AcademicPres

Available online at www.notulaebiologicae.ro

Print ISSN 2067-3205; Electronic 2067-3264

Not Sci Biol 2 (4) 2010, 64-71

Notulae Scientia Biologicae

AM Fungi Influences the Photosynthetic Activity, Growth and Antioxidant Enzymes in *Allium sativum* L. under Salinity Condition

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Abstract

Potential of Arbuscular mycorrhizal (AM) fungi in alleviating adverse salt effects on growth was tested in garlic (*Allium sativum* L.). Towards this objective we analyzed the AM root colonization and the activities of various antioxidant enzymes like peroxidase, catalase, and superoxide dismutase at 0, 100, 200 and 300 mM salinity levels. The activities of all the antioxidant enzymes studied were found to be increased in AM garlic plants. Antioxidant activity was maximum in 100 and 200 mM NaCl (sodium chloride) in AM and non-AM plants. Proline accumulation was induced by salt levels and it was more in leaves as well as roots of AM plants as compared to non-AM plants, this indicating that mycorrhiza reduced salt injury. Growth parameters of garlic plants like leaf area, plant fresh and dry weight and antioxidant enzyme activities were higher at moderate salinity level. This work suggests that the mycorrhiza helps garlic plants to perform better under moderate salinity level by enhancing the antioxidant activity and proline content as compared to non-AM plants.

Keywords: *Allium sativum*, antioxidant enzymes, AM fungi, proline, salt stress

Introduction

Accumulation of salts on the soil surface is one of the most serious agricultural problems in arid and semiarid regions including India (Akhter, 2004). In India, 7 million hectars of land is saline because of over-irrigation with ground water of high salt content (Bhoopander *et al*., 2003). Yearly, more land are rendered unproductive due to accumulation of salt which inhibit crop growth and productivity. *A. sativum* L. (garlic) is one of the important crops grown on one lac twenty thousand hector area in arid and semiarid regions of India for its bulbs which is an important spice/condiment. For the plant host the cost of AM colonization is the delivery of 4-20% of photosynthetically fixed carbon to its fungal partner (Wright *et al*., 1998; Bago *et al*., 2000). Historically, these costs must have been offset by the benefits to the colonized plant. AM symbiosis is complex biological interactions; their impact varies in different environmental conditions and depends on the specific combination of plant and fungus involved (Johnson *et al*., 1997; Burleigh *et al*., 2002; Smith *et al*., 2003). Consequently, profitable use of AM symbioses in an agricultural context requires the selection of a suitable combination of plant host, fungal partner and agricultural practice to balance costs and benefits. Mycorrhizal colonization in plants involves a number of morphological and biochemical events. In different plant systems, several workers have demonstrated that AM fungi diminish detrimental effects of salinity (Ruiz-Lozano *et al.,* 1996; Ruiz-Lozano and Azcon 2000; Al-Karaki and Hammad 2001; Feng *et al*., 2002).

Several groups of enzymes that may hydrolyze phosphorus esters are commonly called phosphatases (Tabatabai and Bremner, 1969), are present in mature arbuscules and intraradical hyphae of AM fungi (Ezawa *et al.,* 1995; Gianinazzi *et al*., 1979). Colonization of wheat and onion by various *Glomus* spp. (including *G. mosseae*) resulted in significant increases in root surface and rhizosphere acid phosphatase activities (Dodd *et al*., 1987).

Plants under salt stress initiate some defense mechanism to protect themselves from harmful effect of oxidative stress. ROS (Reactive Oxygen Species) scavenging is one such common defense response against abiotic stress (Vranova *et al*., 2002). During salt stress excessive generation of ROS such as superoxide radical (O_2^-), Hydrogen peroxide (H_2O_2), hydroxyl radical (OH^-) occurs (Becana, 2000). Generation of these ROS cause rapid cell damage by triggering off a chain reaction (Imlay, 2003) and causes by significant damage to membranes and other essential macromolecules such as photosynthesis, pigments, protein, nucleic acid and lipid (Lin *et al.,* 2000; Foyer *et al*., 1994).

The major ROS scavenging system includes a complex enzymatic group such as catalase (CAT), peroxidase (POD), superoxide dismutases (SOD), non enzymatic molecules such as (proline, glycine betain, sorbitol, manitol) (Prochazkova *et al*., 2001). Plants possess an antioxidant defense system, which maintains level of ROS within the cell. SOD catalyses the dismutation reaction of super oxide anion hydrogen peroxide and oxygen. However hydrogen peroxide is toxic to cell and is further detoxified by CAT and POD to water and oxygen.

Received 12 August 2010; accepted 28 October 2010

Proline is most common osmolyte and osmoprotectant in plants under stress conditions (Hasegawa *et al*., 2000; MacCue and Hanson, 1990; Serrano and Gaxiola, 1994) which is often considered to be involved in stress resistance mechanisms and osmotic adjustment in stressed tissues of plant (Ashraf and Foolad, 2007). Induced Proline accumulation in AM plant is subjected to drought stress has been reported (Azco'n *et al*., 1996; Goicoechea *et al*., 1998). Similar studies were done in *Vigna radiate* and *Vicia faba* plant (Jindal *et al*., 1993; Rabie and Almadina, 2005).

Therefore purpose of the present study is to investigate the role of AM fungal species *Glomus fasciculatum* (Gf) under salinity stress and its effect on growth enhancement, physiological and biochemical (antioxidant enzymes like CAT, POD, SOD and proline accumulation) parameters in AM garlic (*A. sativum* L.) as compared to non treated control. Therefore the presence study was undertaken to evaluate protective potential of AM fungi to salt stress on a spice and medicinal important plants of India *A. sativum* L.

Materials and methods

Plant material and experimental design

The cloves of garlic (*A. sativum* L.) local variety Godavari (selection 2) was obtained from National Research Center of Onion and Garlic, Rajgurunagar Maharashtra, India. These were surface sterilized with 0.01% $HgCl_2$. These clove were grown in plastic bags having size 20x30 cm. containing 3 kg of steam sterilized (121°C and 103.42 k pa pressure for 1 h) garden sandy loamy soil. Soils were analyzed with respect to: Sand 80% Silt 15% and Clay 5% by website: www.pedosphere.com. The experiments were conducted under natural light and temperature conditions above ground level.

Three month old 30 g of mycorrhizal inoculum *Glomus fasciculatum* containing AM colonized roots, rhizosphere soil having extramatrical mycelium and spores (10-15 spores/g of soil) was use for each seedlings. The inoculum was placed five cm. below each clove. Non mycorrhizal garlic plants consisted of same inoculum but autoclaved (100°C, 103.42 k pa pressure for 1 h). The experimental design consisted of Completely Randomized Block design in 2 x 4 factorial design with mycorrhizal factor (AM and non AM) and salt factor (0, 100, 200 and 300 mM NaCl) having nine replicates each. The treatments consisted of: (1) non-AM control i.e. zero salinity level and three different NaCl levels of 100 mM, 200 mM, and 300 mM, respectively (C, C+1S, C+2S, C+3S) and AM inoculated plants with zero salinity level, AM inoculated three different NaCl levels of 100 mM, 200 mM, and 300 mM (Gf, Gf+1S, Gf+2S, Gf+3S) respectively. In each bag three plants were maintained, thirty day old mycorrhizal and non mycorrhizal garlic seedlings were subjected to three different salinity levels by addition of 100 ml solution containing 100 mM, 200 mM, and 300 mM, NaCl to each pot for twice in a week. Thereafter 200 ml of water was added two days of interval.

Growth measurement and biochemical analysis

Plants were harvested after 45 and 75 days of AM inoculation and analyzed for morphological parameters such as leaf area, total biomass, percent root colonization, mycorrhizal dependency and tolerance indices. At each salinity level, the mycorrhizal dependency (M.D.) of the plant was calculated according to Gerdemann (1975), as:

$$\text{M.D.}=\frac{\text{Dry weight of AM plant at a particular level of salinity}}{\text{Dry weight of non - AM plant at the same level of salinity}}\text{x}100$$

AM colonization

The percentage of AM colonization in roots was analyzed by clearing and staining of roots by the method (Phillips and Haymans, 1970) method and percent AM colonization in root was determined by gridline intersect method Giovannetti and Mosse (1980). Proline was determined by (Bates *et al*., 1973). Proline content was expressed as µmol proline/g of tissue.

Relative water content (Barr et al., 1962)

Leaf was cut in to 5-10 cm^2, and then weighed immediately to record fresh weight. Leaf sample was floated in deionized water in Petri dish for 4 hours at normal room temperature and light. After 4 hours, the sample was taken out from water, and surface water was removed and again weighed to obtain fully turgid weight. Sample was dried in an oven at 80°C for 24 hours weighed again.

Formula: RWC (%)=[(Fresh wt.-dry wt.)/(turgid wt.-dry wt.)] x 100.

Physiological and biochemical parameters

Chlorophyll content was determined by method Arnon (1949), Acid and alkaline phosphatase was measured by the method of Lowry *et al.* (1954).

Antioxidant enzyme activity assay

Enzyme extracts were prepared in extraction buffer Enzyme extracts were prepared in extraction buffer containing 1M Tris-acetate buffer (pH 6.0), 0.5 M EDTA.Na2 (pH 8.0), 2% w/v PVP, 0.1 mM PMSF, 0.2% v/v Triton x 100 by grinding 0.5 g leaf or root sample in 5 ml extraction buffer. Extracts were centrifuged at 10,000 x g at 4°C for 10 min, and the supernatant was used as source of enzyme. Every assay was conducted three times. SOD activity was determined by Beauchamp and Fridovich (1971) method. SOD activity was expressed in units. One unit (U) is defined as the amount of change in absorbance by unit h^{-1} mg^{-1} protein. Guiacol POD was assayed by Putter's (1974) method. The POD activity was expressed in unit per mg of protein. CAT activity was measured by Aebi's method

(1984). The enzyme activity was expressed in U μg^{-1} protein (U=1 mM of H_2O_2 reduction $min^{-1}\mu g^{-1}$ protein). The protein content was determined using Bradford's method (1979). Proline content was estimated by method (Bates *et al.,* 1973), Absorbance was read at 520 nm. Proline content was expressed as µmol proline/gm of tissue.

Statistical analysis

Data were analyzed by One Way ANOVA followed by Duncan's multiple new range test and different small bold alphabetical letters indicate significant differences at $p<0.05$ level.

Results and discussion

After 75 days of AM inoculation and after stress recovery mycorrhizal garlic plants at second level of salinity showed significant increase in leaf area (Tab. 1). After 45 and 75 days of AM inoculation in first and second level of salinity stressed mycorrhizal garlic plants showed more plant fresh weight as compared to non mycorrhizal garlic plants. Increase in morphological parameters in AM garlic plants during moderate salinity condition was observed which states that mycorrhiza helps garlic plants to survive luxuriantly under saline conditions. Many studies have indicated that inoculation with AM fungi improves growth of plant under salt stress condition (Yano *et al.,* 2003; Giri and Mukerji, 2004; Cho *et al.*, 2006; Ghazi Al-Karaki, 2006). After 45 and 75 days of AM inoculation, dry weight in mycorrhizal garlic plants at second level of salinity level was found to increase significantly as compared to non mycorrhizal garlic plants. The higher biomass in moderately saline condition by *Glomus mosseae* inoculated with tomato plants showed similar results (Ghazi Al-Karaki, 2001). Thus, mycorrhizal fungi improve plant growth under salt stress condition (Al-Karaki, 2000; Centrell and Lindermann, 2001).

After 45 days of AM inoculation, mycorrhizal garlic plants in second and third level of salinity showed significant increase in relative water content as compared to non mycorrhizal garlic plants. After stress recovery mycorrhizal garlic plants in non stressed condition was found to increase significantly in relative water content as compared to non mycorrhizal garlic plants (Tab. 2).

Proline is an important organic compound that participates in osmotic adjustment (Morgan, 1984; Kishor *et al*., 1995). Proline act as a major reservoir of energy and nitrogen for utilization during salinity stress (Goas *et al.*, 1982). After 45 days of AM inoculation the shoot proline accumulation was found to increase significantly in mycorrhizal garlic plants at first and second level of salinity levels as compared to non mycorrhizal garlic plants. After 75 days of AM inoculation the shoot proline accumulation in non-mycorrhizal garlic plants increased significantly as compared to mycorrhizal garlic plants at first second and third level of salinity stress. Proline is accumu-

Tab. 1. Morphological parameters in *Allium sativum* L. after 45 and 75 days of AM treatment under non- salinity and salinity conditions

Treatments	Leaf area (cm^2)		Fresh weight (g)		Dry weight (g)	
	45 days	75 days	45 days	75 days	45 days	75 days
C	8.750±1.670ab	10.417±1.160abc	1.40±0.31ab	1.42±0.09a	0.263±0.10 ab	0.274±0.03 ab
C+1S	8.700±0.668ab	9.033±0.731abcd	1.34±0.53ab	1.26±0.26a	0.164±0.09 ab	0.247±0.01 ab
C+2S	6.163±1.165ab	7.163±0.954cd	1.33±0.22ab	0.98±0.29 a	0.170±0.05 b	0.234±0.05 ab
C+3S	4.550±0.831b	5.550±0.686d	1.22±0.54b	0.95±0.13 a	0.169±0.04 b	0.202±0.01 ab
Gf	8.636±1.867ab	11.303±1.360ab	1.53±0.29ab	1.52±0.47 a	0.249±0.01 ab	0.365±0.10 ab
Gf+1S	11.027±5.012a	12.360±3.149a	1.71±0.23ab	1.49±0.17 a	0.317±0.03 ab	0.334±0.04 ab
Gf+2S	9.000±1.632ab	10.666±1.699abc	2.13±0.43a	1.50±0.25 a	0.383±0.08 a	0.378±0.13a
Gf+3S	6.996±2.372ab	8.330±1.439bcd	1.43±0.08ab	0.87±0.36 a	0.279±0.05 ab	0.260±0.09b

Tab. 2. Relative water content, shoot and root proline accumulation in *Allium sativum* L. after 45 and 75 days of AM treatment under non- salinity and salinity conditions

Treatments	Relative water content (%)		Proline (u mole/g of tissue x 10^{-3})			
			Shoot		Root	
	45 days	75 days	45 days	75 days	45 days	75 days
C	81.225±7.017abc	77.981±14.712a	1.442±0.150d	3.737±0.181f	1.206±0.110c	4.855±0.216c
C+1S	81.023±10.607abc	85.611±13.251a	2.030±0.190d	4.944±0.144de	2.383±0.360b	6.827±0.150b
C+2S	74.621±16.937bc	72.574±13.100a	5.326±0.409b	4.620±0.150e	2.266±0.150b	6.621±0.144b
C+3S	70.047±14.250c	76.799±6.3355a	5.356±0.041b	5.120±0.190d	2.442±0.110b	7.357±0.978b
Gf	92.790±14.298ab	94.188±29.595a	1.706±0.150d	4.090±0.110f	1.530±0.340c	9.093±0.314a
Gf+1S	98.204±4.1616a	90.429±6.0914a	2.678±0.397c	6.739±0.272a	2.648±0.144b	9.270±0.563a
Gf+2S	96.124±4.1414a	93.446±13.688a	7.239±0.381a	5.944±0.150b	4.149±0.438a	10.123±0.61a
Gf+3S	91.929±16.073ab	80.044±5.5963a	5.297±0.401b	5.120±0.190c	4.267±0.479a	9.829±0.166a

lated in shoots and enhances osmotic adjustment. Proline accumulation was more in shoots of AM garlic plant than shoots of non-AM garlic plants. In roots, proline accumulation after 45 days of AM inoculation was found to significantly increase in mycorrhizal garlic plants at second and third salinity level as compared to non mycorrhizal garlic plants. Proline accumulation in roots was found to increase as compared to shoots, except in second levels of salinity treated non mycorrhizal shoot, this higher proline accumulation in roots as compared to shoot may be due to the fact that the roots are the primary site for saline stress and the mycorrhiza colonized in roots may have induced accumulation of proline and other antioxidant enzymes in roots.

After 45 days of AM inoculation, mycorrhizal dependency in AM treated garlic plants during first second and third level of salinity stress was 203.77%, 233.84% and 168.77% respectively. After 75 days of AM inoculation, mycorrhizal dependency in AM treated garlic plants during first second and third level of salinity stress was 136.65%, 169.67% and 128.53% respectively. After 45 and 75 days of AM inoculation mycorrhizal garlic plants in second salinity level showed more tolerance to salinity stress as compared to non mycorrhizal garlic plants. Thus increment in mycorrhizal dependency could be concluded that the benefits symbiotic association between AM fungi and garlic plants increased under salinity conditions. Mycorrhizal dependency in lower and moderate saline conditions was higher, but in higher saline condition it went on decreasing, hence we concluded that at first and second level of salinity conditions mycorrhiza help not only for acclimatization but also for continued nutrient uptake during progressive growth stages in garlic plants. Mycorrhizal garlic plants were found to be more tolerant in second level of salinity stress condition because mycorrhizal inoculation protects the plants against the detrimental effect of salt, which may be due to the root development higher nutrient acquisition in response to AMF colonization was suggested to be a plant strategy for salt stress tolerance (Poss *et al.*, 1985).

As shown in Fig. 1a, after 45 days of AM inoculation, the mycorrhizal non-stressed garlic roots showed 33.33% AM colonization, during saline conditions the AM colonization was higher in second level of salinity (30%) treated garlic plants than first and third level of salinity (13.33 and 16.66%) treated garlic plants. But after 75 days of AM inoculation, second level of salinity treated garlic plants showed 60% AM colonization which was higher than other salinity treatments. That means at second salinity level the percent root colonization increased and at third salinity level it was found to be inhibited. Similar results were obtained by Copwann *et al.* (1996) and Rosendal *et al.* (1991).

The plant is stimulated by colonization to a limitation of Na transport towards the leaves, and leads to better functioning of chloroplast and photosynthetic efficiency, as shown by Al-Karaki (2000) and Rabie (2005). Our results indicated that after 45 and 75 days of AM inoculation in all salinity levels, mycorrhizal garlic plants showed higher chlorophyll content as compared to non mycorrhizal garlic plants (Fig. 1b). Thus, AM symbiosis could enhanced the photosynthetic ability of garlic leaves, which was in agreement with the results of other studies (Giri and Mukerji, 2004; Sannazzaro *et al.*, 2006; Colla *et al.*, 2008, Sheng *et al.*, 2008).

Phosphatases of mycorrhizae are both specifically induced in the presence of *Glomus* spores and are sensitive to the levels of phosphate in the environment (Pacovsky *et al.,* 1991). MacDonald and Lewis (1978) cytochemically demonstrated the presence of acid phosphatase in *G. mosseae*. In our experiment after 75 days of AM inoculation acid and alkaline phosphatase activities significantly increased in mycorrhiza inoculated garlic plant as compared to non mycorrhizal garlic plants. In second level of salin-

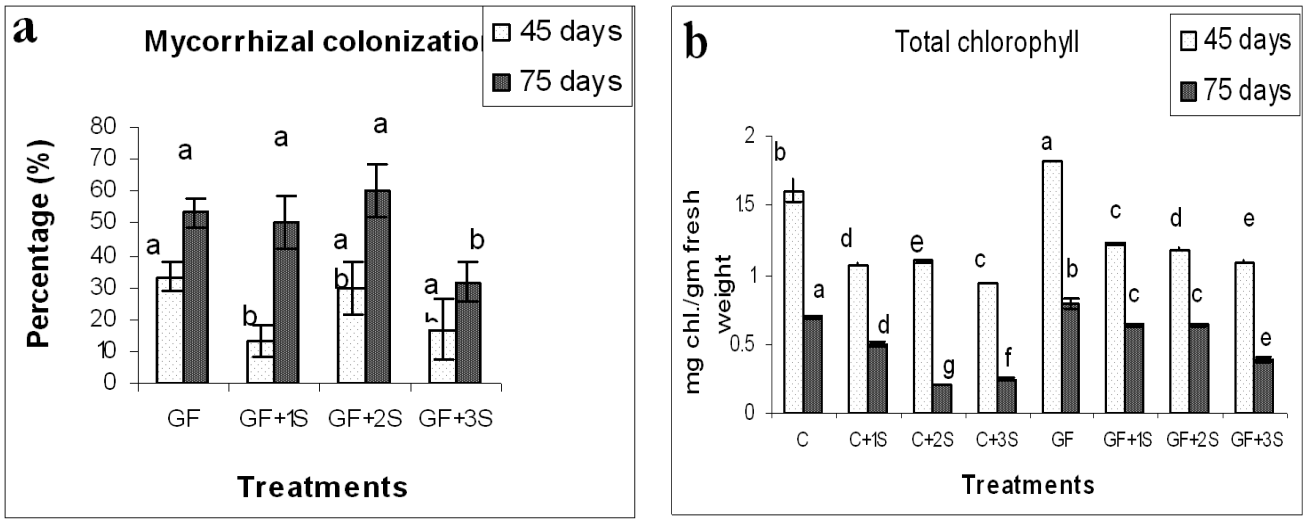

Fig. 1. Percentage of AM colonization and Chlorophyll content of *Allium sativum* L. after 45 and 75 days of AM treatment

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Tab. 3. Acid and Alkaline phosphatase activity in *Allium sativum* L. after 45 and 75 days of AM treatment under non- salinity and salinity conditions

Treatments	Acid Phosphatase μmole pnp-release/g fresh wt.		Alkaline Phosphatase μmole pnp-release/g fresh wt.	
	45 days	75 days	45 days	75 days
C	3.837±0.462 a	4.071±0.018 e	1.249±0.053 a	3.958±0.028 c
C+1S	4.120±0.364 a	3.909±0.033 f	1.228±0.106 a	3.184±0.028 f
C+2S	3.919±0.405 a	3.755±0.057 g	1.184±0.069 ab	4.007±0.022 c
C+3S	3.763±0.600 a	3.621±0.022 h	1.079±0.089 b	3.950±0.032 c
Gf	3.997±0.439 a	4.218±0.039 d	1.228±0.015 a	4.333±0.028 b
Gf+1S	4.184±0.064 a	4.845±0.025 b	1.197±0.035 ab	3.668±0.052 e
Gf+2S	4.223±0.015 a	5.097±0.047 a	1.282±0.057 a	4.644±0.050 a
Gf+3S	4.220±0.014 a	4.714±0.040 c	1.269±0.022 a	3.822±0.022 d

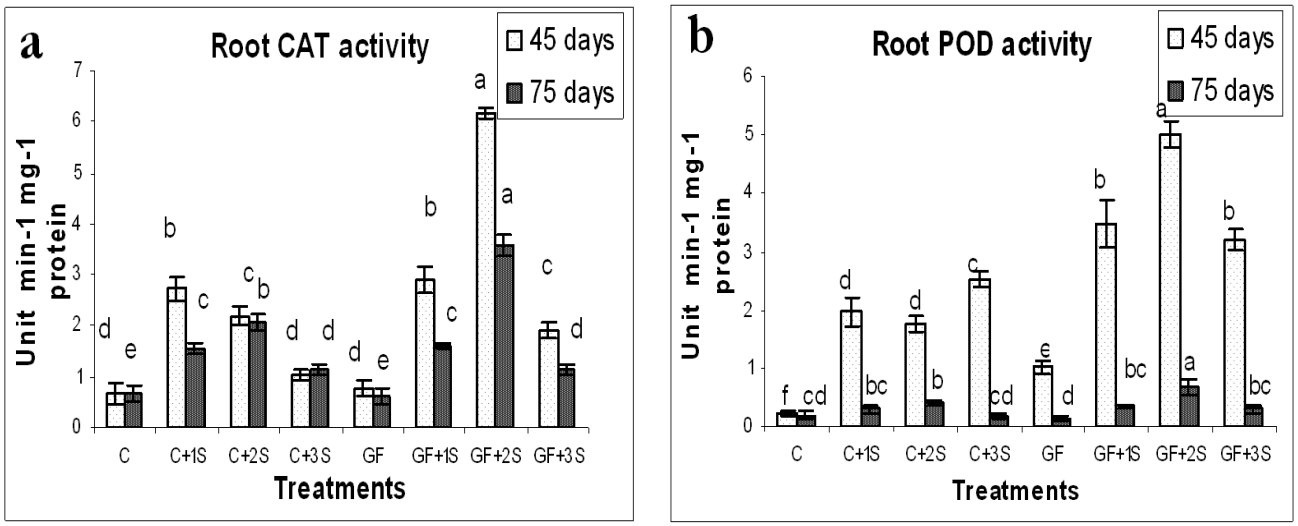

Fig. 2. CAT and POD activity from roots of *Allium sativum* L. after 45 and 75 days of AM treatment

ity stressed mycorrhizal garlic plants, phosphatase activity was much higher (Tab. 3). This increase in activity was positively correlated to phosphate uptake by mycorrhizal garlic plants under salinity conditions.

Cells under salt stress initially accumulate salts as free osmotica; however, a toxic specific ion effect appears after a certain threshold salt level. An excess of these ions may alter membrane integrity, enzymatic activity, protein and nucleic acid metabolism (Hasegawa *et al.,* 2000; Mansour and Salama, 2005). The production of toxic oxygen derivatives increased in biotic and abiotic stresses. Plants possess efficient scavenging system of ROS that protect them from oxidative damage (Foyer *et al.*, 1994). As a part of this system antioxidant enzymes are key elements in defense mechanism. The activity of antioxidant enzymes has been reported to increase under saline conditions in the case of salt tolerant cotton (Meloni *et al.*, 2003). As shown in Fig. 2a, after 45 days of AM inoculation, induced CAT activity in all treatment After 45 days of AM inoculation, CAT activity was to be higher (6.10%, 179.8% and 87.15%) in mycorrhizal than non mycorrhizal garlic plants at first second and third level of salinity treatments and declined after 75 days of AM inoculation. After 75 days of AM inoculation, the CAT activity was higher (3.00, 73.39 and 2.32%) than non mycorrhizal garlic plants at first second and third level of salinity treatments. The CAT activity in roots of non mycorrhizal garlic plant increased in 100 mM and 200 mM NaCl treatments, but at higher salinity level, CAT activity was found to decrease. The overall CAT activity was observed to be more in mycorrhizal garlic plants than non mycorrhizal garlic plants in first and second level of salinity treatment.

As shown in Fig. 2b, after 45 days of AM inoculation the POD activity was higher (76.29%, 184.76% and 26.84%) in AM inoculated garlic plants as compared to non mycorrhizal garlic plants at first second and third level of salinity conditions. POD activity was highly induced in mycorrhizal garlic plants in 100 and 200 mM NaCl stress. After 75 days of AM inoculation, POD activity in mycorrhiza inoculated garlic plants was significantly higher (10.96%, 62.60% and 59.79%) as compared to non mycorrhizal garlic plants at first second and third level of salinity respectively. But in comparison with the early stage of salt stress, POD activity was found to reduce in later stage of salt stress especially in third level of salinity stress. The CAT, POD activities were largely induced in

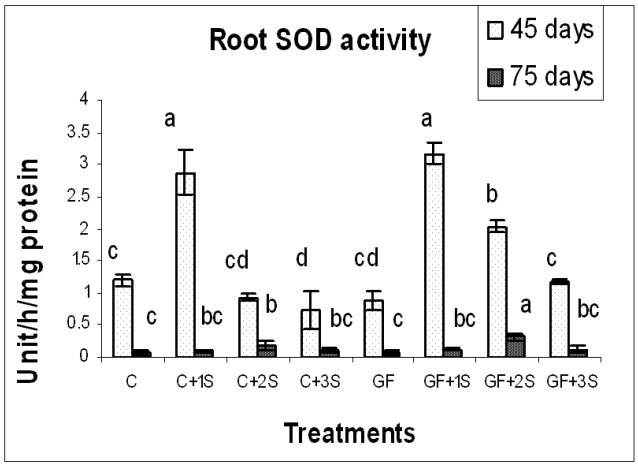

Fig. 3. SOD activity from roots of *Allium sativum* L. after 45 and 75 days of AM treatment

salinity conditions and were found to be higher in AM treated garlic plants than non-AM plants. The level of antioxidant response depends on species, development and metabolic state of plant as well as duration and intensity of stress (Reddy *et al.*, 2004). Salinity stress increased the antioxidant mechanism in root which is the immediate organ to suffer from salinity more efficiently than leaves.

As shown in Fig. 3, Mycorrhizal garlic plants showed higher SOD activity as compared to non mycorrhizal garlic plants in all treatments. After 45 days of AM inoculation the SOD activity was (10.49%, 118.86% and 59.32%) in mycorrhizal garlic plants as compared to non-mycorrhizal inoculated garlic plants at first second and third level of salinity respectively. After 75 days of AM inoculation, SOD activity of AM inoculated garlic plants was significantly higher (17.17%, 61.90% and 12.13%) as compared to non mycorrhizal garlic plants at first second and third level of salinity. But in comparison with the early stages of salt stress the effect of AM and also SOD activity reduced during later stages of salt stress especially in third level of salinity stress. In the experiment, SOD activity was largely induced by AM fungi in saline and non saline conditions, SOD play important role in detoxification of active oxygen species (O_2^-) to O_2 and H_2O_2 mostly in biotic and abiotic stresses. The SOD activity was found to decline after long periods of salt stress which might be the result of adaptation to salt stress. In lettuce (*Lactuca sativa*) plant colonized by *Glomus mosseae* and *Glomus deserticola* under drought stress condition the SOD activities were reported to be higher (Porcel, 2003).

The increased activity of antioxidant enzymes under salt stress is often related to the enhanced tolerance to stress. Acevedo *et al.* (2001) showed that rapid and continued increased in CAT activity might indicate that CAT is a major enzyme detoxifying hydrogen peroxide in barley under salt stress, since ROS produced through multiple pathways including SOD, under salt stress leads to an overall two fold increase in CAT activity than SOD could better contribute in maintaining steady state level of cellular hydrogen peroxide. Oxidative burst was found to be lower in mycorrhizal garlic plants than non-mycorrhizal garlic plants ultimately led to maintaining cell membrane osmosis. Similar results have been reported from tomato i.e. by enhancing antioxidant enzyme activity and cell membrane osmosis under salt stress, there is an improvement to salt resistance in mycorrhizal plants (He Zhong Qun *et al.*, 2007).

AM colonization is often found to be inhibited during salt stress which was reported by Copwann *et al.* (1996) and Rosendal *et al.* (1991). Our results suggested that the POD, CAT and SOD activities were associated with mycorrhizal colonization and increasing level of antioxidant enzymes led to enhanced tolerance of AM Garlic plants to salt stress.

Conclusions

Inoculation of *G. fasciculatum* was found to be more promising to induce growth of garlic plants under lower and moderate salinity levels. Mycorrhiza protects the plants from salinity injury by increasing biomass content, photosynthetic activity and phosphatase activity by enhancing nutrient status. This study also states that AM fungi helps in increment of antioxidant enzymes CAT, POD, SOD plays an important role in regulation of growth for positive adaptation of AM garlic plants to salt stress. So the strategy of application of mycorrhizal species *G. fasciculatum* as a biofertilizers to garlic crop by enhancing yield of garlic crop cultivated in saline soil areas.

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