that organic management provides a better habitat quality and causes reduced environmental stress on herbaceous plants. Although the study did not consider olive trees directly, it is reasonable to expect that the conditions found in the understory reflect the general health of the entire olive agroecosystem. We can conclude that organic management in the conditions of our study better supports carbon

sequestration and water availability to plants, which are crucial factors in desertification-prone regions. Given the extent of olive agroecosystems in the Mediterranean region, keeping soil covered with plants all year round – or at least for the longest possible period of time not interfering with olive productivity and fire risk – seems recommendable in order to mitigate climate change and desertification constraints.

To our best knowledge, this is the first study assessing how agricultural management affects the intraspecific trait variability of herbaceous plants in the understory of olive plantations (see also Chelli et. 2018 a review of Italian studies of functional traits). Therefore, it will be necessary to replicate this methodology in different soil and climate conditions to assess whether organic management of olive plantations is more sustainable.

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Author contributions M.M wrote the main manuscript and O.M. prepared all figures and tables. All authors reviewed the manuscript.

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Data availability Data will be published as electronic supplementary material upon manuscript acceptance.

Declarations

Competing interests The authors declare no competing interests.

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