

Effects of Mycorrhiza on Fiber Quality Parameters, Root Characteristics and Yield of Organic Cotton (*Gossypium Hirsutum* L.)

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Abstract. Organic cotton consists of a new industrial crop product. Field experiment was conducted to determine the effects of mycorrhiza on fiber quality parameters and yield components of cotton crop (*Gossypium hirsutum* L.). The experiments, conducted during 2006 and 2007, were laid out in a split plot design with four replicates, two main plots (organic and conventional system) and two sub-plots (cotton varieties: Athena and Fandom). There were statistically significant differences in reflectance between these two varieties. Moreover, there were correlation between lint characteristics and regression as well as linear functions between AMF and statistical important values of lint characteristics.

Keywords: organic cotton, mycorrhiza, fiber quality parameters, root characteristics, yield.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a major industrial crop in Greece (Avgoulas *et al.*, 2005), India (Blaise, 2006), Turkey (Dagdelon *et al.*, 2009), USA (Nichols *et al.*, 2004), Pakistan (Parvez *et al.*, 2004) and Australia (Hulugalle *et al.*, 2004). The main factors affecting development of cotton plant include climate (temperature, humidity, wind and sun time *et.c.*) and cultivation techniques. For a specific environment, optimum production can be achieved by establishing a balance between vegetative and generative growth. Cotton is one of the most important fiber-producing plants. Cotton and synthetic fibers meet most of the world's textile. It is a crop that its perennial, indeterminate growth habit and its specific adaption to water regime (Hearn, 1994), make it extremely sensitive to environmental conditions and management practices (Oosterhuis, 1994). Management practices *e.g.* on cultivation system, especially during flowering period, affect the cotton fiber properties (Bradov and Davidonis, 2000). Hence, there is a concern about the impact of various farming practice changes on the lint quality parameters and price discounts for fiber. The expression of fiber properties genetic potential depends on complex interaction among crop management and growth environment. However, it is mentioned that cotton cultivation is characterized by high water requirements and use of substantial amounts of fertilizers and pesticides.

On the other hand, organic cotton consists of a new industrial crop product and that's the main reason that there are few references to organic cotton in the literature (Blaise, 2006; Moran and Greenberg, 2009; Thomopoulos *et al.*, 2008). Organic cotton is grown using methods and materials that have a low impact on the environment. Its fiber is used in

everything from personal care items, to home furnishings, children's products and clothes of all kinds and styles. In addition, organic cotton seed is used for animal feed, and its seed oil is used in a variety of food products (Bilalis *et al.*, 2010). Organic cotton can also be presented as the solution to the current cotton market crisis, because its price can reach more than 20% above market (Haynes, 2006).

Cotton's plants are capable of engaging water and nutrition elements, even if they are in small amount in the soil, due to their extensive root system. However, the root absorptive ability grows higher in the case of fungus cohabitation. Colonization of the land by plants some 400 million years ago was associated with the colonization of their primitive roots by soil-borne filamentous fungi (Nicolson, 1975; Simon *et al.*, 1993; Taylor *et al.*, 1995). Today, 90% to 95% of land plants still maintain some type of mycorrhizal association so that "mycorrhizas, not roots, are the chief organs of nutrient uptake by land plants" (Smith and Read, 1997). Symbiotic associations between mycorrhizal fungi and plant roots are widespread in nature and can provide a range of benefits to the host plant. Of the several mycorrhizal symbiosis, arbuscular mycorrhizas are much the most abundant. The study of arbuscular mycorrhizal fungi has fundamental and practical importance. First of all because in most environments "root biology" is actually "mycorrhizal biology", and secondly because of the practical importance of AM in fields as diverse as sustainable agriculture, horticulture, reforestation, and ecosystem management (Barea and Jeffries, 1995). Arbuscular mycorrhizal fungi (AMF) are plant root symbiosis that provide many benefits to crop production and agro ecosystem function. Therefore, management of AMF is increasingly seen as important to ecological farming (Bilalis and Karamanos, 2010).

It has not been studied before the impact of mycorrhizal symbiosis on lint characteristics of the organic cotton. The main objective of this study was to determinate the effects of mycorrhizal symbiosis on fiber quality and yield components on organic cotton crop.

MATERIALS AND METHODS

A cotton crop (*G. hirsutum* L.) was established in Karditsa (Central Greece), 304 km north of Athens. The soil was a clay loam (28.2% clay, 32.5% silt and 39.3% sand) with pH 7.11, organic matter 1.01%, electrical conductance (EC) 0.45 mS cm⁻¹, NO₃-N 16.3 mg kg⁻¹ soil, P 15.8 mg kg⁻¹ soil, K 257 mg kg⁻¹ soil, Fe 77.4 mg kg⁻¹ soil and Mg 1301 mg kg⁻¹ soil. The experimental site has mild rainy winters and hot-dry summers. The experiment was established on an area of 2496 m² according to a split plot design with four replicates: the two main plots (tillage systems: conventional and organic) and two sub-plots (cotton varieties: *Athena* and *Fandom*). The subplots size were 10 x 8 m. According to soil analysis, in the conventional plots, 400 kg ha⁻¹ of fertilizer (20:10:10 kg ha⁻¹ N: P₂O₅: K₂O) was applied before sowing. In organic plots, vetch crop (*Vicia sativa* L. var *Alexandros*), as green manure was incorporated into the soil on 20 April 2009. The amount of total N that accumulated on vetch plants was 207 kg ha⁻¹. Cotton was sown by hand, respectively, in the same plots, at a seed rate of 28 kg ha⁻¹ and in an intra row spacing of 96 cm. The field area was irrigated 3 times with a drip irrigation system consisting of laterals with 20 mm diameter with in-line drippers and at 0.40 m distance. For defoliation on conventional plots pyraflufen-ethyl was used in recommended dose 100 ml ha⁻¹. Finally, weeds in organic plots, were controlled by hand, with two hoeing being carried out. That is the basic weed control in organic agriculture. In addition, conventional plots received herbicide treatment as usual: fluometuron 50% SC (Cotoran, 50 SC) at the recommended dose of 2.5 kg active ingredient ha⁻¹.

As concerned as samplings, measurements and methods of fiber quality are the followings: lint was analyzed for micronaire (fiber fineness), length (mm), strength (g tex⁻¹), uniformity ratio (%), reflectance (whiteness, %Rd), yellowness (+ b), elongation (%) and leaf trash ratio (%). Leaf area was measured using an automatic leaf area meter (Delta-T Devices Ltd, Burwell, Cambridge, UK) and converted into LAI by multiplying by the average crop density of each plot.

The high Volume Instrument (HVI) spectrum (by Zellweger Uster Inc., Uster, Switzerland) was used to determine lint quality: 1) The fiber length, 2) The fiber elongation, 3) The fiber strength, 4) The micronaire, 5) The reflectance (%) and yellowness (+b) (represented the degree of cotton pigmentation, 6) Maturation and moisture, 7) AMF and Short Fiber Index (SFI), 8) Leaf Area Index (LAI), 9) Root volume, 10) Root weight and 11) Yield of cotton.

For estimating analysis of variance and comparisons of means the software Statsoft 24 was used. The LSD test was used to detect and separate the mean treatment differences. Regression and correlation analyses were used to describe the relationships between mycorrhizal symbiosis and fiber characteristics. All comparisons were made at the 5% level of significance.

RESULTS AND DISCUSSION

The facts represented on Tables 1 and 2 have arisen from the statistical analysis of the experimental facts related to the effect of the cultivation system (organic-conventional), the cultivated varieties (Athena-Fandom) and their interaction. It's about the characteristics of the lint, plant, mycorrhizal symbiosis and relationship between the lint characteristics and the mycorrhizal symbiosis which is the main subject of this report. Through the Table 1 we can observe that the MAT medians, as about the cultivation systems, were statistically different ($p_{level} < 0.05$) with a prevalence of the organic system (89.37%) in addition to the conventional (86.62%). The same difference between the two systems occurred on strength. In the organic system the value was 33.862 g.tex⁻¹ whereas in the conventional system was 32.175 g.tex⁻¹.

As concerned plant's characteristics, root weight showed statistical differences. In fact on the organic system value median was 17.425 g.lt⁻¹ and the conventional system was 16.237g.lt⁻¹. This happens due to the fact that the reduced usage of pesticides and herbicides enhances the growth of root system. Also, the yield was higher in the conventional system 458.13 Kg.ha⁻¹ in addition to the conventional 424.25 Kg.ha⁻¹.

There were statistically significant differences in reflectance (RD) between Athena and Fandom varieties. Athena's value for reflectance was 74.037% whereas Fandom's value for this lint characteristic was 71.563%. The interaction occurred significantly on strength only.

There were correlation between lint characteristics and regression as well as linear functions between AMF and statistical important values of lint characteristics (Table 2). Specifically, positive correlation was observed between micronaire ($p = 0.0011$), maturation ($p = 0.0397$), length ($p = 0.016$), strength ($p = 0.0054$), reflectance ($p < 0.0001$) and the AMF. In correspondence, the regression p-levels for these characteristics were the same. That fact indicates strong relationship between those characteristics and AMF. Furthermore, it is based on the influence of the AMF symbiosis because of the effect of the plant physiology and specifically on the water absorption and the photosynthetic rate. The authors suggested that AMF symbiosis may have increased the number of photosynthetic units. Moreover, photosynthetic storage and export rates have been increased by the AMF fungi (Wang *et al.*,

1989). Stomatal conductance, transpiration as well as photosynthesis are stimulated by AMF symbiosis about as frequently under non-stressed as under drought conditions. This symbiosis augments nutrient uptake by roots, which deplete the rhizosphere at a rate dependent on water availability, as well as the concentration and soil mobility of the nutrient. Successful colonization is very important in degraded soils where nutrient availability is low. Furthermore, internal CO₂ concentration was lower in non-AM alfalfa plants than in AM alfalfa plants. It has also been found that VA mycorrhizal fungi caused a greater storage of photosynthates. It was important to observe that the regression of these indices were positive. That means that the micronaire, maturation, length, strength and reflectance values rise as the AMF symbiosis rises. This was also based on values of those characters, where the organic system (AMF percentage was higher than conventional system) indicates higher values for those characters (Tab. 1).

Tab. 1

Influence of Crop system and cultivated varieties on fiber properties, seed cotton yield, root characteristics and LAI
Means in each column followed by the same latter are not significantly different. The LSD ($p=0.05$) for cultural systems and cotton varieties are also shown. Significant at $*p=0.05$, ns: not significant.

	Maturation	Micronair	LEN	Strength	RD	AMF	SFI	MOIST	ELG	Yellowness	LAI	Root volume	Root weight	YIELD
	(%)	values	(mm)	(g.tex ⁻¹)	(%)	(%)		(%)	(%)	b		cm.cm ⁻³	g.lt ⁻¹	Kg.ha ⁻¹
System														
Organ	89.37 ^a	4.27 ^a	29.93 ^a	33.86 ^a	72.96 ^a	0.526 ^a	5.650 ^a	7.47 ^a	4.762 ^a	7.25 ^a	3.448 ^a	4.2670 ^a	17.42 ^a	458.13 ^a
Conv	86.62 ^b	3.79 ^a	29.85 ^a	32.17 ^b	72.63 ^a	0.482 ^a	6.012 ^a	7.57 ^a	5.062 ^a	7.58 ^a	4.318 ^a	2.5470 ^a	16.23 ^b	424.25 ^b
Cultivars														
Athena	87.75 ^a	3.9425 ^a	29.89 ^a	33.16 ^a	74.03 ^a	0.490 ^a	5.862 ^a	7.60 ^a	4.662 ^a	7.60 ^a	3.756 ^a	3.866 ^a	16.88 ^a	448.25 ^a
Fandom	88.25 ^a	4.1213 ^a	29.89 ^a	32.87 ^a	71.56 ^b	0.518 ^a	5.800 ^a	7.45 ^a	5.162 ^a	7.25 ^a	4.009 ^a	2.949 ^a	16.77 ^a	434.13 ^a
Interactions														
S x C	ns	ns	ns	s	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Tab. 2

Correlation and regression between lint characteristics and AMF, as well as the linear function of each one

	Correlation coefficients(r)	p-level	Regression(b)	p-level	linear functions
MIC	0.7378	0.0011	4.9589	0.0011	MIC= 1.27 + 4.96*AMF
MAT	0.5184	0.0397	0.1877	0.03966	MAT= 0.78 + 0.19*AMF
LEN	0.7207	0.0016	7.3619	0.00163	LEN= 26.4 +7.36*AMF
UNF	0.0281	0.9178	ns	0.9177	ns
STR	0.6599	0.0054	12.5878	0.00541	STR= 26.2 + 12.6*AMF
ELG	-0.1398	0.6057	ns	0.6057	ns
MOIST	0.08	0.766	ns	0.7659	ns
RD	0.8788	<0.0001	53.249	<0.0001	RD= 41.2 + 53.2*AMF
B	-0.0972	0.7203	ns	0.7202	ns

MIC :micronaire , MAT: maturation, LEN: length, STR: strength (g tex⁻¹), UNF: uniformity ratio (%), RD: reflectance (whiteness, Rd), B: yellowness (+ b), ELG: elongation, MOIST: Moisture, SFI: Short Fiber Index, LAI: Leaf Area Index, ns: not significant

CONCLUSION

Results of this study indicate that there were significant differences between organic and conventional cotton for maturation, strength, root weight and yield. The yield was higher in the conventional system in comparison to the organic one. Athena had the highest strength, reflectance, moisture, root volume, root weight and yield. AMF percentage was higher in organic than conventional system. Furthermore, a positive correlation was observed between Micronaire, Mature, Length, Strength, Reflectance and AMF. To conclude, mycorrhizal helps the absorption of water and contributes to the rate photosynthesis thus contribute to fiber composition and quality.

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