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Arbuscular Mycorrhizal Fungi: A Blessing or A Curse for Weed Management in Organic Olive Crops?

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Abstract

Arbuscular Mycorrhizal (AM) fungi form symbiotic associations with the roots of many plants including important weeds. Cultural practices affect the populations and the infectivity of AM fungi. Density, biomass, root density, AM root colonization and N% of weeds were compared in the two olive production systems (organic and conventional). Weed species differed in the response to AM root colonization. The highest AM root colonization was found for *Lactuca serriola*, *Picris echioides*, *Plantago lanceolata* and *Gallium aparine*. In addition, *Avena sterilis*, *Fumaria officinalis* and *Stellaria media* had the lowest AM root colonization. The highest AM root colonization of weeds was found in organic olive fields. AM root colonisation of weeds influences the density and biomass of competitive weeds. A positive correlation was found between AM root colonization and weed growth. Moreover, the different cultural practices in two production systems influence the weed AM root colonization. There were significant differences in the density and biomass of competitive weeds (*Avena sterilis* L.; *Galium aparine* L.; *Lactuca serriola* L.; *Picris echioides* L.; *Plantago lanceolata* L.; *Sonchus oleraceus* L.), with the highest values being found in organic olive fields. On contrast, there were no significant differences between the organic and conventional systems in the density and biomass of non-competitive weeds (*Anthemis arvensis* L.; *Fumaria officinalis* L.; *Lamium aplexicaule* L.; *Lolium rigidum* Gaudin.; *Stellaria media* (L.) Vill.; *Veronica hederifolia* L). Our results indicate that organic cultural practices significantly increased weed biomass and AM root colonization. The mycorrhizal symbiosis is an important factor influencing weed growth.

Keywords: AM fungi, competition, cultural system, root colonization, weed.
Abbreviations: AM-Arbuscular mycorrhiza; CON-conventional; ORG-organic, RD- root density; WD-weed density; WB-weed biomass.

Introduction

Arbuscular mycorrhiza (AM) are probably the most common and widespread form of plant/fungus symbioses, both in terms of the number of plant species involved, including angiosperms, gymnosperms, pteridophytes and even bryophytes, and in terms of their occurrence in most major terrestrial ecosystems (Smith et al., 2001). Most of the major plant families are able to form mycorrhiza, the arbuscular mycorrhizal (AM) association being the prevalent mycorrhizal type involved in agricultural systems. However, 80% of plant species in surveyed lands are mycorrhizal (Wang and Qiu, 2006). The establishment of the AM symbiosis begins with the colonization of a compatible root by the hyphae produced by AM fungal soil propagules, asexual spores or mycorrhizal roots. Even dead roots from annual plants can be a good source of inoculum. After attachment of a hypha to the root surface by means of an apperssorium, the fungus penetrates into the cortex and forms distinct morphologically specialized structures: inter- and intracellular hyphae, coils and arbuscules. After host colonization, the fungal mycelium grows out of the root exploring the soil in search of mineral nutrients, and can also colonize other susceptible roots (Requena et al., 2007). Both the fungi and the plant benefit from this relationship: The mycorrhizal fungi ensure nutrient uptake from soil, while the plant host transfers organic carbon obtained from photosynthesis to the fungus (Azul et al., 2008). Mycorrhizas play a key role in nutrient cycling in the ecosystem and also protect plants against environmental and cultural stress (Azcon-Aguilar and Barea, 1997). Miransari et al. (2009) indicated the important role of AM in overcoming the stress of soil compaction on wheat nutrient uptake and the great importance of managing soil biological communities in agricultural systems. AM fungi inoculation technology can benefit olive cultivation, particularly in arid regions where native AMF levels are low (Dag et al., 2009). Soriano-Martin et al. (2006) reported that olive root colonization with *Glomus* species reduced the juvenile period of olive trees. Therefore, inoculation of olive plantlets with *Glomus* species is recommended as an olivicultural practice. Porras-Soriano et al. (2006) found that plantlets inoculated with *Glomus* species (*G. mosseae*, *G. intraradices* and *G. claroideum*) grew taller, had more and longer shoots, and showed higher plant N, P and K concentrations.AM fungi are plant root symbionts that provide many benefits to crop production and agroecosystem function. Therefore, management of AM fungi is increasingly seen as being important to ecological

Table 1. Summary of production practices and inputs 2006, 2007, 2008 and 2009.

Type of input/practice	Input/Practice	Organic		Conventional	
		2006-2007	2008-2009	2006-2007	2008-2009
Fertilizer	Composts	x*	x		
	Green manures	x			
	Chemicals fertilizers			x	x
Weed control	Mechanical cultivation	x	x	x	x
	Chemical herbicides			x	x[1]

*x indicates the differences in specific production practices among each of production systems-[1]In 2008 and 2009, the herbicides were applied after weed measurements.

Table 2. Influence of cultural system (organic: ORG and conventional: CON) on density, dry matter and N content of weeds in 2008 (mean values±standard deviation).

Weed type	Weed density (no. m^{-2})		Weed biomass (g m^{-2})		Weed N %	
	ORG	CON	ORG	CON	ORG	CON
Non-competitive						
Anthemis arvensis	4.1±0.45	3.7±0.33	9±2.01	6.4±2.45	4.22±0.24	3.74±0.11
Fumaria officinalis	2.4±0.74	3.1±0.51	1.4±0.56	1.5±0.21	1.88±0.21	1.31±0.18
Lamium aplexicaule	3.1±0.46	2.5±0.34	6.9±1.21	7.8±0.56	2.92±0.09	2.64±0.21
Lolium rigidum	2.1±0.39	2.4±0.21	4.8±0.51	3.8±0.78	3.47±0.29	2.78±0.31
Stellaria media	4.8±0.76	3.5±0.65	8.9±1.45	7.1±2.09	2.59±0.10	2.60±0.09
Veronica hederifolia	3.4±0.51	4±1.01	5.1±0.89	6.8±1.05	4.57±0.07	4.22±0.12
Total[a]	19.9a	19.2a	36.1a	33.4a	-	-
Competitive						
Avena sterillis	6.8±1.21	3.5±1.32	11.1±1.12	8.6±0.78	3.92±0.31	3.24±0.21
Galium aparine	3.7±0.43	4.1±0.45	21.5±1.34	16.2±2.21	1.71±0.09	1.24±0.12
Lactuca serriola	3.8±0.43	2.8±0.21	22.1±1.78	13.3±3.32	3.50±0.09	3.16±0.21
Picris echioides	1.1±0.34	0.9±0.24	10.7±0.54	9.2±0.65	3.37±0.09	3.21±0.03
Plantago lanceolata	4.2±0.32	3.9±0.19	17.1±1.45	12.1±2.11	3.63±0.11	3.18±0.12
Sonchus oleraceus	2.9±0.23	1.6±0.12	25.4±3.56	12.8±2.78	2.96±0.21	2.70±0.34
Total	22.5a	16.8b	107.9a	72.2b	-	-

[a]Means in each row followed by the same letter are not significantly different.

farming. Agronomic weeds that form a symbiotic relationship with AM fungi can increase the diversity and abundance of agronomically beneficial taxa of AM fungi (Vatovec et al., 2005). AM fungi influence plant community structure (Urcelay and Díaz, 2003). Jordan et al. (2000) reported that AM fungi can affect the nature of weed communities in agroecosystems in a variety of ways, including by changing the relative abundance of mycotrophic weed species (hosts of AM fungi) and non-mycotrophic species (not hosts). It is quite plausible that interactions with AM fungi can increase the beneficial effects of weeds on the functioning of agroecosystems. Through a variety of mechanisms, weed–AM fungi interactions may reduce crop yield losses to weeds, limit weed species shifts, and increase the positive effects of weeds on soil quality and beneficial organisms. Conventional high-input cropping systems can substantially reduce AM fungal diversity and abundance (Jordan et al., 2000; Bilalis and Karamanos, 2010). Low-input systems, such as organic farming, are generally more favourable to AM fungi and AM fungi have the potential to substitute for the fertilizers and biocides which are not permitted in organic systems (Gosling et al., 2006). The contribution to soil quality by AM, in terms of the functional capacity of soil, and thus the potential to rely on them in crop rotation in the long term, seems to be higher in low-input than in conventional cropping systems (Kahiluoto et al., 2009). However, agronomic management can strongly affect the abundance of AM fungi in agroecosystems, although linkages between particular management factors and specific patterns of abundance often appear to be inconsistent (Jordan et al., 2000). The main objective of this study was to evaluate the responsiveness of certain weed species to AM fungi in organic and conventional olive crops.

Results and discussion

Weed root growth AM root colonization

Weeds are an important variable in organic crop production, both economically and ecologically. Weeds may serve to maintain diversity and agronomically beneficial taxa of AM fungi (Vatovec et al., 2005). Chen et al. (2004) observed that the number of AM fungal spores increased significantly with increasing weed species number. In addition, Lutgen and Rilling (2004) found that areas with a high density of the invasive mycorrhizal weed *Centauria maculosa* (spotted knapweed) generally had lower AM fungi hyphal lengths compared with areas receiving chemical or combined mechanical and chemical management treatments. AM fungi are particularly important in organic farming systems and other sustainable systems which rely on biological processes, rather than agrochemicals, to supply nutrient and to control weeds, pests and diseases (Harrier and Watson, 2003). There were no significant differences between the organic and conventional systems in root density (Figure 1) of *Anthemis arvensis* L.; *Fumaria officinalis* L.; *Lactuca serriola* L.; *Lamium aplexicaule* L.; *Lolium rigidum* Gaudin.; *Stellaria media* (L.) Vill. There were significant differences between the organic and conventional systems for root density of *Avena sterilis* L., *Galium aparine* L., *Picris echioides* L., *Plantago lanceolata* L., *Sonchus oleraceus* L. and *Veronica hederifolia* L. Concerning the AM root colonization of competitive weeds , there were significant differences

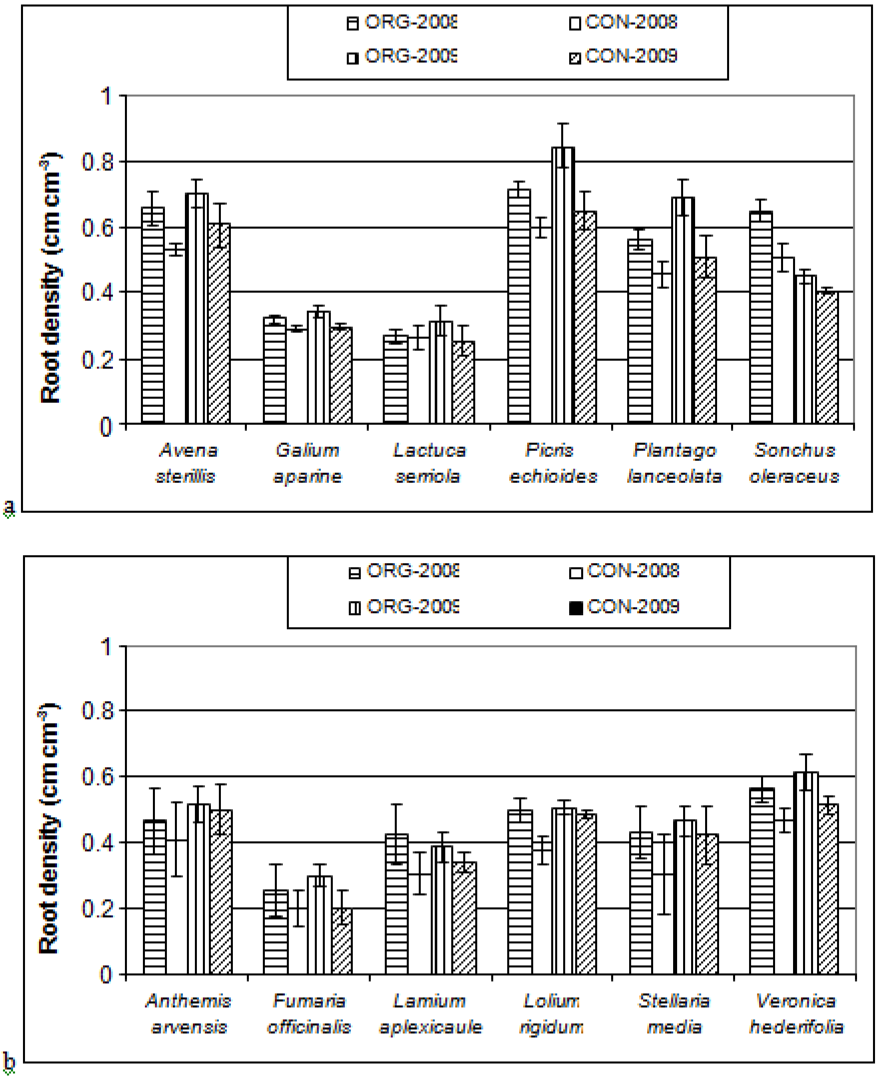

Fig 1. Influence of cultural system (organic: ORG and conventional: CON) on root density (cm cm^{-3}) of a) competitive and b) no competitive weeds. Bars indicate standard deviation.

between the organic and conventional systems (z=2.824, *p*=0.004; z=2.980, *p*=0.002; z=2.445, *p*=0.014; z=3.059, *p*=0.002; z=2.044, *p*=0.04; and z=2.510, *p*=0.012 for *Anthemis, Fumaria, Lamium, Lolium, Stellaria* and *Veronica*, respectively, Table 5). Also, Baumgartner et al. (2010) observed that the weed control methods had a significant interaction with year on frequency, diversity and richness of mycorrhizal weeds. Santos et al. (2006) found that mycorrhizal colonization and microbial activity of soil was affected by herbicides. Peixoto et al. (2010) also found that mycorrhizal root colonization of peanut plants was influenced by herbicide trifluralin. Moreover, many farm management practices, such as the use of water-soluble P fertilizers and biocides, are disruptive to the AM communities, which become impoverished, both in terms of numbers of individuals and species diversity (Gosling et al., 2006). Assaf et al. (2009) observed that organic matter amendments potentially increased AM fungal spore population and colonization levels. For non-competitive weeds, the order of decreasing AM root colonization was *Anthemis (16-38%), Lolium (19-35%), Lamium (14-34%)>Veronica (8-29%)>Fumaria (2-18%), Stellaria (2-16%).* The lowest AM root colonization was found in *Fumaria officinalis* and *Stellaria media* (Figure 2). The highest AM root colonization was recorded in *Lactuca serriola*. Moreover, concerning the competitive weeds, the order of decreasing AM colonization was *Lactuca (20-45%) >Picris (16-32%), Plantago (14-32%), Sonchus (12-28%), Galium (9-32%) >Avena (4-22%).* Moreover, Vatovec et al. (2005) found substantial variation in mycorrhizal responsiveness and hosting behaviour among 14 weeds of temperate field-crop agroecosystems.

Weed density and growth

Weed competitiveness is an attribute that is influenced by environmental conditions and was also associated with high leaf area, greater height, canopy structure and development (Bilalis et al., 2009; Efthimiadou et al., 2009; Karimmojeni et al., 2010). Also, Chen et al. (2004) reported that with well-developed root systems, competitive weeds had a strong ability to acquire available N from soil and grew very fast, resulting in high plant biomass and plant nitrogen. Concerning the weed density of non-competitive weeds (*Anthemis arvensis* L., *Fumaria officinalis* L., *Lamium aplexicaule* L., *Lolium rigidum* Gaudin., *Stellaria media* (L.) Vill., *Veronica hederifolia* L.) there were no significant differences (Table 5) between the organic and conventional

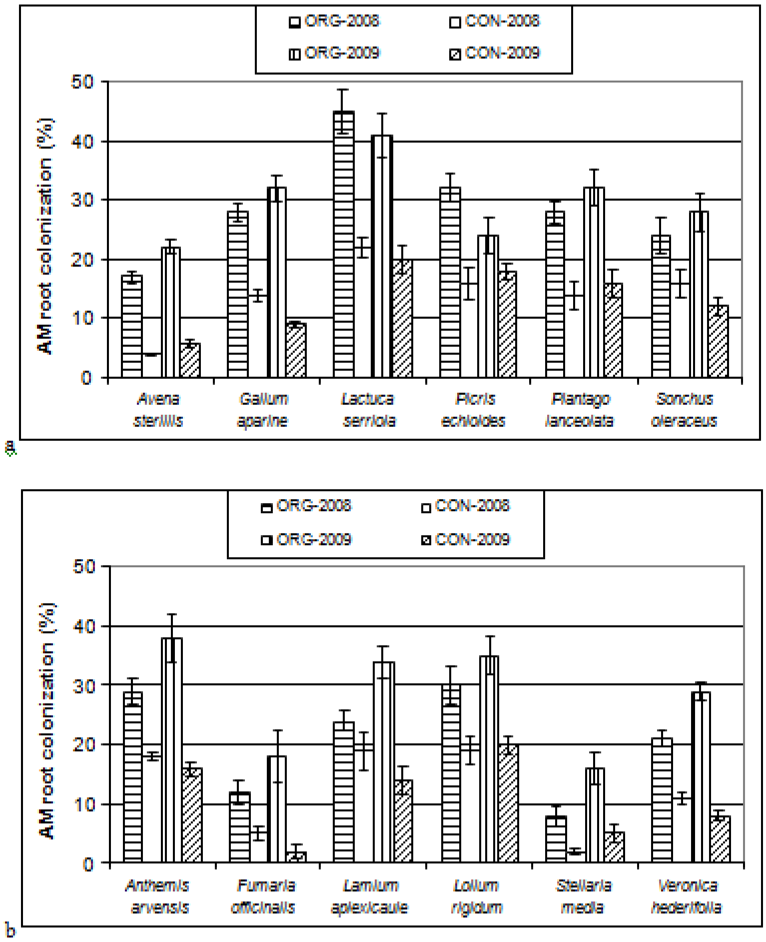

Fig 2. Influence of cultural system (organic: ORG and conventional: CON) on AM root colonization (%) of a) competitive and b) no competitive weeds. Bars indicate standard deviation.

system (z=1.412, *p*=0.157). There were, however, significant differences (z=3.271, *p*=0.0017, Table 5) between the organic and conventional systems in the density of competitive weeds (*Avena sterilis* L., *Galium aparine* L., *Lactuca serriola* L., *Picris echioides* L., *Plantago lanceolata* L., *Sonchus oleraceus* L.). The highest density of competitive weeds was found in organic olive fields (Table 2 and 3). Moreover, there were no significant differences (z=1.804, *p*=0.071) between the organic and conventional systems for weed biomass (Table 2 and 3) of non-competitive weeds (*Anthemis arvensis* L.; *Fumaria officinalis* L.; *Lamium aplexicaule* L.; *Lolium rigidum* Gaudin.; *Stellaria media* (L.) Vill.; *Veronica hederifolia* L). There were significant differences (z=3.657, *p*=0.0002, Table 5) between the organic and conventional systems in the biomass of competitive weeds (*Avena sterilis* L., *Galium aparine* L., *Lactuca serriola* L., *Picris echioides* L., *Plantago lanceolata* L., *Sonchus oleraceus* L.). The highest biomass of competitive weeds was found for organic olive fields. Weed competitiveness is aided by AM root colonization. A positive correlation was found between AM root colonization and weed biomass in the present study (Table 4). Moreover, Smith et al. (2008) reported that AM fungi have beneficial effects on *Vincetoxicum rossicum* (pale swallow-wort) survival and growth. In addition, Rinaudo et al. (2010) reported that the biomass of two out of six weed species were significantly reduced by AM fungi (by 66% and 59%) while the biomass of four weed species was only slightly reduced (by 20% to 37%). Fernadez-Aparicio et al. (2010) found that seed germination of the *Orobanche* and *Phelipanche* species is reduced in the presence of root exudates from pea plants colonized by AM fungi *Glomus mosseae* and *G. intraradices*. Moreover, Lendzemo et al. (2005) reported that with AM fungal inoculation, a significant interaction (30% and more than 50% on maize and sorghum, respectively) in the number of *Stringa hermonthica* shoots was noted. Concerning the N% content of weeds *Stellaria media* (L.) Vill. and *Sonchus oleraceus* L., there were no significant differences between the organic and conventional systems. There were significant differences between the organic and conventional systems in N% content of *Anthemis arvensis* L., *Avena sterilis* L., *Galium aparine* L., *Fumaria officinalis* L., *Lactuca serriola* L., *Lamium aplexicaule* L., *Lolium rigidum* Gaudin., *Picris echioides* L., *Plantago lanceolata* L. and *Veronica hederifolia* L. The highest N% of these weeds was found for organic olive fields. Moreover, the lowest N% was found for *Fumaria officinalis* and *Galium aparine* (Table 2 and 3). A positive correlation was found between root density and N% (Table 4). Gosling et al. (2006) reported that mycorrhizal colonization of plants can offer considerable benefits in terms of growth and nutrient uptake. An AM root is potentially capable of absorbing nutrients from soil *via* two pathways: directly into the root cells themselves and *via* the fungal symbiont (Smith et al., 2001). Karagiannidis et al. (2002) reported that P and N uptake in tomato and eggplants were higher in mycorrhizal treatment than in controls. Mycorrhizal fungi constitute an important biological resource. To better benefit from mycorrhiza at the farm level, an increased

Table 3. Influence of cultural system (organic: ORG and conventional: CON) on density, dry matter and N content of weeds in 2009. Mean values±standard deviation.

Weed type	Weed density (no. m^{-2})		Weed biomass (g m^{-2})		Weed N (%)	
	ORG	CON	ORG	CON	ORG	CON
Non-competitive						
Anthemis arvensis	4.7±0.46	3.1±0.32	14.6±1.12	10.7±0.67	4.54±0.21	4.20±0.12
Fumaria officinalis	3.3±0.42	2.8±0.34	2.2±0.76	3.5±0.87	1.93±0.21	1.24±0.19
Lamium aplexicaule	4.2±0.54	4.7±0.65	9.6±0.43	9.1±0.61	2.94±0.32	2.38±0.12
Lolium rigidum	1.5±0.31	1.3±0.45	7.2±2.10	5.2±1.78	3.56±0.14	2.92±0.32
Stellaria media	3.4±0.12	3.2±0.41	12.3±1.76	10.1±1.54	2.54±0.12	2.59±0.32
Veronica hederifolia	2.2±0.39	2.7±0.41	8.8±0.98	6.9±1.32	4.27±0.31	3.80±0.18
Total[a]	19.3a	17.8a	54.1a	44.5a	-	-
Competitive						
Avena sterillis	7.2±1.05	3.4±1.32	14.5±0.61	10.5±0.52	4.06±0.45	3.26±0.32
Galium aparine	3.9±0.32	2.9±0.45	18.9±2.45	8.9±3.21	1.79±0.13	1.29±0.18
Lactuca serriola	4.1±0.21	4.2±0.48	20.6±2.76	11±1.78	3.31±0.12	2.99±0.09
Picris echioides	3.1±0.21	1.9±0.89	13.1±0.79	7.4±1.49	3.56±0.11	3.15±0.14
Plantago lanceolata	3.9±0.63	2.2±0.51	18.8±1.83	9.8±4.14	3.66±0.32	2.92±0.17
Sonchus oleraceus	3.3±0.32	3±0.67	24.3±3.65	14.2±2.77	2.78±0.45	2.51±0.31
Total	25.5a	17.6b	110.2a	61.8b	-	-

[a]Means in each row followed by the same letter are not significantly different.

Table 4. Correlation coefficients[**a**] between parameters of weeds.

2008	Organic				Conventional			
	WB	RD	AM	N%	WB	RD	AM	N%
Weed density (WD)	ns	ns	ns	ns	ns	ns	ns	ns
Weed Biomass (WB)		ns	0.53**	ns		ns	0.47*	ns
Root density (RD)			ns	0.53**			ns	0.64**
AM root colonization				ns				ns
2009	**Organic**				**Conventional**			
	WB	RD	AM	N%	WB	RD	AM	N%
Weed density (WD)	ns	ns	ns	ns	ns	ns	ns	ns
Weed Biomass (WB)		ns	0.67*	ns		ns	0.67**	ns
Root density (RD)			ns	0.61**			ns	0.61**
AM root colonization				ns				ns

[a]r was calculated using the linear equation. *, ** Significant at P=0.05 and P=0.01, respectively; ns: not significant

understanding of mycorrhizal functioning in agroecosystems is necessary. To begin with, screenings can be carried out to assess which native plants, including weeds, are mycorrhizal (Cardoso and Kuyper, 2006).

Material and methods

Field experiment

Experiment set-up

The experiment was repeated twice. Our study was established in olive crops in the Agrinio area at Western Greece, during 2008 and 2009. In April of each year, a field was selected and designated one of two treatments: organic or conventional. Olive spacing was 10 m between rows and 10 m within rows. The soil type was a silt loam. Twelve fields for each treatment were chosen. Fields were chosen based on geographic location (within an 20 km radius of Agrinio). Each replicate (field) included approximately 40 olive trees and covered an area of 0.2 ha. Differences in specific production practices among each of the treatments are shown in Table 1.

Organic olive crops

Fields designated as organic were managed according to organic agriculture guidelines. The organic fields were certified by DIO certification body. In the organic system, plant nutrition was based on biological N fixation and replacing K and P using compost. In 2006 and 2007, Vetch was sown on November at a rate of 80 kg ha^{-1}. Vetch crop was incorporated into the soil on April. On Febrary of 2008 and 2009, the compost – consisting of a mixture of farmyard manure and legume residue (Complemumosan by Vassilopoulos S.A.), was applied at a rate of 20 kg per olive tree. The weeds were controlled by mechanical cultivation. A rotary hoe was used.

Conventional olive crops

The conventional cropping system was relying on mineral N-P-K fertilization. On February of each year (2006-2009) the inorganic fertilizer (11-15-15) was applied at a rate of 2 kg per olive tree. The weeds were controlled by herbicides and mechanical cultivation. The herbicides glyphosate (Roundup 36 SL; Monsanto Hellas) and oxyfluorfen (Goal 24 EC; Basf Agro Hellas) were applied at 1260 g a.i. ha^{-1} and 1200 g a.i. ha^{-1}, respectively.

Samplings, measurements and methods

Weed density and biomass

The number and dry weight of dominant weeds (and) were assessed. Weeds were categorized as competitive (*Avena*

Table 5. Wilcoxon Matched Pairs Test of weed parameters: Comparison between organic (ORG) and conventional (CON) olive production systems in terms of competitive and non-competitive weed parameters (WD: total weed density, WM: total weed biomass, AM: weed–AM root colonization).

Comparison	Wilcoxon Matched Pairs Test					
	Non-competitive weeds			Competitive weeds		
	Pairs	Z	p-Value	Pairs	Z	p-Value
ORG_WD & CON_WD	12	1.412	0.157949	12	3.271	0.001070
ORG_WM & CON_WM	12	1.804	0.071199	12	3.657	0.000255

	Non-competitive weeds			Competitive weeds			
Comparison	Pairs	Z	p-Value		Pairs	Z	p-Value
ORG & CON AM Anthemis	12	2.824	0.004475	ORG & CON AM Avena	12	3.374	0.001034
ORG & CON AM Fumaria	12	2.980	0.002876	ORG & CON AM Galium	12	3.206	0.002113
ORG & CON AM Lamium	12	2.445	0.014489	ORG & CON AM Lactuca	12	3.032	0.002051
ORG & CON AM Lolium	12	3.059	0.002220	ORG & CON AM Picris	12	3.456	0.000796
ORG & CON AM Stellaria	12	2.044	0.040868	ORG & CON AM Plantago	12	3.105	0.002013
ORG & CON AM Veronica	12	2.510	0.012068	ORG & CON AM Sonchus	12	3.871	0.000134

sterilis L. (wild oat); *Galium aparine* L. (cleavers); *Lactuca serriola* L. (wild lettuce); *Picris echioides* L. (bristly oxtongue); *Plantago lanceolata* L. (buckhorn plantain) and *Sonchus oleraceus* L. (sow thistle)) and non-competitive (*Anthemis arvensis* L. (corn chamomile); *Fumaria officinalis* L. (drug fumitory); *Lamium aplexicaule* L. (common henbit); *Lolium rigidum* Gaudin. (wimmera ryegrass); *Stellaria media* (L.) Vill. (chickweed) and *Veronica hederifolia* L. (ivyleaf speedwell)). The competitive weeds grow more rapidly, have upright growth habit and allelopathic ability and have large leaves. Weeds were recorded on April 2008 and 2009. A 1 m × 1 m quadrate was used, 6 times per field. All weeds were collected from the measured area and weighed in order to determine the dry matter.

Weed root growth and AM root colonization

Two weed root samples were collected from the 0–35 cm layer by using a cylindrical auger (25 cm length, 10 cm diameter). For the first sample, roots were separated from the soil by soaking the samples overnight in 30 ml of a 0.5% solution of sodium hexametaphosphate. Afterwards, the sample was stirred for 5 min and washed over a 5 mm mesh-sieve. The roots thus held on the sieves were decanted into a 0.1% trypan blue FAA staining solution (mixture of 10% formalin, 50% ethanol and 5% acetic acid solutions). For the determination of root length density, the stained root sample was placed on a high resolution scanner (Hewlett Packard 4c, Palo Alto, CA, USA) and images captured using Delta-T software (Delta–T Scan version 2.04; Delta–T Devices Ltd, Burwell, Cambridge, UK). The root dry weight was determined after drying for 48 h at 70ºC. The second root sample was cleaned and stained with trypan blue in lactophenol, according to the method of Phillips and Hayman (1970). The percentage of root length colonized by AM fungi was determined microscopically with the gridline-intersection method at a magnification of ×30-40 (Giovannetti and Mosse, 1980).

Statistical Analysis

The statistical analysis of the data was performed with the Statsoft (1996) logistic package. Differences between treatment means were compared at p= 5%, with Paired Sample Comparison analysis, to find significant differences (Wilcoxon, 1945). This analysis was used to calculate the confidence intervals for the difference between the population means and the ratio of the population variances, and to calculate confidence intervals for the hypotheses means, variances, and medians. Correlation analyses were used to describe the relationships between weed biomass, density, N%, root density and AM root colonization.

Conclusion

Weed species differed in the response to AM root colonization. While mycorrhizal symbiosis had no effects on the growth of non-competitive weeds, competitive weed growth was positively influenced by the present of the fungal symbiont. There were significant differences between the organic and conventional systems in the density and biomass of both non-competitive weeds and competitive weeds. The highest biomass and density of competitive weeds was found in organic olive fields. Collectively, our results indicate that mycorrhizal symbiosis is an important factor influencing weed growth. AM enhance the competitive ability and growth of competitive weeds in organic olive crops

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