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Increasing Salt Tolerance in Two Pecan Rootstocks ("Desirable" and "Graking") by Mycorrhizal Inoculation

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THE EFFECT of inoculation with mycorrhizal fungi (*Glomus mosseae and Glomus australe*) on salt stress response of two pecan rootstocks ("Desirable" and "Graking") grown under different salinity levels (0.0, 1000 and 2000 mg/L^{-1}) was investigated. Generally, it could be concluded that all the studied growth parameters were significantly decreased with saline irrigation water compared to those which didn't receive salt treatments and these decrements were paralleled with increasing salt concentration.Yet, average number of burned leaves /plant showed the above-mentioned tendency. Whereas root length did not take definite trend. Inoculation with mycorrhizal fungi (MHZ) minimized the harmful effect of salinity. Stocks were treated with high salinity concentration (2000 mg/L^{-1}) without MHZ inoculation was considered the most drastic treatment, since it gained the lowest growth values. Concerning the response of two pecan cultivars under study to salinity expressed as number of leaves, root, and top dry weights, root length and thickness of main root, "Desirable" rootstock obtained higher values than "Graking".

The soil addition of mycorrhizal fungi (especially *G. australe*) improved leaves chlorophyll (A and B) and total carbohydrates contents than the control. Increasing salinity in irrigation water significantly increased leaf osmotic potential and proline contents. Meanwhile, inoculation with MHZ fungi significantly decreased leaf osmotic potential and proline contents in leaves of the two cultivars when compared with saline treatments only. Moreover, "Desirable" rootstock exhibited higher levels of proline and total carbohydrates than "Graking" rootstock. Irrigation with saline water decreased leaf N, P and K contents as compared with other treatments (unsterilized, sterilized, MHZ1, and MHZ_2). On the contrary, Ca, Na, and Cl contents were increased. Inoculation with MHZ increased leaf N, P and K content in the tested pecan rootstocks as compared with the non-inoculated ones. In contrast, the addition of MHZ reduced leaf

Ca, Na, and Cl contents compared with seedling treated with salinity only. Roots anatomical studies revealed that, as salinity increased thickness of root cross section, thickness of cortex and no. of xylem cells decreased. On the contrary, thickness of roots vascular bundles, and root pith thickness increased. However, inoculation with mycorrhizal fungi (*G. mosseae and G. australe*) increased significantly thickness of root cross section, thickness of root cortex, number of root xylem arches and number of root xylem cells in both cultivars grown under 1000 and 2000 mg/l^{-1} salt concentrations compared to the control under the same concentrations and without mycorrhizae.

Conclusively, inoculated soil with mycorrhizal fungi (*G.mosseae and G. asturale*) may play an important role in alleviating salt stress of "Desirable" and "Graking" pecan rootstocks through enhancing growth, increasing leaves chlorophyll (A and B), total carbohydrates, N, P and K contents and reducing proline, Ca, Na, and Cl contents.

Salinity is a widespread problem in arid and semiarid regions. In Egypt, the problem is acute, where about 60% of the arable soils are classified as salt affected (Balba, 1969). Soil salinity causes great losses to agriculture by lowering the yields of various economic crops (Hassan & El-Samnoudi, 1993). Salinity stress always accompanied by different changes in plant metabolism, which in turn affects plant constituents. The most harmful effects due to increasing the osmotic pressure are reduction in water availability to plants (Saad El-Dien *et al.*, 1992), enhancement of stomatal resistance (Sherin, 2002), reduction in assimilates partitioning to roots (Gaser, 1992) and unbalance of nutrients due to ion toxic effect on physiological process (Valia & Potiel, 1997).

Pecan trees were once thought to tolerate a considerable level of salinity, but susceptible to chloride (Cl) damage (Harper, 1946). Moreover, wide variations in response to salinity among pecan rootstock cultivars were studied (Miamoto *et al.*, 1985, and Miamoto, 1990). The salt affected pecan trees are generally stunted, lack vigor and have small leaves, resulting in severely reduced growth (Emtithal *et al.*, 1996). Short-term solutions to salt stress are needed to bridge the gap between today's approach and a future agriculture that uses genetically improved plants (Abou El- khashab *et al.*, 1997). Ectotrophic mycorrhizae are essential for establishment of tree seedlings for good growth and development in soils low in nutrients. Inoculation with suitable mycorrhizal fungi, is well documented by reports from various parts of the world (Antunes & Cardoso, 1991, Chandrashekara, *et al.*, 1995, Abdel- Aziz *et al.*, 1997 and Entry *et al.*, 1999). Mycorrhizal fungi are able to absorb and accumulate in the fungus mantle various elements and translocate these elements to host root tissues. They can also break down certain complex minerals and organic substances in the soil and make it available to their hosts (Mona, 2001). Several investigators reported that mycorrhizal fungi enhance growth and improve leaf nutrient content of their host plant (Gardiner & Christensen, 1991 and Helail *et al.*, 1993) on pear seedlings, (Helail & Awad, 1993) on citrus seedlings, (Wafaa *et al.*, 2000) on almond and (Mona, 2001) on guava and banana seedlings. Generally, all pecan trees and seedlings seemed to have ectomycorrhizae on their roots especially in the upper 12-18 inches of soil, which can compensate the loss of roots either during certain cultural practices which destroy feeder roots and reduce their feeding capacity ((Marx, 1971), or through the transplanting process that results in slow growth and prolongs the time required to produce standard seedling (Helail, 1993). Few studies have focused on alleviation of environmental stresses by means of mycorrhizal fungi (Rinaldelli & Mancuso, 1996 and Mancuso & Rinaldelli, 1996). They indicated that, mycorrhizal fungi reduced the effect of salt stress on olive seedlings. Based on these preliminary observations, this investigation was conducted to confirm the effect of inoculation with mycorrhizal fungi (*Glomus mosseae* and *Glomus australe*) on alleviating salt avoidance in two pecan rootstocks ("Desirable" and "Graking").

Material and Methods

The present investigation was conducted during the two consecutive seasons of 2000 and 2001 at the nursery of the Horticulture Research Institute, Agriculture Research Centre at Giza, Egypt. In early February of both seasons, plastic pots of 30cm diameter were filled with a mixture of sand and clay at the ratio of 1: 1. The soil was disinfected by spraying with 2% formalin solution and left for 10 days to be air dried, thereafter, inoculation with mycorrhizal fungi treatments was added according to the method of Meng *et al.* (1977). One – year old "Desirable" and Garzona pecan rootstocks nearly similar in vigour and size with pruned roots at 15cm below the crown were planted in the previously prepared pots (one plant/pot). The nurslings were irrigated with tap water twice a weak before application of saline solution.

On May 15th, ten treatments (groups) were arranged in a randomized complete block design with four replicates and each replicate consisted of 3 plants. Thereafter, plants were irrigated with one litre of two saline solutions twice weekly and leached with tap water every fourth irrigation to prevent salt accumulation, the control was irrigated with tap water. Treatments were as follows:

1. Unsterilized soil (control)
2. Sterilized soil
3. *Glomus mosseae*
4. *Glomus australe*
5. Salt (1000 ppm)
6. Salt (1000 ppm) +*G. mosseae*
7. Salt (1000 ppm) +*G. australe*
8. Salt (2000 ppm)
9. Salt (2000 ppm) +*G. mosseae*
10. Salt (2000 ppm) +*G. australe*

Salt concentrations 1000 and 2000 mg L^{-1} were derived from mixing stock solutions of $CaCl_2$ (2M), NaCl (4M), KCl (1M), $MgSO_4$ (1M), K_2SO_4 (1M), and Na_2SO_4 (1M). One litter of 1000 mg L solution was prepared by adding 0.34 ml of $CaCl_2$, 1.72 ml of NaCl, 0.42 ml of $MgSO_4$, 0.29 ml of K_2SO_4 and 2.97 ml of Na_2SO_4 per litter. For the 2000 mg. L^{-1} treatment, 0.90ml of $CaCl_2$, 2.80ml of NaCl, 1.24ml of $MgSO_4$, 1.03ml of K2SO$_4$, 1.49ml of KCl, and 5.00ml of Na_2SO_4. This yielded a milliequivalent ratio of about 1 CL: 1SO_4 and a sodium adsorption ratio (SAR) of 12 [$SAR=Na^+/(Ca^{2+}+ Mg^{2+}/2)$ in both cases.

Growth measurements

In mid-September of each season, 12 plants from each treatment were gently removed from the soil and washed carefully with tap water, then morphological measurements were recorded as follows:

- Stem length (cm) and diameter increment (5 cm above the crown) were recorded as the difference between the beginning and the end of both seasons on May 15th and September 15th.
- Average number of leaves/ plant
- Average leaf area cm2 (4-leaves/ plant) using area meters CL-203.
- Assimilation area (cm2/ plant) was calculated according to the following equation:

Average number of leaves/ plant x Average leaf area.

- Average number of burned leaves/ plant.
- Thickness of main roots (cm).
- Length of the longest root (cm).
- Number of root branches/plant.
- Dry weight of root system (gm).
- Dry weight of aerial portions (gm).

Leaf osmotic potential

Total soluble salts were determined in the sap of leaf samples (twenty middle leaflets of the stem, middle leaf used) by refractometer and the equivalent values of osmotic potential (bars) were estimated according to Gusov (1960).

Leaf chemical constituents

1. Photosynthetic pigments

The quantitative analysis of photosynthetic pigments (mg/g) was determined in fresh leaf samples (0.5gm). The optical densities were measured colourmetrically at 660 and 640 wavelengths for chlorophyll (A and B), respectively according to Brougham (1960).

2. Total carbohydrates in leaves

Total carbohydrates were determined colourmetrically in dry leaves according to the method described by Dubious *et al.* (1956).

3. Proline content (mg./gm.F.W.)

It was determined in fresh leaves according to the method described by Bates (1973).

4. Leaf minerals content

Leaf samples were ground and dried at 70°C till constant weight for the determination of N, P, K, Ca, Na, and Cl as follows:

a) Nitrogen was determined by the modified micro-Kjeldahl method as outlined by Pregl (1945).
b) Phosphorus was determined colormetrically according to the stannous chloride method (Jackson, 1958).
c) Potassium and sodium contents were flame photometrically determined (Brown & Lilleland, 1946).
d) Calcium was determined by using Atomic Absorption spectrophotometer according to Brandifeld & Spincer (1965).
e) Chloride content was estimated according to the methods of Higinbothan *et al.* (1967).

Histological studies

Fresh samples of roots (5 cm before the end of the white roots) were taken at the end of the experimental period, cleaned from dust and immediately killed and fixed in FAA solution, dehydrated with tertiary butyl alcohol, infiltrated and embedded in pure paraffin wax of 56-58°C melting point. Cross sections of 10-15 microns were prepared using a rotary microtone. The prepared sections were stained with erthorosine and crystal violet (Johanson, 1940). The cross sections were mounted in canada balsam, air dried, examined and microscopically photographed. Section areas were calculated and statistically analyzed.

Statistical analysis

The experimental treatments were arranged in a factorial complete randomized design. Data recorded in both seasons were subjected to analysis of variance according to Snedecor & Cochran (1980) and means were differentiated using Duncan's multiple range test (Duncan, 1955).

Results and Discussion

Growth parameters

Data presented in Tables 1-4 show the effect of irrigation with saline water and soil inoculation with mycorrhizae fungi on the growth parameters (expressed as stem length and diameter increment, assimilation area, number of leaves /plant, leaf area, number of burned leaves, root length, thickness of main root, number of lateral roots / plant and root and top dry weights) of "Desirable" and "Graking" pecan seedlings during 2000 and 2001 seasons.

Generally, it could be concluded that all the studied growth parameters significantly decreased with saline irrigation water compared to those which didn't receive salt treatments and these decrements were paralleled with the increase of salt concentration. However, number of burned leaves /plant increased by increasing salinity in irrigation water. Whereas, root length did not show definite trend.

Concerning the specific effect of the two pecan cultivars under study, "Desirable" rootstock obtained higher values of number of leaves, assimilation area, average of leaf area, root, and top dry weights, root length and thickness of main root than "Graking", while, number of burned leaves/ plant" increased significantly in seedlings of "Graking. Whereas no significant differences were observed between the two studied cvs. in number of lateral roots and stem length in both seasons.

In addition, growth parameters of plants grown in unsterilized soils (control) were increased significantly than plants grown in sterilized soils. However, there were slight differences between plants inoculated with mycorrhizae and control ones (unsterilized).

Many investigators (Miyamoto & Gobran, 1983 and Miyamoto *et al.*, 1985) previously proved the adverse effect of salinity on pecan plants. Moreover, Miyamoto (1990) found wide variations in response to salinity among pecan

TABLE 1. Effect of saline water and soil inoculation with mycorrhizal fungi on growth of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Stem length increment (cm)						Stem diameter increment (cm)						No. of leaves/ plant					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean
Unsterilized soil (control)	3.21 e	3.97 a	3.59 A	3.22 e	4.00 b	3.61 C	0.190 ab	0.140 d	0.165 A	0.240 ab	0.210 cd	0.225 AB	8.34 c	7.37 d	7.86 AB	9.10 b	9.24 a	9.17 A
Sterilized soil	2.85 f	3.20 e	3.02 B	2.31 hi	3.35 d	2.93 E	0.163 c	0.133 de	0.148 A	0.210 cd	0.180 ef	0.195 B	7.14 ef	7.24 de	7.19 C	8.15 e	8.23 e	8.19 C
Glomus mosseae	3.44 d	3.64 c	3.54 A	3.63 c	3.98 b	3.81 B	0.177 bc	0.100 fg	0.138 AB	0.230 bc	0.177 ef	0.203 AB	9.00 a	7.09 ef	8.05 A	8.43 d	8.83 c	8.63 B
Glomus australe	3.81 b	3.34 d	3.58 A	3.53 c	4.65 a	4.09 A	0.206 a	0.127 de	0.167 A	0.257 a	0.207 d	0.231 A	8.65 b	6.60 g	7.63 B	8.52 d	8.38 d	8.45 B
Salt (1000 ppm)	2.17 h	1.49 k	1.83 E	2.48 i	2.66 g	2.57 F	0.097 fg	0.060 ij	0.078 D	0.163 fg	0.110 ij	0.136 CD	6.74 g	5.18 k	5.96 F	6.06 j	5.17 k	5.62 F
Salt (1000 ppm)+ *G.mosseae*	2.84 f	2.30 h	2.57 C	2.90 f	3.37 d	3.14 D	0.14 d	0.090 gh	0.115 BC	0.197 de	0.130 hi	0.163 C	7.16 ef	5.96 i	6.56 D	6.48 h	7.11 f	6.80 D
Salt (1000 ppm) + *G. australe*	2.87 f	2.50 g	2.69 C	2.83 f	3.38 d	3.11 D	0.170 bc	0.100 fg	0.135 AB	0.183 ef	0.143 gh	0.163 C	7.00 f	5.52 j	6.26 E	6.97 g	6.19 i	6.58 E
Salt (2000 ppm)	1.74 j	1.11 l	1.42 F	1.32 l	1.24 l	1.28 H	0.040 jk	0.067 k	0.033 E	0.103 jk	0.060 l	0.082 E	4.58 l	3.33 n	3.95 I	4.08 m	3.16 n	3.62 H
Salt (2000 ppm) + *G.mosseae*	2.18 h	1.90 i	2.04 D	1.92 k	2.50 hi	2.21 G	0.100 fg	0.053 ij	0.076 D	0.137 h	0.083 k	0.110 DE	5.22 k	4.21 m	4.72 H	4.33 l	5.12 k	4.73 G
Salt (2000 ppm) + *G. australe*	2.26 h	1.58 k	1.92 DE	2.31 j	2.61 gh	2.46 F	0.113 ef	0.070 hi	0.092 CD	0.127 hi	0.100 jk	0.113 D	6.27 h	4.43 l	5.35 G	5.07 k	4.15 m	4.61 G
Mean	2.74 A	2.50 A		2.67 B	3.17 A		0.139 A	0.090 A		0.185 A	0.140 A		7.01 A	5.69 B		6.72 A	6.56 A	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

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TABLE 2 . Effect of saline water and soil inoculation with mycorrhizae fungi on growth of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Leaf area (cm²)						Assimilation area(cm²/plant)						No. of burned leaves/ plant					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean
Unsterilized soil (control)	33.21 b	23.67 g	28.44 A	28.56 b	22.56 f	25.56 A	245.5 a	193.4 e	219.4 A	263.9 b	205.3 c	234.6 A	0.79 o	0.93 l	0.86 H	0.76 o	0.86 m	0.81 H
Sterilized soil	29.42 d	19.50 l	24.46 C	25.31 d	20.20 g	22.75 B	212.9 c	139.4 h	176.1 C	208.5 c	165.4 e	186.9 C	0.82 o	1.00 k	0.91 G	0.83 n	0.93 l	0.88 G
Glomus mosseae	33.98 a	22.81 h	28.39 A	31.34 a	18.43 hi	24.89 A	237.6 b	203.4 d	220.5 A	276.7 a	155.5 f	216.1 B	0.68 p	0.85 m	0.76 I	0.52 s	0.68 q	0.60 J
Glomus australe	31.06 c	22.58 h	26.82 B	31.26 a	20.67 g	25.97 A	200.4 d	192.4 e	196.4 B	261.7 b	176.4 d	219.1 B	0.57 q	0.82 n	0.70 J	0.63 r	0.71 p	0.67 I
Salt (1000 ppm)	26.41 f	16.31 k	21.36 E	22.42 f	14.77 k	18.60 D	136.7 h	109.9 j	123.3 E	115.9 i	92.77 j	104.3 F	1.44 h	1.94 e	1.69 D	1.80 i	2.20 e	2.00 D
Salt (1000 ppm)+ *G.mosseae*	28.30 e	17.72 j	23.01 D	24.38 e	15.66 j	20.02 C	168.7 f	127.0 i	147.8 D	123.7 h	133.2 g	128.4 E	1.29 j	1.70 g	1.50 F	1.61 k	1.97 h	1.79 F
Salt (1000 ppm) + *G. australe*	27.93 e	20.13 i	24.03 C	26.22 e	17.95 i	22.09 B	154.2 g	140.8 h	147.5 D	170.5 de	125.1 h	147.8 D	1.37 i	1.80 f	1.59 E	1.72 j	2.02 g	1.87 E
Salt (2000 ppm)	22.20 h	12.05 n	17.13 G	16.35 j	10.69 m	13.52 F	73.99 m	55.12 n	64.6 G	51.64 m	43.65 n	47.65 H	2.07 c	2.30 a	2.22 A	2.27 d	2.88 a	2.58 A
Salt (2000 ppm) + *G.mosseae*	23.86 g	15.24 l	19.55 F	18.08 i	12.91 l	15.49 E	100.5 k	79.49 m	90.0 F	92.61 j	72.86 kl	82.74 G	1.97 d	2.10 b	2.04 B	2.11 f	2.67 b	2.39 B
Salt (2000 ppm) + *G. australe*	23.93 g	13.78 m	18.85 F	19.20 h	13.23 l	16.26 E	104.8 jk	86.33 l	95.6 F	79.69 k	66.76 l	73.23 G	1.79 f	2.07 c	1.93 C	2.02 g	2.37 c	2.19 C
Mean	28.03 A	18.38 B		24.31 A	16.72 B		163.5 A	132.7 B		164.5 A	123.7 B		1.28 B	1.56 A		1.43 B	1.73 A	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

TABLE 3. Effect of saline water and soil inoculation with mycorrhizal fungi on root characteristics of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Thickness of main root (cm)						Root length (cm)						No. of lateral roots/ plant					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi	Grak.	Mean
Unsterilized soil *(control)*	0.90 d	0.90 d	**0.90 A**	1.13 b	0.93 ef	**1.03 BC**	89.58 a	65.74 d	**77.66 A**	71.17 a	57.94 d	**64.56 A**	4.41 c	4.10 d	**4.25 B**	4.07 d	3.87 e	**3.97 B**
Sterilized soil	1.07 b	0.70 g	**0.88 AB**	1.60 a	1.00 de	**1.30 A**	63.95 de	56.46 g	**60.21 D**	54.38 e	62.81 c	**58.60 B**	3.90 e	3.60 f	**3.75 CD**	3.80 e	2.93 h	**3.37 D**
Glomus mosseae	1.13 a	0.77 f	**0.95 A**	1.13 b	1.03 cd	**1.08 B**	60.93 f	36.64 k	**48.79 F**	50.72 g	46.40 h	**48.56 D**	4.80 a	4.60 b	**4.70 A**	4.67 a	4.43 b	**4.55 A**
Glomus australe	0.97 c	0.63 hi	**0.80 BC**	1.10 bc	0.90 fg	**1.00 BC**	52.40 h	32.67 l	**42.53 G**	42.91 i	40.23 j	**41.57 E**	4.30 c	4.40 c	**4.35 B**	4.27 c	4.10 d	**4.18 B**
Salt (1000 ppm)	0.67 gh	0.50 l	**0.58 EF**	0.97 d-f	0.77 hi	**0.87 D-F**	77.19 b	68.75 c	**72.97 B**	64.73 b	54.15 e	**59.44 B**	2.40 h	2.23 h	**2.32 EF**	2.63 i	2.63 i	**2.63 E**
Salt (1000 ppm)+ *G.mosseae*	0.83 e	0.60 ij	**0.72 CD**	0.97 d-f	0.90 fg	**0.93 CD**	64.92 d	47.30 i	**56.11 E**	50.72 g	46.40 h	**48.56 D**	3.83 e	3.83 e	**3.83 C**	3.80 e	3.57 f	**3.68 C**
Salt (1000 ppm) + *G. australe*	0.77 f	0.57 jk	**0.67 DE**	1.00 de	0.83 gh	**0.92 C-E**	56.84 g	42.83 j	**49.83 F**	52.89 f	51.90 f	**52.40 C**	3.50 f	3.60 f	**3.55 D**	3.40 g	3.30 g	**3.35 D**
Salt (2000 ppm)	0.43m	0.33 n	**0.38 G**	0.73 ij	0.67 j	**0.70 G**	66.00 d	62.62 ef	**64.31 C**	62.45 c	64.60 b	**63.53 A**	1.63 j	1.90 i	**1.77 G**	1.53 k	1.57 k	**1.55 G**
Salt (2000 ppm) + *G.mosseae*	0.70 g	0.43 m	**0.57 F**	0.83 gh	0.77 hi	**0.80 E-G**	57.52 g	37.85 k	**47.69 F**	42.87 i	38.80 k	**40.84 E**	2.70 g	2.33 h	**2.52 E**	2.77 hi	2.87 h	**2.82 E**
Salt (2000 ppm) + *G. australe*	0.53 kl	0.37 n	**0.45 G**	0.73 ij	0.77 hi	**0.75 FG**	45.87 i	28.20 m	**37.03 H**	34.86 l	39.41 jk	**37.14 F**	2.23 h	2.03 i	**2.13 F**	2.33 j	2.30 j	**2.32 F**
Mean	**0.80 A**	**0.58 B**		**1.02 A**	**0.86 A**		63.52 A	47.91 B		52.77 A	50.27 A		3.37 A	3.26 A		3.33 A	3.16 A	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

TABLE 4. Effect of saline water and soil inoculation with mycorrhizal fungi on dry weight of root system and aerial portion of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Root system (gm)						Aerial portion (gm)					
	2000			2001			2000			2001		
	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean
Unsterilized soil (control)	15.32 d	14.83 e	**15.07 C**	16.41 c	15.39 d	**15.90 C**	21.48 a	17.50 f	**19.49 A**	25.93 b	16.09 hi	**21.01 B**
Sterilized soil	13.35 i	14.03 g	**13.69 E**	14.50 e	13.68 f	**14.09 D**	19.20 c	15.61 gh	**17.41 B**	23.87 cd	24.10 cd	**23.98 A**
Glomus mosseae	18.01 a	15.59 c	**16.80 A**	17.58 b	15.45 d	**16.52 B**	20.44 b	10.54 k	**15.49 C**	25.63 bc	22.88 de	**24.26 A**
Glomus australe	17.39 b	15.34 d	**16.36 B**	18.31 a	16.52 c	**17.42 A**	18.76 d	11.89 j	**15.32 C**	27.83 a	21.33 ef	**24.58 A**
Salt (1000 ppm)	11.60 k	10.70 m	**11.15 F**	13.48 fg	11.48 h	**12.48 F**	15.23 h	8.38 m	**11.81 E**	18.07 g	14.90 i	**16.48 C**
Salt (1000 ppm)+ *G.mosseae*	14.56 f	13.53 h	**14.05 D**	13.61 fg	13.27 g	**13.44 E**	18.29 e	9.02 l	**13.66 D**	20.57 f	17.40 gh	**18.98 B**
Salt (1000 ppm) + *G. australe*	14.48 f	13.11 j	**13.80 E**	15.40 d	13.54 fg	**14.47 D**	15.97 g	8.29 m	**12.13 E**	22.61 de	18.68 g	**20.64 B**
Salt (2000 ppm)	8.21 p	7.15 q	**7.68 I**	9.49 j	8.04 k	**8.77 H**	9.32 l	5.76 p	**7.54 H**	15.64 hi	8.59 k	**12.12 D**
Salt (2000 ppm) + *G.mosseae*	11.22 l	9.82 o	**10.52 G**	10.59 i	9.39 j	**9.99 G**	13.18 i	7.11 n	**10.15 F**	16.88 gh	11.14 j	**14.01 CD**
Salt (2000 ppm) + *G. australe*	10.41 n	8.27 p	**9.34 H**	11.28 h	9.51 j	**10.39 G**	11.96 j	6.42 o	**9.19 G**	17.52 gh	11.33 j	**14.42 CD**
Mean	**13.46 A**	**12.24 B**		**14.07 A**	**12.63 B**		**16.38 A**	**10.05 B**		**21.45 A**	**16.64 A**	

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

rootstocks. Similar results were obtained by Abbas (1999) and Sherin (2002) on olive seedlings, Gaser (1992) on orange plants and Hoult *et al.* (1997) on mango seedlings. The depressive effect of salinity on plant growth may be due to the increase in the osmotic potential of the soil which results in a reduction in the availability of water to the plant, in addition, the toxic effect of some ions which make a disturbance in the normal metabolisms of the plant.

Inoculation with MHZ fungi in this concern minimized the harmful effect of salinity. Seedlings were irrigated with saline water and inoculated with MHZ fungi, all the growth parameters increased with the exception of burned leaves / plant whereas, root length did not take definite trend. Stocks were irrigated with high salinity concentration (2000 mg/L^{-1}) without mycorrhizal inoculation was considered the most drastic treatment, since it gained the lowest growth values.

A significant interaction was observed between saline water, inoculation with MHZ and cultivars, the highest average of growth parameters (except for stem length increment and number of burned leaves) was observed in Desirable transplants inoculated with MHZ without salt and control (unsterilized). While the lowest record was obtained from Graking cv. at high salinity concentration (2000 mg/L^{-1}).

Similarly, Mancuso & Rinadelli (1996) proved that MHZ fungi minimized the harmful effect of salinity in olive seedlings.

Generally, mycorrhizal fungi improved and enhanced growth of the tested pecan rootstocks under salinity. The beneficial effects of MHZ on growth often related to the increase of nutrients uptake or growth hormones such as auxins cytokinines, gibberellins and vitamins which may be present at higher concentrations (Mona, 2001).

Leaf osmotic potential

Results reported in Table 5 reveal that, the increase in leaf osmotic potential was correlated with increasing salinity concentration in the irrigation water from 1000 to 2000 mg/L^{-1}.

On the other hand, adding MHZ to the soil led to reduce leaf osmotic potential compared with seedlings under salinity only.

There was no significant difference in leaf osmotic potential between "Desirable" and "Graking" cvs. in both growing seasons.

TABLE 5. Effect of saline water and soil inoculation with mycorrhizal fungi on Leaf osmotic potential and chlorophyll (A) and (B) contents of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Leaf osmotic potential (bar)						Chlorophyll (A) mg/g F.W.						Chlorophyll (A) mg/g F.W.					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean
Unsterilized soil (control)	16.33 o	17.10 l	**16.72 F**	15.60 q	16.53 n	**16.07 H**	0.94 fg	0.96 ef	**0.95 C**	1.18 e	1.20 d	**1.19B**	0.56 d	0.59 c	**0.57 C**	0.60 e	0.64 d	**0.62 B**
Sterilized soil	17.42 k	15.48 p	**16.45 G**	16.38 o	18.04 k	**17.21 F**	0.91 gh	0.92 gh	**0.92 CD**	1.07 g	1.11 f	**1.09 C**	0.47 f	0.50 e	**0.48 EF**	0.52 g	0.55 f	**0.53 C**
Glomus mosseae	16.85 m	16.58 n	**16.72 E**	16.00 p	17.27 l	**16.64 G**	1.13 d	1.25 b	**1.19 B**	1.20 d	1.23 c	**1.22 B**	0.64 b	0.65 b	**0.65 B**	0.71 ab	0.68 c	**0.70 A**
Glomus australe	16.96 m	17.36 k	**17.16 E**	17.06 m	17.40 l	**17.23 F**	1.22 c	1.32 a	**1.27 A**	1.29 a	1.25 b	**1.27 A**	0.70 a	0.72 a	**0.71 A**	0.69 bc	0.72 a	**0.71 A**
Salt (1000 ppm)	19.96 f	20.45 d	**20.20 C**	21.10 e	20.37 f	**20.74 C**	0.87 i	0.81 k	**0.84 E**	0.93 i	0.97 h	**0.95 E**	0.30 j	0.42 g	**0.36 H**	0.45 j	0.48 i	**0.46 D**
Salt (1000 ppm)+ *G.mosseae*	17.61 j	18.50 g	**18.06 D**	19.65 h	18.31 j	**18.98 E**	0.91 gh	0.90 h	**0.91 D**	0.99 h	1.07 g	**1.03 D**	0.51 e	0.47 f	**0.49 E**	0.49 hi	0.51g h	**0.50 D**
Salt (1000 ppm) + *G. australe*	18.09 i	18.35 h	**18.22 D**	20.05 g	19.17 i	**19.61 D**	0.98 e	0.93f-h	**0.96 C**	0.99 h	1.05 g	**1.02 D**	0.54 d	0.51 e	**0.52 D**	0.52 g	0.55 f	**0.54 C**
Salt (2000 ppm)	22.31 b	24.05 a	**23.18 A**	23.57 b	24.08 a	**23.83 A**	0.75 lm	0.78 l	**0.77 G**	0.84 k	0.76 m	**0.80 H**	0.28 j	0.36 i	**0.32 I**	0.27 m	0.22 n	**0.25 F**
Salt (2000 ppm) + *G.mosseae*	20.23 e	21.13 c	**20.68 B**	22.33 c	21.30 d	**21.81 B**	0.82 jk	0.74 m	**0.78 FG**	0.88 j	0.88 j	**0.88 F**	0.39 h	0.42 g	**0.40 G**	0.33 l	0.51g h	**0.42 E**
Salt (2000 ppm) + *G. australe*	20.46 d	20.02 f	**20.24 C**	21.27 d	20.37 f	**20.82 C**	0.85ij	0.77 l	**0.81 EF**	0.86 k	0.81 l	**0.84 G**	0.44 g	0.47 f	**0.45 F**	0.39 k	0.40 k	**0.40 E**
Mean	**18.62 A**	**18.90 A**		**19.30 A**	**19.28 A**		**0.94 A**	**0.94 A**		**1.02 A**	**1.04 A**		**0.48 A**	**0.52 A**		**0.50 A**	**0.53 A**	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

It is also clear that, leaf osmotic potential was at low extent in plants which didn't receive salt treatments of both cultivars. Where, a significant progress in leaf osmotic potential of all tested plants owe to raising salinity levels in the irrigation water. In this respect, Hartz (1984) stated that, "salts lead to reduce available water in the soil and it could prevent water uptake when the soil is at field capacity". Mervet (1996) previously reported these results on grapevine seedlings and Sherin (2002) on olive seedlings.

Leaf chemical constituents

1. Photosynthetic pigments content

Table 5 also indicates that, chlorophyll (A and B) significantly decreased in leaves of all pecan seedlings under salinity in both seasons.

As for the response of rootstocks, differences had no true effect. On this concern, Gaser (1992) stated that "irrigation with saline water greatly affect plant photosynthesis process, via inhibiting pigment formation". These results are in agreement with those of Emtithal *et al.* (1996) on pecan seedlings and Abbas (1999) on olive seedlings.

The soil addition of MHZ fungi (especially *G. australe*) improved leaves chlorophyll (A and B) content than the control.

Transplants of both studied cvs. formed significantly the greatest chlorophyll (A and B) when inoculated with MHZ only. However, salt treatments without MHZ recorded the least values in both cultivars. The increase in leaf chlorophyll content in mycorrhizal plants could be attributed to the ability of MHZ to secrete cytokinens like substances (Nawar *et al.*, 1988).

2. Total carbohydrates content

Plants which were inoculated with MHZ fungi had significantly the highest total carbohydrates content in the leaves when compared with non-inoculated ones.

The present results (Table 6) show a significant reduction in total carbohydrates under saline conditions compared with the other treatments without salts.

In addition, "Desirable" seedlings had significantly higher total carbohydrates than "Graking" in both growing seasons.

As for the interaction between the three factors under study, the greatest values of total carbohydrates were recorded in Desirable cv. when inoculated

TABLE 6. Effect of saline water and soil inoculation with mycorrhizal fungi on leaf total carbohydrates and proline contents of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Total carbohydrates mg/g F.W						Proline mg/g F.W.					
	2000			2001			2000			2001		
	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean
Unsterilized soil (control)	4.33 f	4.29 g	**4.31 CD**	5.15 d	5.01 f	**5.08 C**	1.90 no	1.88 o	**1.89 G**	1.39 m	1.29 b	**1.34 G**
Sterilized soil	3.30 o	4.02 ij	**3.66 H**	5.20 e	5.00 f	**5.10 C**	1.97 m	1.91 n	**1.94 F**	1.49 k	1.42 l	**1.45 F**
Glomus mosseae	4.45 e	4.20 h	**4.33 C**	5.31 a	5.11 c	**5.21 A**	1.53 p	1.36 q	**1.44 H**	1.18 p	1.19 p	**1.19 I**
Glomus australe	5.07 a	4.93 b	**5.00 A**	5.24 b	5.11 c	**5.18 B**	1.54 p	1.22 r	**1.38 I**	1.30 n	1.26 o	**1.28 H**
Salt (1000 ppm)	3.85 l	3.89 k	**3.87 G**	4.88 h	4.21 l	**4.55 E**	3.00 c	2.90 d	**2.95 B**	2.48 c	2.27 e	**2.38 B**
Salt (1000 ppm)+ *G.mosseae*	4.76 c	4.03 i	**4.40 B**	4.94 g	4.42 j	**4.68 D**	2.51 i	2.29 l	**2.40 E**	2.17 h	1.98 j	**2.08 E**
Salt (1000 ppm) + *G. australe*	4.55 d	4.01 j	**4.28 D**	5.01 f	4.39 k	**4.70 D**	2.65 g	2.40 k	**2.52 D**	2.21 g	2.14 i	**2.18 D**
Salt (2000 ppm)	3.55 n	3.70 m	**3.62 I**	4.13 m	3.92 o	**4.03 G**	3.20 a	3.12 b	**3.16 A**	2.84 a	2.50 b	**2.67 A**
Salt (2000 ppm) + *G.mosseae*	4.02 ij	4.01 j	**4.02 F**	4.52 i	4.02 n	**4.27 F**	2.73 f	2.59 h	**2.66 C**	2.35 d	2.24 f	**2.30 C**
Salt (2000 ppm) + *G. australe*	4.19 h	4.03 ij	**4.11 E**	4.41 jk	4.12 m	**4.26 F**	2.87 e	2.47 j	**2.67 C**	2.50 b	2.22 g	**2.36 B**
Mean	**4.21 A**	**4.11 B**		**4.88 A**	**4.53 B**		**2.39 A**	**2.21 B**		**1.99 A**	**1.85 B**	

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

with MHZ without salt, but the lowest records were at high salinity concentration (2000 mg/l^{-1}) in both cultivars. These results are in agreement with those obtained by Mona (2001).

3. Proline content

Table 6 also show that, irrigation with saline water significantly increased the proline content in the leaves of the two cultivars under investigation. The capacity of the plant to accumulate proline under saline conditions is positively correlated with salt concentration in the irrigation water.

Meanwhile, inoculation with MHZ significantly decreased proline content in the leaves when compared with saline treatments only.

Moreover, "Desirable" rootstock exhibited higher level of proline than "Graking" rootstock.

The least contents of proline were recorded with Graking cv. inoculated with MHZ without salt followed by Desirable cv., while the lowest values were obtained with Desirable rootstock followed by Graking at high salt concentration (2000 mg/L $^{-1}$).

These results are in agreement with the findings of El-Said *et al.* (1995) and Abbas (1999). They suggested that proline function as a source of solute for intera- cellular osmotic adjustments under saline condition. Furthermore, proline has been used as an evaluation parameter for selecting salinity and drought resistant varieties (Bates, 1973).

4. Leaf minerals content

It is clear from the data in Tables 7 and 8 that irrigation with saline water even at the lower experimented level (1000 mg/L^{-1}) significantly decreased N, P and K contents in leaves of the two studied pecan cvs. as compared with non-salted ones (sterilized, unsterilized, MHZ_1, and MHZ_2) in both 2000 and 2001 seasons. On the contrary, Ca, Na, and Cl contents were increased significantly as a result of irrigation with saline water, and higher concentration of salts recorded the highest amounts of Ca, Na and Cl contents.

Moreover, it was found that "Graking" rootstock had a great ability to accumulate higher amounts of K and P (in the first season only) in their leaves than "Desirable" rootstock, while seedlings of "Desirable" had a higher level of N in the first season only. Meanwhile, both cultivars showed insignificant differences in Na^+ and Cl^- contents in the growing seasons.

TABLE 7. Effect of saline water and soil inoculation with mycorrhizal fungi on leaf N, P and K% contents of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Nitrogen %						Phosphorus %						Potassium %					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean
Unsterilized soil (control)	2.31 c	2.14 e	**2.23 C**	2.42 d	2.31 e	**2.36 B**	1.38 m	1.41 l	**1.40 G**	1.30 j	1.30 j	**1.30 G**	1.33 j	1.52 f	**1.42 B**	1.42 h	1.50 de	**1.46 B**
Sterilized soil	2.19 d	2.12 ef	**2.16 D**	2.26 f	2.22 g	**2.24 C**	1.26 p	1.34 n	**1.30 H**	1.18 l	1.25 k	**1.22 H**	1.22 m	1.38 hi	**1.30 C**	1.38 j	1.47 f	**1.43C**
Glomus mosseae	2.43 b	2.32 c	**2.38 B**	2.53 a	2.41 d	**2.47 A**	2.59 d	2.78 b	**2.68 B**	2.39 b	2.26 d	**2.33 B**	1.66 d	1.79 a	**1.73 A**	1.50 d	1.67 a	**1.59 A**
Glomus australe	2.50 a	2.45 b	**2.49 A**	2.50 b	2.46 c	**2.48 A**	2.73 c	2.84 a	**2.78 A**	2.48 a	2.39 b	**2.44 A**	1.71 b	1.69 c	**1.70 A**	1.48ef	1.66 a	**1.57 A**
Salt (1000 ppm)	1.95 j	1.92 kl	**1.93 F**	2.10 h	2.04 j	**2.07 E**	1.19 q	1.30 o	**1.25 I**	1.19 l	1.11 m	**1.15 I**	1.17 n	1.34 j	**1.26 D**	1.24 m	1.41 hi	**1.33 D**
Salt (1000 ppm)+ *G.mosseae*	2.11 fg	2.04 h	**2.08 E**	2.20 g	2.12 h	**2.16 D**	2.08 i	2.32 f	**2.20 D**	2.23 e	1.99 g	**2.11 D**	1.30 k	1.57 e	**1.44 B**	1.39 ij	1.54 c	**1.47 B**
Salt (1000 ppm) + *G. australe*	2.10 g	2.01 i	**2.05 E**	2.25 f	2.12 h	**2.18 D**	2.18 g	2.41 e	**2.25 C**	2.35 c	2.08 f	**2.21 C**	1.40 h	1.45 g	**1.43 B**	1.35 k	1.58 b	**1.46 B**
Salt (2000 ppm)	1.80 n	1.70 o	**1.75 H**	1.90 m	1.94 l	**1.92 G**	1.13 r	1.25 p	**1.19 J**	1.17 l	1.05 n	**1.11 J**	1.08 o	1.25 l	**1.17 E**	1.06 o	1.31 l	**1.18 E**
Salt (2000 ppm) + *G.mosseae*	1.91 l	1.83 m	**1.87 G**	1.98 k	1.99 k	**1.99 F**	1.63 k	2.15 g	**1.89 F**	2.09 f	1.83 h	**1.96 E**	1.19 n	1.39 hi	**1.29 C**	1.22 m	1.44 g	**1.33 D**
Salt (2000 ppm) + *G. australe*	1.93 jk	1.90 l	**1.92 F**	2.07 i	2.04 j	**2.06 E**	1.75 j	2.11 h	**1.93 E**	2.01 g	1.71 i	**1.86 F**	1.23 lm	1.37 i	**1.30 C**	1.19 n	1.49 def	**1.34 D**
Mean	**2.12 A**	**2.04 B**		**2.22 A**	**2.16 A**		**1.79 B**	**1.99 A**		**1.84 A**	**1.70 B**		**1.33 B**	**1.48 A**		**1.32 B**	**1.51 A**	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

TABLE 8 . Effect of saline water and soil inoculation with mycorrhizal fungi on leaf Ca, Na and Cl% contents of "Desirable" and "Graking" pecan rootstocks (2000 and 2001 seasons).

Treatments	Ca %						Na %						Cl %					
	2000			2001			2000			2001			2000			2001		
	Desi.	Grak.	Mean	Desi.	Grak	Mean	Desi.	Grak.	Mean	Desi.	Grak.	Mean	Desi	Grak.	Mean	Desi.	Grak.	Mean
Unsterilized soil (control)	1.84 l	1.92 ij	1.88 E	1.93 f-h	i.98 h-j	1.88 E	0.29 g	0.27 h	0.28 E	0.33 f-h	0.31 h-j	0.32 EF	0.99 hi	1.02 g	1.00 EF	0.95 h	0.92 ij	0.94 E
Sterilized soil	1.75 m	1.88 k	1.82 F	1.95 f-g	1.92 f-i	1.82 F	0 26 hi	0.25 hi	0.26 EF	0.32 g-i	0.29 jk	0.31 FG	0.96 j	1.0 g-i	0.98 FG	0.93 hi	0.90 j	0.92 E
Glomus mosseae	1.91 j	1.96 h	1.93 D	1.91 g-i	1.80 j	1.93 D	0.24 ij	0.23 jk	0.24 FG	0.30 ij	0.27 k	0.29 G	0.98 ij	0.96 j	0.97 G	0.92 ij	0.94 hi	0.93 E
Glomus australe	1.94 h	1.95 h	1.95 D	1 89 h-j	1.84 ij	i.95 D	0 23 jk	0.21 k	0.22 G	0.31 h-j	0.30 ij	0.30 FG	1.01g h	1.04 f	1.03 DE	0.98 g	0.98 g	0.98 D
Salt (1000 ppm)	2.20 cd	2.11 e	2.16 B	2 08 bc	1.99 c-g	2.16 B	0 38 bc	0.35 d	0.37 BC	0.36 d	0.34 ef	0.35C D	1.16 bc	1.01 e	1.013 B	1.19 c	1.16 d	1.18 B
Salt (1000 ppm)+ *G.mosseae*	1.99 g	1.96 h	1.98 C	1.99 d-g	1.93 f-h	1.98 C	0.33 e	0.31 fg	0.32 D	0 34 c-g	0.31 h-j	0.32 D-F	1.08 e	1.05 f	1.07 C	1.12 e	1.09 f	1.10 C
Salt (1000 ppm) + *G. australe*	2.03 f	1.94 hi	1.98 C	1.97 e-h	1.96 e-h	1.98 C	0.35 de	0.33 ef	0.34C D	0.35 de	0.34 ef	0.35 C-E	1.04 f	1.06 f	1.05 CD	1.10 ef	1.12 e	1.11 C
Salt (2000 ppm)	2.31 a	2.25 b	2.28 A	2.18 a	1.81 j	2.28 A	0.41 a	0.39 ab	0.40 A	0.44 a	0.39 bc	0.41 A	1.20 a	1.16 bc	1.018 A	1.26 a	1.22 b	1.24 A
Salt (2000 ppm) + *G.mosseae*	2.11 e	2.19 d	2.15 B	2.05 b-e	2.06 b-d	2.15 B	0.36 cd	0.34 de	0.35 BC	0.39 bc	0.35 de	0.37 BC	1.14 cd	1.13 d	1.14 B	1.19 c	1.17 d	1.18 B
Salt (2000 ppm) + *G. australe*	2.22 c	2.11 e	2.17 B	2.10 b-d	2.01 b-f	2.17 B	0.38 b	0.35 d	0.37 B	0.40 b	0.37 cd	0.38A B	1.17 b	1.09 e	1.13 B	1.15 d	1.20 bc	1.18 B
Mean	1.33 B	1.48 A		2.00 A	1.92 A		0.32 A	0.30 A		0.35 A	0.33 A		1.08 A	1.06 A		1.08 A	1.07 A	

Desi.=Desirable Grak.= Graking

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

Concerning the addition of MHZ, it was effective in increasing leaf N, P (especially G. mosseae) and K contents. Moreover, when added to saline water treatments it, significantly increased leaf N, P, and K content than those irrigated only with saline water. However, leaf Ca, Na and Cl contents took the opposite trend. Regarding the interaction, Desirable rootstock exhibited the highest N values when inoculated with MHZ only, while the lowest were obtained in salt treatments only in both cvs. Whereas, the lowest P (in first season) and K contents were obtained in Graking rootstock. On the other hand, Desirable cv. showed the highest amount of leaf Ca, Na and Cl contents especially at high salt concentration (2000 mg/L^{-1}). These results are in line with those reported by Emtithal (1996) on pecan, Mervet (1996) on grapevines, Abbas (1999) and Sherin (2002) on olive. In addition, Bernstein *et al.* (1972) concluded that, high reduction in plant growth under salinity was possibly due to the accumulation of Cl^- in plant tissues with toxic amounts and affect stomatal closure, causing water loss and leaf injury symptoms. Besides, the reduction in plant K^+ content may be attributed to the increase in Na^+ uptake, which resulted in cationic imbalance in the plant by depressing K^+ uptake.

Generally, the data in Tables 7 and 8 reveal that, MHZ fungi inoculation increased leaf N, P and K content in the tested pecan rootstocks as compared with the untreated ones. In contrast, the addition of MHZ fungi reduced leaf Ca, Na, and Cl contents compared with seedling treated with salinity only. MHZ fungi may lead to marked increase in respiration, which enhances the cation exchange and the accumulation of the mineral elements (Blankeman *et al.*, 1976).

Histological studies

The effect of salt concentrations 1000 and 2000 mg/l^{-1} on "Desirable" and Graking" pecan cvs. is shown in Tables 9 and 10. Data reveal that, as salinity increased thickness of root cross section, thickness of cortex, number of xylem cells and root xylem arches decreased. On the contrary, thickness of roots vascular bundles, and root pith thickness increased as salinity increased. As for the treatments without salt, there were slight differences between plants grown in soil sterilized or unsterilized except for thickness of cross section and number of xylem cells, the control plants grown in unsterilized soils were significantly increased comparing with plants grown in sterilized soils.

In addition, both cultivars showed insignificant differences except for pith thickness, which is Desirable exhibited higher values than Graking.

TABLE 9. Effect of saline water and soil inoculation with mycorrhizal fungi on the root anatomy of "Desirable" and "Graking" pecan rootstocks.

Treatments	Thickness of cross section (µm)			Thickness of cortex (µm)			Thick. of vascular bundles (µm)		
	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean
Unsterilized soil (control)	121.0 b	133.7 a	**127.3 A**	20.67 de	24.67 a	**22.67 A**	59.00 O	55.33 P	**57.17 F**
Sterilized soil	96.33 e	103.00 c	**99.67 B**	21.67 cd	21.67 cd	**21.67 AB**	64.67 k	63.00 l	**63.83 E**
Glomus mosseae	82.67 f	100.30 d	**91.50 C**	20.00 ef	23.33 b	**21.67 AB**	61.67 m	66.00 j	**63.83 E**
Glomus australe	99.67 d	101.70 cd	**100.70 B**	19.67 ef	22.00 c	**20.83 B**	60.33 n	51.00 q	**55.67 F**
Salt (1000 ppm)	50.33 k	62.67 i	**56.50 G**	13.00 k	16.00 hi	**14.50 DE**	84.00 b	78.00 g	**81.00 B**
Salt (1000 ppm)+ *G.mosseae*	82.67 f	83.00 f	**82.83 D**	16.00 hi	19.00 f	**17.50 C**	79.67 ef	70.00 h	**74.83 C**
Salt (1000 ppm) + *G. australe*	77.00 g	74.00 h	**75.50 E**	17.33 g	17.33 g	**17.33 C**	68.33 i	71.00 h	**69.67 D**
Salt (2000 ppm)	47.00 l	49.00 lk	**48.00 H**	11.33 l	15.00 ij	**13.17 E**	92.33 a	82.33 c	**87.33 A**
Salt (2000 ppm) + *G.mosseae*	63.33 i	58.67 j	**61.00 F**	13.33 k	16.67 gh	**15.00 D**	79.33 ef	81.00 d	**80.17 B**
Salt (2000 ppm) + *G. australe*	61.00 i	63.00 I	**62.00 F**	14.67 j	15.67 hj	**15.17 D**	78.67 fg	80.00 de	**79.33 B**
Mean	**78.10 A**	**82.90 A**		**16.77 A**	**19.13 A**		**72.80 A**	**69.77 A**	

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

TABLE 10. Effect of saline water and soil inoculation with mycorrhizal fungi on the root anatomy of "Desirable and "Graking" pecan rootstocks.

Treatments	No. of xylem arches			No. of xylem cells			Pith thick. (µm)		
	Desirable	Graking	Mean	Desirable	Graking	Mean	Desirable	Graking	Mean
Unsterilized soil (control)	24.00 f	28.00 d	**26.00 B**	23.00 c	22.00 d	**22.50 A**	11.00 j	9.00	**10.00 E**
Sterilized soil	28.67 c	25.00 e	**26.83 AB**	21.33 e	18.67 f	**20.00 B**	10.67 j	7.66 lm	**9.16 F**
Glomus mosseae	30.33 b	24.00 f	**27.17 A**	25.00 b	21.00 e	**23.00 A**	8.00 l	7.33 m	**7.66 G**
Glomus australe	33.33 a	21.67 g	**27.50 A**	26.00 a	20.67 e	**23.33 A**	9.33 k	6.00 n	**7.66 G**
Salt (1000 ppm)	12.67 no	15.00 l	**13.83 E**	11.00 j	14.67 i	**12.83 EF**	17.00 d	15.33 f	**16.17 B**
Salt (1000 ppm)+ *G.mosseae*	15.67 k	19.00 i	**17.33 D**	15.67 h	17.67 g	**16.67 D**	14.33 g	12.00 i	**13.17 C**
Salt (1000 ppm) + *G. australe*	20.00 h	17.33 j	**18.67 C**	19.00 f	11.00 f	**19.00 C**	12.67 h	10.67 j	**11.67 D**
Salt (2000 ppm)	6.33 r	11.00 p	**8.67 G**	5.67 l	9.00 k	**7.33 G**	22.33 a	18.67 b	**20.50 A**
Salt (2000 ppm) + *G.mosseae*	10.00 q	13.67 m	**11.83 F**	9.00 k	15.00	**12.00 F**	17.67 c	15.00 f	**16.33 B**
Salt (2000 ppm) + *G. australe*	12.33 o	13.00 n	**12.67 F**	10.67 j	16.00 h	**13.33 E**	16.00 e	17.33 cd	**16.67 B**
Mean	**19.33 A**	**18.77 A**		**16.63 A**	**17.37 A**		**13.90 A**	**11.90 B**	

Means of each factor or interaction in each season having the same letters are not significantly different at 5%.

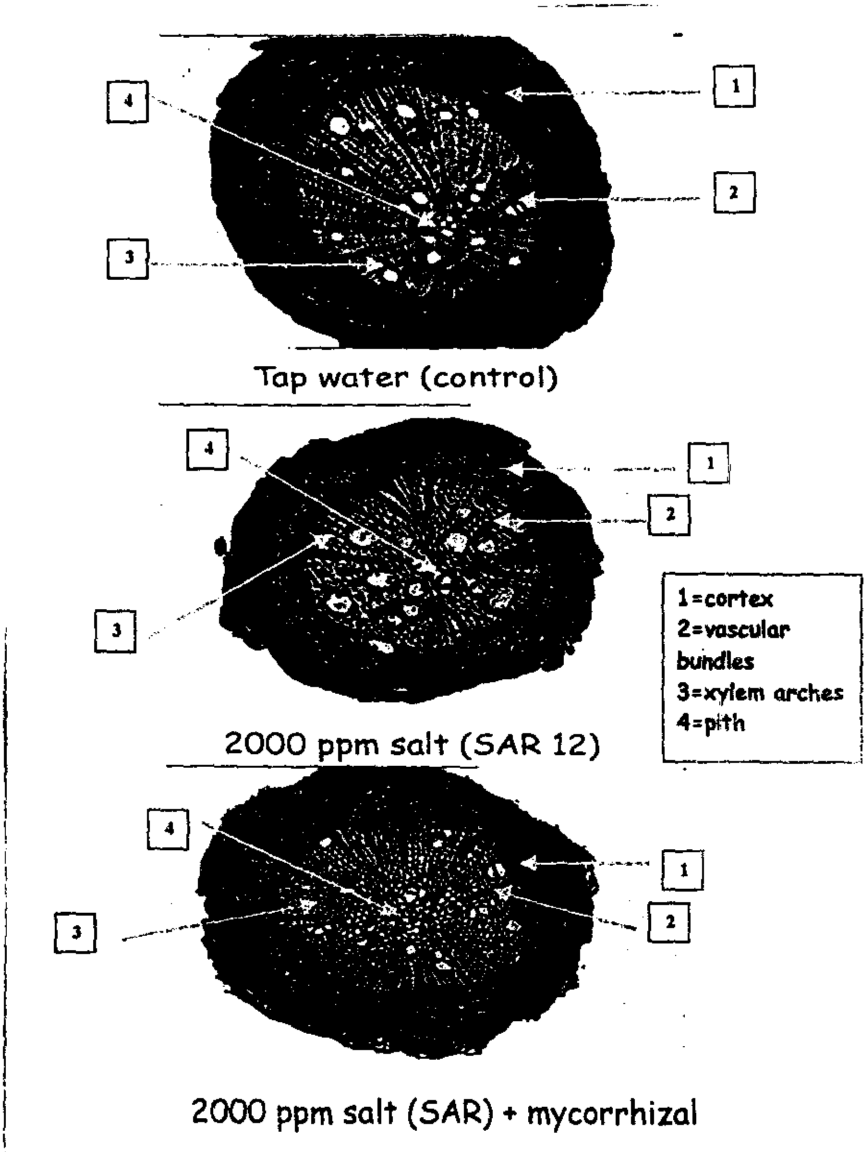

Fig. 1. Root transvers sections of (Desirable) pecan root stock as affected by salinity and inoculation with micorrhizal fungi (*G. Mosseae*) X = 17x 10.

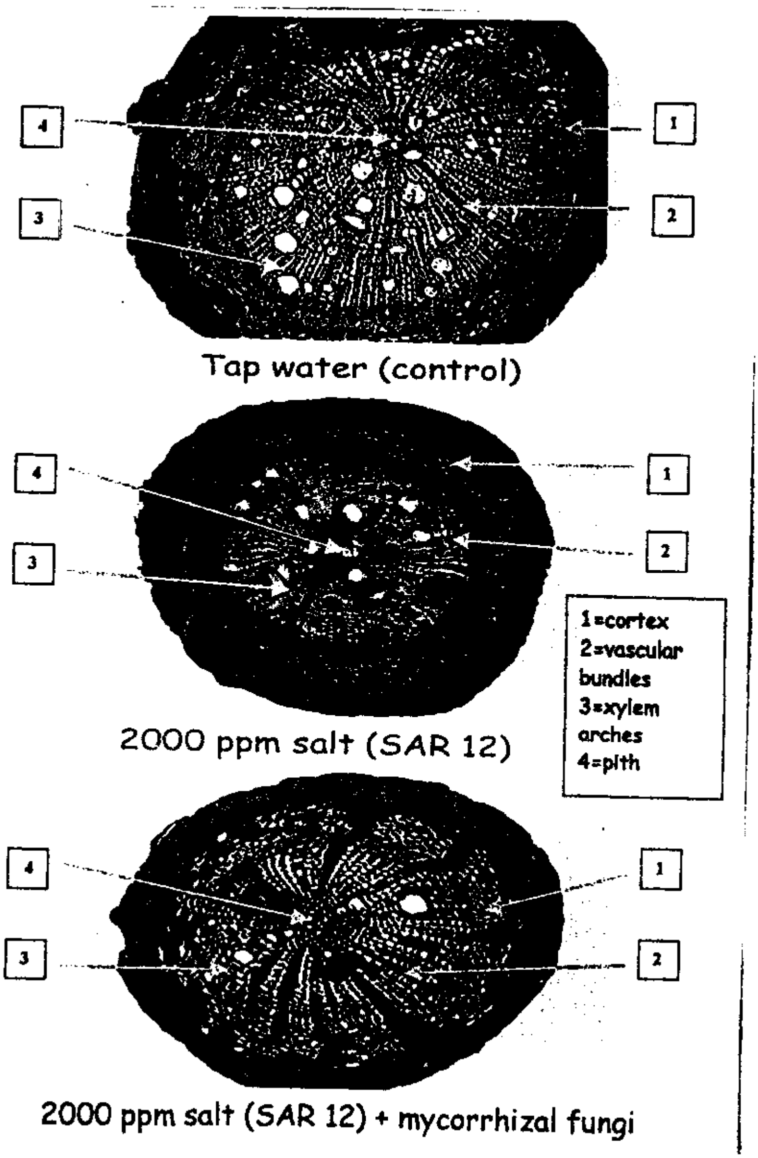

Fig.2. Root transverse sections of (Graking) pecan rootstock as affected by salinity and inoculation with mycorrhizal fungi (*G. mosseae*). X = 17 X 10

However, inoculation with mycorrhizal fungi (*G. mosseae and G. australe*) increased significantly thickness of root cross section, thickness of root cortex, number of root xylem arches and number of root xylem cells in both cultivars grown under 1000 and 2000 mg/l^{-1} salt concentrations compared to the control under the same concentrations and non-inoculated with mycorrhizae (Fig. 1 & 2)

These results are in agreement with those of Salama (1985) on citrus rootstocks and Mervet (1996) grapevines. In addition, Strogonove (1962) reported that salinity inhibits the extension growth of cell more than cell division, thickness of cortex and radius of xylem were more pronounced.

Conclusively, inoculated soil with (G.mosseae and *G. asturale*) fungi may play an important role in alleviating salt stress of "Desirable" and "Graking" pecan rootstocks through enhancing growth, increasing chlorophyll (a and b), total carbohydrates, N, P and K contents and reducing proline, Ca, Na, and Cl contents.

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زيادة تحمل الملوحة لأصلى البيكان " ديزايرابل- جراكنج " عن طريق الحقن بفطر الميكورهيزا

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قسم بحوث الزيتون وفاكهة المناطق شبه الجافة – معهد بحوث البساتين – مركز البحوث الزراعية – القاهرة – مصر.

تم دراسة تأثير الحقن بفطر الميكورهيزا (*G.mosseae* and *G. australe*) على مدى مقاومة الملوحة لأصلى البيكان " ديزايرابل–جراكنج " ، النامية تحت مستويات مختلفة من الملوحة (١٠٠٠–٢٠٠٠مجم لتر) . وعموما نستنتج أن قيم قياسات النمو الخضري تتناقص معنويا بزيادة تركيز الملوحة في ماء الري عن معاملة المقارنة، ويتناسب هذا النقص مع زيادة تركيز الملوحة ولكن على العكس من ذلك عدد الأوراق المحترقة / النبات قد زاد بزيادة معدل الملوحة . أما طول الجذر فلم يأخذ اتجاها معيناً. أوضحت النتائج أن الحقن بفطر الميكورهيزا قد قلل من التأثيرات الضارة الناتجة عن الملوحة على النمو الخضري . وقد أعطت النباتات المعاملة بالتركيز العالي من الملوحة (٢٠٠٠مجم لتر) بدون إضافة الميكورهيزا أقل قيما للنمو الخضري . ومن جهة استجابة الأصول تحت الدراسة للملوحة فقد كان أصل الديزايرابل افضل نموا حيث زادت قيم عدد الأوراق – الوزن الجاف للجذور وقمة النبات – طول الجذر – سمك الجذر الرئيسي عن مثيلاتها فى اصل جراكنج .

كما أظهرت الإضافة الأرضية للميكورهيزا وخاصة (*G. australe*) فعالية في زيادة محتوى الأوراق من كلوروفيل أ، ب والكربوهيدرات الكلية عن معاملة المقارنة. أوضحت النتائج كذلك أن زيادة معدل الملوحة في ماء الري أدت إلي زيادة الضغط الأسموزى والبرولين في الأوراق بالإضافة إلى أن أوراق أصل الديزايرابل قد أعطت قيما أعلى من البرولين والكربوهيدرات الكلية عند مقارنتها بأصل جراكنج . كما وجد أن الري بالماء المالح أدي إلي انخفاض محتوى الأوراق من النتروجين والفوسفور والبوتاسيوم عن المعاملات الأخرى. وعلى العكس من ذلك فقد زاد محتوى الأوراق لكل من الكالسيوم والصوديوم والكلورين عند الرى بالماء المالح . ولكن عند الحقن بفطر الميكورهيزا للأصول تحت الدراسة فقد زاد محتوى الأوراق من النيتروجين والفوسفور والبوتاسيوم بينما اتخذ الكالسيوم والصوديوم والكلوريد اتجاها عكسيا عند مقارنتها بالشتلات المعاملة بالملوحة فقط.

أظهرت الدراسة التشريحية للجذور أن زيادة الملوحة أدت إلي النقص في سمك كل من قطاع الجذر والقشرة وعدد خلايا الخشب ، بينما زاد سمك الحزم الوعائية للجذر وسمك طبقة النخاع . ولكن عند إضافة الميكورهيزا أدت إلي زيادة معنوية في سمك قطاع الجذر وسمك القشرة وعدد الأذرع الخشبية وعدد خلايا الخشب للصنفين تحت الدراسة النامية تحت مستويين من الملوحة (١٠٠٠و٢٠٠٠مجم لتر) وذلك بالنسبة لمعاملات المقارنة فقط عند نفس المستويات من الملوحة وكذلك النباتات الغير معاملة بالميكورهيزا.

نستنتج من هذا البحث أن حقن التربة بالميكورهيزا (*Glomus mosseae and Glomus australe*) يمكن أن يلعب دورا هاما في تقليل أضرار الملوحة في أصلى البيكان " ديزايرابل–جراكنج " عن طريق تنشيط النمو ، وزيادة محتوى الأوراق من الكلوروفيل(أ ، ب) والنتروجين والفوسفور والبوتاسيوم ونقص محتواها من البرولين والكالسيوم والصوديوم والكلورين .