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Full Length Research Paper

Effect of arbuscular mycorrhiza and different doses of phosphor on vegetative and generative components of strawberries applied with different phosphor doses in soilless culture

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Two strawberry cultivars (Camarosa and Maraline) grown in soilless culture were inoculated with two arbuscular mycorrhizal fungi (*Glomus clarum* and *Glomus caledonium*) and three phosphor doses (10, 30 and 60 ppm). The effects of arbuscular mycorrhiza on the vegetative and reproductive characteristics of strawberries were evaluated. Total yield, fruit size, runner number, dry weight of leaves, fruit characteristics such as pH, acidity and total soluble solids were also determined. The results show that mycorrhizal inoculation statistically increased the yield in Maraline cultivar and had no significant effect on other vegetative characteristics. On the other hand, both phosphor and mycorrhizal inoculations resulted in significant decrease on total soluble solids and pH in the fruits of both cultivars. Our limited study shows that mycorrhizal inoculation of the strawberry plants may cause minor biotic stress on the strawberry plant.

Key words: Mycorrhizae, strawberry, phosphor, soilless.

INTRODUCTION

Plants face several environmental stresses and mostly evolve various mechanisms that cope with these stress factors. These stress factors have been classified into abiotic and biotic factors. Soil/plant relations, weeds, nutrient deficiency, mycorrhizae, salinity etc. are some of the stress factors. Arbuscular mycorrhizal (AM) fungi were reported by several researchers as enhancer of root systems and they are known to support stronger, healthier, higher-yielding plants through increased nutrient acquisition (Miller, 2000), reduce levels of water stress (Augé, 2001), lower disease incidence (St-Arnaud et al., 1995), and increase phytohormone production (Shaul-Keinan et al., 2002). However, the current perception is that these obligate symbionts play no or little role in soils where nutrient availability are higher (Olsen et al., 1999). Improved plant growth in response to AM colonization is mostly achieved in soils where available soil phosphorus (P) is limited.

Conventional agriculture practices for high-value crops in most countries often include abundant fertilization leading to nutrient accumulation in the soils. In particular, P accumulates in soils with a P fertilization history (Zhang et al., 1995). Zhang et al. (2004) concluded that large amounts of residual fertilizer P were available in the soil during subsequent years following fertilization due to the slow conversion process of residual fertilizer P to available P forms. From the point of view of mycorrhizal effects mentioned earlier, limited amount of P may be sufficient for the normal plant development by the efficient uptake of mycorrhizal support. There are reports on the mycorrhizal effect on the strawberry plants, where some say the plants can benefit considerably from arbuscular mycorrhizae when the availability soil P is limited (Daft and Okusanya, 1973), some say there is small or no benefit from mycorrhizae for strawberries with adequate nutrition (Kiernan et al., 1984).

The aim of the present study was to determine the

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Table 1. AMF colonization ratio in roots five moths after inoculation.

Colonization (Percentage root length)			
Source	**10 ppm P**	**30 ppm P**	**60 ppm P**
Mareline			
No mycorrhiza	0.6	2.2	2.3
G. clarum	27.6	30.3	28.6
G. caledonium	32.6	38.7	36.5
Camarosa			
No mycorrhiza	1.2	1.8	2.1
G. clarum	30.5	33.6	36.1
G .caledonium	40.2	43.4	41.6
LSD: 17.67			

efficiency of two mycorrhizal species on P uptake in two strawberry cultivars under varying P concentrations in the growth medium and identify relationships between mycorrhiza and P on the vegetative growth and yield. For these vegetative parameters such as leaf, crown and runner numbers, as well as yield parameters were determined. In addition, effects of P or mycorrhiza on the titratable acidity, total solible solid content and pH of fruit contents were also evaluated.

MATERIALS AND METHODS

Inocula of two AM fungal species, *Glomus clarum* and *Glomus caledonium* were obtained from Cukurova University, Adana, Turkey, and was maintained on maize plants growing in pasteurized soil in plastic pots. The design of the experiment was a 3 factorial with two different AM inocula and a non-mycorrhizal control, combined with tree levels of P addition and three replicates per treatment. Inoculum of each mycorrhizal fungus was mixed with equal proportion of steam sterilized potting mix (equal parts of soil:sand:perlite, v:v). Then, the mycorrhizal inoculum with approximately 1000 spores was added in the ratio of 1:10 to pumice, which was used as plant growth substrate. Six uniform frigo plantlets of Camarosa and Maraline strawberry cultivars per replicate were planted into 12 L pots with three different pumice culture (inoculated with *G. clarum, G. caledonium* or uninoculated) in an unheated greenhouse in the end of March of 2008. The strawberry plants were drip irrigated with the nutrition solution at different intervals according to the plant growth stage when predawn water potential drops below -0.5 MPa. Three phosphor doses (10, 30 and 60 ppm) with the standard plant nutrient solution (containing 210 ppm nitrogen, 200 ppm calcium, 560 ppm potassium and other micronutrients) were applied to strawberry plants.

Plants were sampled five months after inoculation. The third plant in each replicate was removed with part of the newly formed root system. A sample of newly formed roots was rinsed under running tap water and fixed in formalin:acetate:alcohol (1:1:18) for subsequent estimation of the VA mycorrhizal infection. The percentage of infected root length was determined by the gridline intersect method (Giovannetti and Mosse, 1980). Runners formed were recorded when they were 10 cm long, and then removed. Leaf and crown numbers per plant were assesed when the experiment was finished seven months after planting. Mature fruit from each replicate of cultivars were analyzed for soluble solids (SS), pH and titratable acidity (TA) at every harvest. All data were analyzed with randomized block design methods using an SPSS package computer programme (SPSS, 1993). Significant differences between mean values were based on Duncan's multiple range tests (Duncan, 1955).

RESULTS AND DISCUSSION

AM colonization ratio in roots

The impact of inoculation on strawberry root colonization differed from non inoculated plants five months after inoculation. Although the plants without AM inoculation had low levels of colonization level, the roots of inoculated plants showed from 27.6 to 43.4% colonization in roots. Inoculation resulted in a significantly greater colonization at both cultivars compared to without AM fungi (at 0.01 level). However, this increase in colonization did not correspond to a significant increase in yield. No significant difference was also found at P level in both cultivars and between cultivars (at 0.05 level) (Table 1).

Yield components (yield per plant, fruit number, fruit weight)

There was no significant effect of P and mycorrhizal applications on the fruit sizes of both cultivars, although the fruits of Maraline were larger than Camarosa cultivar's. While the differences of fruit yield in Camarosa were not significant among application at 5% level, the fruit number per plant was significantly affected by both P and mycorrhiza applications. The yield of Maraline cultivar increased with increasing P doses and by *G. clarum.* The fruit number of maraline was also increased by the mycorrhizal applications while there was no significant effect of P doses in Maraline cultivar (Table 2).

Table 2. Some plant and fruit characteristics for Camarosa and Maraline strawberry cultivars grown with different levels of P and arbuscular mycorrhiza species.

Source	Yield (g/plant)	Fruit number per plant	Runner number per plant	Fruit weight (g/fruit)	Soluble solid content (%)	pH	Acidity	Leaf Number	Crown number per plant
Camarosa									
10 ppm P	57.0	7.4^{b**}	9.0^{b}	7.7	13.84^{a}	3.94^{a}	0.99^{a}	34.8	2.4^{b}
30 ppm P	50.9	7.4^{b}	10.6^{ab}	6.9	13.48^{b}	3.80^{c}	0.99^{a}	35.8	2.9^{ab}
60 ppm P	61.0	8.4^{a}	11.7^{a}	7.2	12.62^{c}	3.86^{b}	0.89	36.0	3.2^{a}
LSD	Ns*	0.9	ns	ns	0.24	0.04	0.05	ns	0.6
No mycorrhiza	52.8	7.4^{b}	9.5	7.1	13.81^{a}	3.88^{b}	0.96	35.6	2.1^{b}
G. clarum	62.2	8.5^{a}	10.8	7.3	13.72^{a}	3.93^{a}	0.98	35.8	3.0^{a}
G. caledonium	53.8	7.3^{b}	11.0	7.4	12.42^{b}	3.79^{c}	0.93	35.4	3.4^{a}
LSD	ns	0.9	ns	ns	0.24	0.04	ns	ns	0.6
Mean	56.3	7.7	10.4	7.3	13.31	3.87	0.95	35.6	2.9
Maraline									
10 ppm P	93.5^{b}	11.8	10.1	7.9	14.44^{a}	3.97^{a}	1.56	33.3	3.1
30 ppm P	100.0^{b}	12.3	10.2	8.1	14.19^{b}	3.84^{c}	1.58	34.3	3.4
60 ppm P	112.7^{a}	13.4	11.1	8.4	13.66^{c}	3.89^{b}	1.61	33.9	3.6
LSD	11.5	ns	ns	ns	0.24	0.02	ns	ns	ns
No mycorrhiza	94.7^{b}	11.7^{b}	9.6	8.1	14.39^{a}	3.96^{a}	1.60	33.8	2.9^{b}
G. clarum	112.8^{a}	13.5^{a}	11.0	8.4	14.13^{b}	3.88^{b}	1.61	33.2	3.3^{b}
G.caledonium	98.7^{b}	12.4^{ab}	10.7	8.0	13.77^{c}	3.86^{b}	1.55	34.6	3.9^{a}
LSD	11.5	1.3	ns	ns	0.24	0.02	ns	ns	0.5
Mean	102.0	12.5	10.4	8.2	14.10	3.90	1.58	33.9	3.4

*ns= Not significant at 0.05 level; ** the same alphabets are not statistically different by Duncan test.

Leaf, runner and crown number

Increasing P doses increased the number of runners and crowns in Camarosa while no significant effect of P on the runner or crown number in maraline was evident. Number of off shoots, and of dry matter of mother plants also increased with increasing P application rates. Inoculation of *G. clarum* in maraline and both *G. clarum* and *G. caledonium* in Camarosa increased crown number. Neither P nor mycorrhizal applications affected runner numbers in Maraline. The leaf number was also unaffected by P application rates in both cultivars.

Soluble solids, pH and acidity of fruits

The soluble solids of fruits increased with increasing P doses and mycorrhizal inoculation in both cultivars. Generally, lower pH and acidity were observed by the increasing soluble solids in fruits in both cultivars. Significant differences in fruit acidity in response to P applications were evident only in Camarosa and not in maraline. Finally, the effect of mycorrhizal applications and differing P doses were slightly different in the strawberry cultivars used. This study has shown that AM fungi have little effect on strawberry growth, yield or nutrition. There was no significant effect on the fruit weight and leaf number in both cultivars although there were same differing effect observed by P and mycorrhiza on the other

Table 3. Means and mean separations of several horticultural characteristics for Camarosa and Maraline strawberry cultivars grown with different levels of P and arbuscular mycorrhiza species.

Source	Degrees of freedom	Yield	Fruit number	Runner number	Fruit weight	Soluble solid content	pH	Acidity	SS/Leaf number	Crown number
Camarosa										
P level (P)	2	233	3.32*	16.12*	1.59	3.54**	0.05**	0.03**	3.69	1.37*
Mycorrhizae(M)	2	239	3.45*	5.70	0.15	5.53**	0.05**	0.01	0.36	4.15**
P*M	4	86	0.78	2.51	0.55	1.37**	0.03**	0.01*	0.71	0.09
Error	18	76	0.88	2.72	0.47	0.06	0.00	0.00	3.57	0.33
Maraline										
P level (P)	2	862**	5.59	3.06	0.64	1.46**	0.04**	0.01	2.08	0.48
Mycorrhizae (M)	2	821**	7.54*	5.42	0.36	0.88**	0.03**	0.01	4.65	2.26**
P*M	4	45.04	1.07	2.84	0.85	0.64**	0.01**	0.00	27.38	0.04
Error	18	135.29	1.69	1.69	0.47	0.06	0.00	0.01	22.44	0.26

*and** are significant at 5 and 1%, respectively.

component.

Bull et al. (2005) reported that no differences in market yield were detected between inoculated and non-inoculated plants in their experiments and no differences were detected in AMF colonization between inoculated and noninoculated plants (cultivars Aromas or Diamante), regardless of the commercial inoculum used. Levels of colonization on plants treated did not differ regardless of inoculant reported. Although our results were in agreement with those results regarding to yield, level of AMF colonization in roots differed between inoculated and noninoculated plants in our study. Low colonization of noninoculated plants in our study can be explained by the fact that the pumic culture we used, does not allow the colonization of the AMF as in soil. Chávez and Ferrera-Cerrato (1990) also reported root colonization of some strawberry cultivars, after AM inoculation by the endophytes varied from 25 to 75%, but there was no relation to the extent of fungal colonization with plant growth (Table 3).

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