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Technical Bulletin

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VAM Fungi Improve Salt Tolerance of Plants

Plant roots are intimately associated with soil, both physically and chemically. Soil salinity (saltiness) is an important parameter that affects plant growth and nutrition. Plant roots must draw water and dissolved nutrients from soil. If the soil is salty, the roots must work harder, since salt tends to draw water from the root. The saltier the soil, the stronger is the challenge to the root's draw. Soil can contain various salts, such as sodium chloride (NaCl, or table salt), or calcium chloride ($CaCl_2$), among others.

Various Units are used to Measure Saltiness

Soil salinity can be measured using various units. The most direct way is to measure the amount of salt per unit soil, such as g NaCl per Kg of soil. Salinity can also be measured indirectly. Dissolved salts affect the electrical properties of solutions, making the solution a better electrical conductor. Electrical conductance, or "conductivity" is measured in a unit called a Siemen, formerly called a "mho". The conductivity of soil is measured in micro Siemens per cm (μS/cm) or in deciSiemens per meter (dS/m). The conductivity of sea water is high, about 58 dS/m.

Salinity can also be measured in terms of osmotic pressure exerted on the root. The Pascal is a unit used to measure the osmotic pressure of a saline solution. A Pascal is very small, so often the megaPascal is used (M Pa). And since the pressure exerted by a saline solution is a vacuum, the pressure of the solution is negative. As a solution gets saltier, the Pascal pressure unit gets more and more negative. Each of the units mentioned above appears in the various studies cited below.

Saline Soils

A soil is saline if its exchangeable sodium percent (ESP) is less than 15 and its electrical conductivity is greater than 4mmho/cm or 4 mS/cm (high salt, low-moderate sodium). This is the conductivity of a solution containing 40 mg/L NaCl. The pH of saline soils is usually near neutrality (pH 7.0), with a tendency toward alkalinity, although other factors will affect the pH. Saline soils with an ESP greater than 15 are called saline-alkali soils (i.e., saline-sodic soils, characterized by both high salt and high sodium), and tend to have higher pH's (usually up to 8.5).

Mycorrhizal Fungi in Saline Soils

Since mycorrhizal fungi help the root to absorb water from the soil, it would be logical to investigate the effect of mycorrhizal fungi on plant growth in saline soils. Following are summaries of 5 different studies on this topic. Among the studies presented here, salinity is measured using various different units.

1. Ojala, J.C., et al. 1983. Influence of mycorrhizal fungi on the mineral nutrition and yield of onion in saline soil. Agronomy Journal 75: 255-259

86-day Test with *Glomus fasciculatus* and *G. monosporus*

VAM Treatment	Salinity (M Pa)*	Total Dry Wt. (g/plant)
Control	-0.06	0.32
Avg. 2 VAM fungi		1.02
Control	-0.20	0.11
Avg. 2 VAM fungi		0.41
Control	-0.41	0.05
Ave. 2 VAM fungi		0.17

*Salinity comprised of equal concentrations of $CaCl_2$ and NaCl.

- VAM fungi increased plant dry weight under all salinity conditions measured.

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2. Poss, J.A., et al. 1985. Effect of salinity on mycorrhizal onion and tomato in soil with and without additional phosphate. Plant and Soil 88: 307-319.

3-Month Onion Test with *Glomus deserticola* (data from test with no added P to native soil)

VAM Treatment	EC (dS/m)*	%VAM	Total Dry Wt (g/plant)
VAM	1.0	54	0.79
Control		0	0.16
VAM	2.8	38	0.55
Control		0	0.10
VAM	4.3	43	0.32
Control		0	0.08
VAM	5.9	52	0.14
Control		0	0.07

*Salinity comprised of 2 M Nacl: 1 M $CaCl_2$

2-Month Tomato Test with *Glomus fasciculatum*

VAM Treatment	Salinity (EC, dS/m)*	Dry Weight Shoot (g/plant)
VAM	1.0	4.14
Control		3.47
VAM	5.0	3.88
Control		2.67
VAM	10.0	3.12
Control		1.10

*Salinity comprised of 2 M NaCl: 1 M $CaCl_2$

- VAM fungi increased plant dry weight under all salinity conditions measured.

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3. Pfeiffer, C.M. and H.E. Bloss. 1988. Growth and nutrition of guayule (Parthenium argentatum) in a saline soil as influenced by VAM and P-fertilization. New Phytol. 108: 315-321.

98-Day Test with *Glomus intraradices*; Na = 750 μg/g NaCl; P = 100μg/g as $Ca(H_2PO_4)_2$.

Treatment	Dry Wt. (g)	% PO_4 (shoot)	% VAM
VAM	6.2	0.025	54
VAM + P	5.8	0.035	55
VAM – P + Na	5.6	0.015	38
VAM + P + Na	5.8	0.020	20
Control	3.4	0.008	0
Control + P	5.4	0.017	0
Control – P + Na	1.0	0.005	0
Control + P + Na	5.2	0.016	0

- VAM improved growth and % phosphate in shoots comparably to P input, and mitigated some deleterious effects of NA.

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4. Azcon, R. and F. El-Atrash. 1997. Influence of arbuscular mycorrhizae and P-fertilization on growth, nodulation and N-fixation in Medicago sativa at four salinity levels. Biol. Fertil. Soils 24: 81-86.

63-Days Test on Alfalfa with Glomus mosseae; Salinity = #:2:1 Mixture of NaCl, $CaCl_2$ and $MgCl_2$

VAM Treatment	Salinity (dS/m)	Shoot Dry Wt (g)	# Nodules	%VAM
VAM	0	1520	153	40
	13.8	1090	160	51
	22.2	910	153	51
	28.8	770	33	37
	43.5	680	16	19
Control	0	1040	88	0
	13.8	940	79	0
	22.2	720	59	0
	28.8	570	13	0
	43.5	450	1	0
Control + P (50 mg /Kg soil)	0	1470	94	0
	13.8	970	107	0
	22.2	760	60	0
	28.8	610	19	0
	43.5	490	4	0

- VAM improved both shoot dry weight and number of root nodules formed under all salinity conditions tested more than did the addition of P.

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5. VAM wholly or partially mitigated effects of salinity even better than addition of P at all levels tested. **Mankorios, A. T. et al. 1995. Improved growth and nutrition of soybean in a saline soil associated with VAM. Egypt. J. Bot. 35: 101-117.**

56-Day Soybean Test with Glomus mosseae; Sterile clay loam soil.

VAM Treatment	Salinity*	Height (cm)	Total Wt. (g)	# Leaves
VAM	0	6.9	7.4	28
	1.25	5.1	7.6	23
	2.5	5.0	4.8	17
Control	0	4.8	6.5	20
	1.25	4.9	5.8	17
	2.5	5.0	4.7	13

*g NaCl/kg soil

- VAM improved height, total weight, and leaf growth of soybeans under salt stress compared to controls at similar salinity, until 2.5 g NaCl/Kg soil was reached, where the effect was lost.

General Conclusions

The above data, and that presented in a review (Juniper, S. and L. Abbott. 1993. VAM and soil salinity. Mycorrhiza 4:45-57) suggest the following conclusions:

A. Salt tolerance in plants is improved by VAM. Deleterious effects of soil salinity are significantly less pronounced for plants with VAM compared to plants without VAM.

B. Although the precise mechanism for improved salt tolerance has not yet been explained, it appears to be related to improved absorption and utilization of P, Mg, and Ca by VAM plants (via positive influences on osmotic relations between the soil and the root).

C. VAM fungi seem to provide salt tolerance even if they were isolated from non-saline sites. VAM fungi strains isolated from plants in non-saline soils provide salt-tolerance benefits comparable to VAM fungi isolated from saline soils when each are tested in a saline soil environment.

D. The majority of research on plant salt tolerance and VAM has been done on agricultural crops and some salt marsh species. Little work has been published on other plant species, including woody plants. A recent literature search has uncovered a total of only 12 publications dealing with actual salinity treatments on VAM and non VAM in the scientific literature.