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Salt Tolerance in Mycorrhizal Plants Due To Induced Modifications In Cell Physiology and Biochemistry

Srimathi Priya L.[1]*, Kumutha K.[2] and Pandiyarajan P.[3]

[1]Assistant Professor (Agricultural Microbiology), Department of Soil Science & Agricultural Chemistry, Agricultural College & Research Institute, Killikulam, Vallanad - 628 252, Tutucorin, India

[2]Professor, Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore, India

[3]Professor, Department of, Anbil Dharmalingam Agricultural College, Trichy, India

*Corresponding Author E-mail: agrisriya@gmail.com

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ABSTRACT

A pot culture experiment was taken up to examine the influence of AM inoculation on salinity tolerance in Onion crop. Sodic soil isolates of AM viz., TRY 1, TRY 2, TRY 3 and TFS 1 with two standard cultures (G. intraradices and S. calospora) and a control with salt alone were used. The bulbs of onion were planted and then subjected to three levels of salinity. The results illustrated that the host plants had significant rate of mycorrhizal dependency (MD) which was found to increase with increase in salt levels when treated with AM fungal inoculants. The phosphatase and dehydrogenase enzyme activities increased due to mycorrhizal inoculation at all the three levels of salt while the defense enzymes registered remarkable increase with stress levels. Histochemical studies in onion roots, exhibited a clear difference in root anatomy in the mycorrhizal treatments, with lignification of the vascular cells and vacuole formation. These biochemical changes observed in the plants confirmed the adaptation of mycorrhizal plants not only through defense activities but also influence plant growth and nutrition over the control plants at salt stressed condition.

Key words: *Sodic soil; Mycorrhizal dependency; Phosphatase; Dehydrogenase; Root anatomy*

INTRODUCTION

Salt-affected soil adversely affect the livelihood security of people in more than 100 countries and at present, out of 1.5 billion hectares of cultivated land around the world is affected by excess salt content[44]. The area under salt-affected soils in India is estimated to be 6.73 Mha spread over a number of states across the country. The projections indicate that the country will have 11.7 Mha area affected by salinity and sodicity by 2025[13]. Many of such salt-affected areas remain unproductive for many years because of plant establishment problems. Excessive amounts of salts, mainly sodium (Na^+), in the soil solution creates a stress that not only affects plant physiology (including growth, photosynthesis, protein synthesis, energy, lipid metabolism) but also dispersion of soil aggregates that leads to deterioration of soil hydraulic properties and in turn cause destabilisation of soil structure, resulting in a considerable reduction in crop yield[29].

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The direct effects of salt on plant physiology may involve: (a) reduction in the osmotic potential of the soil solution that reduces the amount of water available to the plant causing physiological drought[26]; (b) toxicity of excessive Na^+ and Cl^- ions towards the cell (toxic effects include disruption to the structure of enzymes and other macromolecules), damage to cell organelles and plasma membrane, disruption of photosynthesis, respiration and protein synthesis[15] and (c) nutrient imbalance in the plant caused by nutrient uptake and/or transport to the shoot leading to ion deficiencies[31] in saline soils.

Mycorrhizal fungi improve rhizosphere health by stimulating root exudation which promotes the growth of other soil microbes[9] and contribute directly to organic carbon content by accounting for 5 to 50% of the total microbial biomass in soil[37] while their colonization might further enhance tolerance[4] and efficient mechanism for P acquisition, especially under stress conditions. Specific ecotypes of AM fungi may be particularly adapted to the peculiar saline or sodic conditions. Though, their contributions to agriculture are well known, their role in crop establishment and maintenance of soil structure and stability under saline conditions has received less attention which insisted the necessity for this study. Hence the present study was taken up with the aim of investigating the effect of AM fungi at various levels of salinity in onion through a pot culture experiment.

MATERIALS AND METHODS

Effect of AM fungi at various levels of salinity in Onion

In the present study, a pot culture study was taken up to analyze the influence of AM inoculation on salinity tolerance in Onion crop. Pots of 12 Kg capacity were filled with sterilized pot mix soil followed by AM inoculation @ 50 g^{-1} pot. AM isolates (TRY 1, TRY 2, TRY 3 and TFS 1) isolated form sodic soils of Trichy district, Tamil Nadu, India, were used as inoculants with two standard cultures (*G. intraradices* and *S. calospora*) for comparison, obtained from Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, while control was maintained without AM inoculation with salt treatment alone. Onion bulbs were planted (4-5 bulbs pot^{-1}) and then subjected to three levels of salinity (1.5, 3.0 and 4.5 dSm^{-1}) by addition of NaCl through irrigation water twice in a week. All the treatments were replicated three times in a completely randomized design.

Treatments:

Inoculants:

Salinity Levels

T1 - *Glomus intraradices* L 1 - 1.5 dSm^{-1}

T2 - *Scutellospora calospora* L 2 - 3.0 dSm^{-1}

T3 - TRY 1 (*Acaulospora* sp.) L 3 - 4.5 dSm^{-1}

T4 - TRY 2 (*Scutellospora* sp.)

T5 - TRY 3 (*Glomus* sp.)

T6 - TFS 1 (*Glomus* sp.)

T7 - Control (NaCl alone)

Observations

Plant sample from each treatment was casually uprooted on 30, 45 and 75 days after sowing (DAS) without damage to the root system and washed with tap water to remove the adhering soil particles. The yield parameters and the biochemical assays of the rhizosphere samples were recorded and analysed.

Total dry matter production

Plants samples were air dried and then kept in an oven at 60° C to 70° C until the constant weight was obtained. Weight of the dried plant samples were recorded and expressed in g $plant^{-1}$. Dry matter production at different stages was recorded for each plant.

Mycorrhizal dependency

It's the degree to which a plant species is dependent on mycorrhizal association to produce its maximum growth or yield at a given level of soil fertility[20].

$$\text{Mycorrhizal dependency} = \frac{\text{Dry weight of Mycorrhizal plant - Dry weight of non-mycorrhizal plant}}{\text{Dry weight of Mycorrhizal plant}}$$

Estimation of AM fungal colonization in Onion roots

The Onion plant roots were washed thoroughly and the root colonization percentage was examined at 30, 60 and 90 DAS as explained by Phillips and Hayman[39].

Estimation of biochemical constituents enzyme activity of Onion roots

Acid phosphatase (EC.3.1.3.2) and alkaline phosphatase activities (EC.3.1.3.1) were extracted and measured in the onion roots as per the method of Morton[35]. The released paranitrophenol was yellow in colour and was measured at 725 nm.

Enzyme Activity in soil

The activity of soil phosphatase was calculated using standard graph[41]. Soil dehydrogenase activity was determined by the method of Casida *et al.*[11].

Defense enzyme activity in roots

Peroxidase activity (EC 1.11.1.7)

The activity of peroxidase enzyme in Onion roots were analysed as per Hammerschmidt *et al.*[24].

Polyphenol oxidase activity (EC 1.14.18.1)

The substrate catechol used was oxidised by the enzyme which was measured as change in absorbance at 495 nm spectrophotometrically as per Mayer *et al*[33].

Catalase activity (EC 1.11.1.6)

Enzyme activity was calculated at 30, 45 and 75 DAS and expressed as g of H_2O_2 $g^{-1}min^{-1}$ as per Sadasivam and Manickam[41].

Super oxide dismutase (SOD) EC 1.15.1.1

Super oxide dismutase was assayed spectrophotometrically and read at 560 nm as per Beauchamp and Fridovich[7].

Proline estimation in leaves of Onion

Proline content was estimated with 0.5 gm of leaf sample each as per Sadasivam and Manickam[41].

Histochemical changes in the roots of Onion crop grown under various levels of salinity

The Onion roots (at 45 DAS) were collected, rinsed with distilled water and cut into small pieces measuring 4-5 mm length and fixed in formalin acetic acid (FAA) solution (5 parts of 35 per cent formalin, 5 parts of glacial acetic acid and 90 parts of ethyl alcohol) for 24 hours. The tissues were then dehydrated using a series of baths consisting of water, ethyl alcohol and tertiary butyl alcohol and embedded in wax. The thin sectioning was done using rotary microtome and the sections were then placed on slides previously coated with Haupt's adhesive[27]. The wax was removed by passing the slides gently through xylol for 10 minutes and rehydrated in a series of baths consisting of xylol -100 per cent (2 changes), xylol + ethanol - 50 : 50 (1 change) and ethanol-100 per cent (2 changes). The slides were kept in each bath for 10 minutes and then stained with saffranin and viewed under Nikon light microscope (40 X).

RESULTS AND DISCUSSION

Effect of AM fungal isolates on plant attributes at various levels of salinity in Onion The observations from pot culture experiment were recorded where, certain isolates of the sodic soil were performing on par with the authenticated cultures. Results of the effect of AM fungal treatments on plant parameters, soil properties and yield attributes are explained here below.

Total dry matter production

Enhanced growth of mycorrhizal plants in saline environments has been related partly to mycorrhizal-mediated enhancement of host plant nutrition[2] . In the present study also, AM fungal treatments were found to influence dry matter production (DMP) which was higher than the non-mycorrhizal plants. DMP was attained the maximum at harvest where, T1 (*G. intraradices*) and T2 (*S. calospora*) were resulting best with 22.82 and 22.03 g $plant^{-1}$ respectively followed by TRY 3 with 21.15 g $plant^{-1}$. But the responses were significant only up to L2 (3.0 dS m^{-1}) where a decline was observed at the third level (4.5 dS m^{-1}) throughout the growth period. Similar results were documented by Ruiz-Lozano[40] who reported that, plant dry weight was reduced in uninoculated plants by about 35% at the highest salt level. At high stress conditions, soil salinity inhibits plant growth and productivity due to direct effects of ion toxicity or indirect effects of saline ions that cause soil/plant osmotic imbalance. The effects of AM fungi (AMF) on enhancing rice plant growth and yield are well-acknowledged through studies by Neha Nancy *et al*[36]., (Table 1).

Mycorrhizal dependency (%)

The rate of dependency of the onion plant on the AM species under salinity was estimated with respect to dry matter production of the crop where, the percentage of dependency was found to increase along with the increase in salt levels especially during the early and mid growth stages. Also, mycorrhizal dependency was noticed the maximum at L3 (4.5 dSm^{-1}) than at L1 (1.5 dsm^{-1}) and L2 (3.0 dsm^{-1}) levels. This shows that, as the plant encounters a stress, these symbiotic associations offers them the tolerating ability to withstand and overcome the deleterious effects. This is in line with reports by Kumar *et al*[30]., who showed that the mycorrhizal dependency (MD) of Jatropha increased from 12.13 to 20.84 per cent under salinity (0–0.4% NaCl) which proved that inoculation with AM fungi lessens the deleterious effect of salt stress on seedling growth parameters under salt levels up to 0.5% NaCl (electrical conductivity of 7.2 dS m^{-1}). (Table 2).

Effect of AM fungal inoculation on the biochemical changes in Onion plant

Proline content in Onion leaves

Proline accumulation in response to salt stress is a good indicator of stress perception[22]. In this study, proline accumulation was maximum at harvest and was found to increase with increase in salinity and showed the highest at L3 (4.5 dSm^{-1}). The potential of compatible solutes to serve as selection criteria for salt tolerance has been reviewed by Ashraf and Harris[5] with the finding that, salinized crop plants may be able to produce osmotically active organic substances, which often accumulate in the cytoplasm to balance the vacuole solute potential. Also, relevant results given by Sannazzaro *et al*[42]., showed, under saline situations mycorrhized plants increased proline and polyamine levels in *L. glaber* roots which played an important role in regulation of root development. These results suggest that modulation of polyamine pools can be one of the mechanisms used by the AM fungi to improve crop adaptation to saline soils. (Table 3).

Acid & Alkaline phosphatase activity

The correlation between phosphatase enzyme activity and the mycelial growth of AM fungus was studied by Ingrid *et al*[25]., who reported that the alkaline phosphatase activity was found to increase with mycorrhizal treatments. In the present investigation, mycorrhizal inoculations significantly influenced the biochemical changes in the rhizosphere of onion when compared to control. Acid phosphatase activities were highest in *G. intraradices* followed by, TRY 3 and *S. calospora* (Table 4a). Similar trend was noticed in case of acid phosphatase activity in soil (Table 4b) also where, maximum activity was observed at 45 DAS in the treatments *G. intraradices* followed by *S. calospora* (118.4 and 99.2 percent increase over control respectively). The Alkaline phosphatase activity in the roots was noticed maximum at L1 (1.5 dSm^{-1}) than at higher levels of salt. Throughout the growth period, T1 (*G. intraradices*) followed by T2 (*S. calospora*) registered remarkable performance with 118.4 and 89.4 per cent increase over control respectively. The increased concentration of acid phosphatases in AM plants were reported earlier[14] and was attributed to the direct fungal secretion or an induced secretion of enzymes by the plants[45]. Increased fungal colonization in roots could have lead to more hyphal production which might have resulted in enhanced activity of phosphatases in mycorrhizal plants than poorly colonized control plants (Table 5).

Dehydrogenase activity

The activity of the enzyme dehydrogenase in an organism or tissue serves as an index of metabolic activity. The dehydrogenase activity in the rhizosphere soil of Onion (Table 6a,b) showed a significant increase at 45 DAS, where the treatment T2 (*S. calospora*) registered the maximum followed by T5 (TRY 3) followed by *G. intraradices*. At all the three stage of observations, it was interesting to note that the though the enzyme activities were maximum at L1 than at L3, the performance of treatments over control were maximum only at L3 (4.5 dSm^{-1}) which remarked the response of mycorrhizal plants being directly proportional to the level of stress. These suggested the upshot of AMF plants during stress conditions which could have therefore triggered up many dehydrogenases. Increased activity might have been resulted also due to the indirect influence of AM fungi on enhancing the rhizosphere microorganisms since, these soil enzymes function as a measurement of the metabolic state of soil microorganisms by relating it to the presence of viable microorganisms and their oxidative capacity[34].

Defense enzyme activities in roots of Onion

The activity of peroxidase, polyphenol oxidase, catalase and superoxide dismutase enzymes were analysed to study the tolerance of mycorrhizal plants against the oxidative stress.

Peroxidases (POX) have been implicated in a number of physiological functions that may contribute to resistance including exudation of hydroxyl cinnamyl alcohol into free radical intermediates, phenol oxidation, polysaccharide cross linking, cross linking of extension monomers, lignification[47] and also correlated with deposition of phenolic materials into plant cell wall during resistant interactions[23]. In the present study, POX activity was found to increase with increase in salinity where, T1 (*G. intraradices*) marked the maximum activity (1.26, 1.40 and 1.66 changes in absorbance min^{-1} g^{-1} of fresh root tissue at L1, L2 and L3 respectively) at 45 DAS with 2.3 per cent increase over control. Corroborative results were observed from Garg and Manchanda[19] who reported increased levels of POX activity at 4 and 6 dSm^{-1} where, it was 3-6 per cent higher in uninoculated plants and showed that POX could be involved in mycorrhizal mediated enhancement of nodular activity in roots of pigeon pea under salinity. These support the inference from the present work that, indirect effect of POX induction on influencing the root growth in Onion (Table 7).

Same trend of increase in activity along with increasing levels of salt was found in the case of polyphenol oxidase (PPO) also in the present study and these results were in line with Ghorbanli *et al*[21]., who demonstrated that under salinity, mycorrhizal roots had relatively higher PPO activity than non-mycorrhizal roots and a relative significant increase in PPO activity was observed at the highest level of stress (150 mM NaCl). Previous studies by Mathur and Vyas[32] which showed an increase in total POX and PPO activities in mycorrhizal plants also supports the results of the present study(Table 8).

Superoxide dis mutase (SOD)

The activity of SOD was found to be increased with increase in salinity levels in all the three stages of observation (Table 31). These enzymes are grouped as Active Oxygen Species (AOS) - the detoxifying enzymes and their production is associated with biotic and abiotic stress factors. The increased SOD activity with increase in salinity recorded in present study is in accordance with the conclusion drawn by Garg and Manchanda[19] who, reported significant SOD activity (1.4 and 2 times higher) in mycorrhizal plants at 4 and 6 dSm^{-1} respectively, when compared to controls. These intricate antioxidant enzymes mediate scavenging of toxic ROS so as to protect cells from the oxidative damage and in addition, increased synthesis and accumulation of compatible osmolytes is another tolerance mechanism employed by plants for ameliorating the damaging impacts of salinity[1]. Compatible solutes that contribute to osmoregulation through maintaining the cell water content include free proline, glycine betaine (GB), sugars and amino acids[1]. Accumulating compatible solutes or ions while bringing efficient sequestration and compartmentation of deleterious ions into the less sensitive parts like vacuole or apoplast is an important trait that determines salt tolerance in plants[6] (Table 9).

Catalase (**CAT**)

In the present study, induction of CAT activity was comparatively higher in mycorrhizal plants by the treatments (Table 10). This offered a systemic resistance through peroxidative removal of H_2O_2 which was also due to response of the increased production of oxygen radicals formed under stress conditions. These observations indicate that certain mechanisms involved in host resistance are activated when the roots are colonized by AM fungi and the induced expression of these enzymes are one among those mechanism.

Catalase has been shown to have been found to increase under salt stress in soybean[12]. A decrease in CAT activity may cause increased peroxide levels during senescence[8]. Recent investigation by Garg and Manchanda[19] showed CAT activity increased with salinity in mycorrhizal plants in the nodules leading to better nodulation and nodule growth at higher salinities when compared to nonmycorrhizal plants. These concluded the resistance mechanism offered by this enzyme to plants experiencing stress conditions.

Histochemical studies

Onion plants were studied for morphological changes in this study by root microtome sectioning which showed, typical cell modifications in the cortex and the vascular bundle where, critical differences were observed between the treatments and the control at each level of stress. In the control plants, root sectioning showed cell enlargement in the cortex as well as in the vascular bundle cells. Elongation in cell size with increase in diameter and decrease in cell numbers were observed in the endodermis, where metaxylem cells also showed prominent increase in size. On comparison, the root samples from the treatments showed increase in number of cells with less diameter and lignification of the endodermis with thickening of the vascular cells (xylem and phloem). More number of thickened cells resulting in reduction in cell size, increase in vascular tissue and lignification due to lignin or suberin deposits found in the exodermis, endodermis and cell wall layers neighbouring the root cortex and medulla protect against dessication and cortex cell death[38]. Thickening of the epidermal cell wall in salinized plants may be the part of the salt tolerant mechanisms[46]. Such alteration in mycorrhizal roots at increased salt levels could have imparted tolerance to Onion plants. Also, there were differences in all the three levels of salt where, cell modifications were typically identifiable in low and medium stress than at high stress (Fig. 1).

AM fungal colonization

The percentage of colonization by AM fungus was analysed in Onion plant roots to determine symbiotic association of the inoculated AM fungal species at each level of stress. AM fungal inoculation significantly increased root colonization in the treatments while, decrease in colonization was observed with increase in salt levels with maximum colonization at L1. The colonization ranged from 30.7 to 43.3 per cent initially at 30 DAS, inclined at 45 DAS ranging from 55.3 to 81.7 per cent and finally declined at harvest showing 30.7 to 50.7 per cent. (Table 11).

Results of this study were consistent with previous reports for AM response in saline conditions[16] and at salt marshes[10]. Entry points of AM fungi per millimeter of colonized roots were observed when exchangeable Na in soil increased which is another evidence of AM fungus adaptability to colonize roots in the adverse soil. Furthermore, in colonized roots, higher requirement for carbohydrates by AM fungi induces higher soluble sugar accumulation in host root tissues, which enhances resistance to salt-induced osmotic stress in the mycorrhizal plant[17]. AM fungal treatments were found to enhance the root colonization and hyphal production which may be attributed to the enhanced phosphatase enzyme activity in the treatments where, a good positive correlation was observed between mycorrhizal colonization and phosphatase activity in roots.

Yield components

Bulb dry matter and Alkaloid content

In the present study, the dry matter content of the Onion bulbs were found to be increased with advancement in growth stage of the crop and an overall decrease was noticed with increase in salt levels (Table 12). At L1, the bulb dry matter was ranging the highest in *G. intraradices* (36.26 per cent) followed by L2 (32.70 per cent). Also, the alkaloid content declined with increase in salt levels in the treatments as well as control. Treatment with *G. intraradices* showed the highest of 0.51 per cent sulphur in Onion bulbs which was on par with *S. calospora* and TRY 3 (Table 13). Similar findings were obtained by Sayed and Verpoorte[43], on regulation of indole alkaloid biosynthesis Effect of mycorrhizal inoculations in promoting alkaloid content in tubers and roots of herbaceous plants were reported earlier by several workers[3]. Karthikeyan *et al*[28]., reported an increase in Ajmalicine content (alkaloid of *Catharanthus roseus*) in the AM fungal inoculated treatments when compared to the control plants.

Table 1. Effect of AM fungal isolates on total dry matter production in Onion against various levels of salinity

S.No	Treatments / Levels	Total Dry matter production (g plant $^{-1}$)												
		30 DAS			Mean	45 DAS			Mean	At harvest			Mean	Per cent increase over control
		L1	L2	L3		L1	L2	L3		L1	L2	L3		
1.	*G. intraradices*	5.46 (60.1)	5.09 (154.5)	3.58 (434.3)	4.71	13.16 (91.2)	10.81 (110.0)	9.43 (194.6)	11.13	25.25 (69.3)	22.90 (75.3)	20.32 (58.5)	22.82	349.3
2.	*S. calospora*	5.87 (72.1)	5.10 (155.0)	2.83 (322.3)	4.60	12.68 (84.3)	10.74 (108.5)	8.46 (164.3)	10.63	23.77 (59.4)	21.56 (65.0)	20.75 (61.8)	22.03	333.6
3.	TRY 1	4.20	3.01	1.93	3.05	9.26	7.51	5.40	7.39	19.54	18.52	16.54	18.20	258.3
4.	TRY 2	5.58 (63.6)	4.10 (105.0)	2.28 (240.2)	3.99	8.57	6.20	5.84	6.87	20.64	19.52	16.54	18.90	272.0
5.	TRY 3	5.50 (61.2)	4.46 (123.0)	3.55 (429.8)	4.50	10.76 (56.3)	9.35 (81.5)	8.36 (161.2)	9.49	22.65 (51.9)	21.26 (62.7)	19.54 (52.4)	21.15	316.3
6.	TFS 1	4.84	3.13	2.10	3.35	8.65	7.11	6.02	7.26	20.70	20.00	17.82	19.50	283.9
7.	Control	3.41	2.00	0.67	2.03	6.88	5.15	3.20	5.08	14.91	13.06	12.82	13.60	-
	Mean	4.98	3.84	2.41	3.74	9.99	8.12	6.67	8.26	21.07	19.54	17.76	19.46	
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**		**SEd**		**CD (0.05)**		
	T	0.07		0.15		0.14		0.29		0.16		0.34		
	L	0.04		0.10		0.09		0.19		0.11		0.22		
	T x L	0.13		0.26		0.25		0.51		0.29		0.59		

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 $dSm^{-1;}$ DAS – Days after sowing ;

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 2 . Effect of AM fungal isolates on mycorrhizal dependency in Onion against various levels of salinity

S. No	Treatments	Mycorrhizal dependency								
		30 DAS			45 DAS			At harvest		
	Levels	L1	L2	L3	L1	L2	L3	L1	L2	L3
1.	*G. intraradices*	37.55	60.71	81.28	47.72	52.36	66.07	40.95	42.97	36.91
2.	*S. calospora*	41.91	60.78	76.33	45.74	52.05	62.17	37.27	39.42	38.22
3.	TRY 1	18.81	33.55	65.28	25.70	31.42	40.74	23.69	29.48	22.50
4.	TRY 2	38.89	51.22	70.61	19.72	16.94	45.21	27.76	33.09	22.50
5.	TRY 3	38.00	55.16	81.13	36.06	44.92	61.72	34.17	38.57	34.40
6.	TFS 1	29.55	36.10	68.10	20.46	27.57	46.84	27.97	34.70	28.06
7.	Control	-	-	-	-	-	-	-	-	-

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1} DAS – Days after sowing

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 3. Effect of AM fungal isolates on proline content in Onion leaves against various levels of salinity

S.No	Treatments	Proline (µg g of leaf $^{-1}$)												
		30 DAS			Mean	45 DAS			Mean	At harvest			Mean	Per cent increase over control
	Levels	L1	L2	L3		L1	L2	L3		L1	L2	L3		
1.	*G. intraradices*	68.0 (223.8)	75.0 (240.0)	71.0 (163.0)	71.3	87.0 (123.0)	92.0 (124.3)	102.0 (104.0)	93.7	180.0 (50.0)	218.0 (51.3)	255.0 (59.3)	217.7	54.0
2.	*S. calospora*	60.0 (185.7)	61.0 (177.2	69.0 (155.5)	63.3	87.0 (123.0)	88.0 (114.6)	96.0 (92.0)	90.3	164.0	183.0 (27.08)	199.0 (24.3)	182.0	28.8
3.	TRY 1	33.0	37.0	38.0	36.0	70.0	77.0	78.0	75.0	157.0	178.0	190.0	175.0	23.8
4.	TRY 2	38.0	45.0	48.0	43.7	80.0	82.0	86.0	82.7	140.0	163.0	180.0	161.0	13.9
5.	TRY 3	50.0 (138.1)	52.0 (136.3)	56.0 (107.4)	52.7	88.0 (125.6)	95.0 (131.7)	100.0 (100.0)	94.3	177.0 (47.5)	193.0 (34.0)	203.0 (26.8)	191.0	35.2
6.	TFS 1	26.0	28.0	37.0	30.3	65.0	69.0	76.0	70.0	167.0 (39.1)	181.0	197.0	181.7	28.6
7.	Control	21.0	22.0	27.0	23.3	39.0	41.0	50.0	43.3	120.0	144.0	160.0	141.3	
	Mean	42.3	45.7	49.4	45.8	73.7	77.7	84.0	78.5	157.9	180.0	197.7	178.5	
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**		**SEd**		**CD (0.05)**		
	T	0.88		1.78		0.92		1.86		1.49		3.02		
	L	0.57		1.16		0.60		1.21		0.97		1.97		
	T x L	1.52		3.09		1.59		3.22		2.59		5.23		

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*

TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*

TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 4a . Effect of AM fungi on acid phosphatase activity in roots of Onion against various levels of salinity

S.No	Treatments / Levels	Acid Phosphatase (µg of PNPP released gram^{-1} of fresh root tissue)												
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	34.0 (126.6)	28.0 (133.3)	24.0 (118.2)	28.7	58.0 (190.0)	57.0 (256.2)	49.0 (308.3)	54.7	241.7	45.0 (200.0)	40.0 (263.6)	37.0 (270.0)	40.7
2.	*S. calospora*	34.0 (126.6)	27.0 (125.0)	21.0 (90.9)	27.3	54.0 (170.0)	50.0 (212.5)	46.0 (283.3)	50.0	212.5	49.0 (226.6)	40.0 (263.6)	35.0 (250)	41.3
3.	TRY 1	22.0	19.0	14.0	18.3	43.0	37.0	36.0	38.7	141.7	30.0	29.0	20.0	26.3
4.	TRY 2	30.0	26.0	20.0	25.3	49.0	45.0	42.0	45.3	183.3	35.0	33.0	32.0	33.3
5.	TRY 3	31.0 (106.6)	29.0 (158.3)	23.0 (181.8)	27.7	56.0 (180.0)	53.0 (231.2)	48.0 (300.0)	52.3	227.1	45.0 (200.0)	43.0 (291.0)	40.0 (300.0)	42.7
6.	TFS 1	21.0	16.0	13.0	16.7	47.0	41.0	39.0	42.3	164.6	34.0	29.0	28.0	30.3
7.	Control	15.0	12.0	11.0	12.7	20.0	16.0	12.0	16.0	-	15.0	11.0	10.0	12.0
	Mean	26.7	22.4	18.0	22.4	46.7	42.7	38.9	42.8		36.1	32.1	28.9	32.4
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.37		0.75		0.66		1.34			0.56		1.14	
	L	0.24		0.49		0.43		0.88			0.37		0.74	
	T x L	0.64		1.30		1.15		2.33			0.97		1.98	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing Values represent mean of three replicates;
Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 4b. Effect of AM fungal isolates on acid phosphatase activity in rhizosphere soil of Onion against various levels of salinity

S.No	Treatments Levels	Acid Phosphatase (µg of PNPP released gram^{-1} of soil)												
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	8.8 (238.4)	6.6 (312.5)	4.8 (300.0)	6.7	21.0 (50.0)	19.0 (171.4)	17.0 (240.0)	19.0	118.4	17.0 (70.0)	15.0 (66.6)	13.0 (116.6)	15.0
2.	*S. calospora*	8.6 (230.7)	5.4 (237.5)	3.6 (200.0)	5.9	20.0 (42.8)	17.0 (142.8)	15.0 (200.0)	17.3	99.2	18.0 (80.0)	14.0 (55.5)	13.0 (116.6)	15.0
3.	TRY 1	6.4	4.6	3.2	4.7	17.0	15.0	14.0	15.3	76.2	15.0	12.0	11.0	12.7
4.	TRY 2	6.0	2.4	2.0	3.5	19.0 (35.7)	16.0 (128.5)	15.0 (200.0)	16.7	91.6	15.0	13.0	12.0 (100.0)	13.3
5.	TRY 3	6.4	5.0	4.6 (283.3)	5.3	18.0	15.0	10.0	14.3	64.8	19.0 (90.0)	15.0 (66.6)	12.0	15.3
6.	TFS 1	6.8 (161.5)	5.2 (225.0)	3.4	5.1	15.0	8.0	7.0	10.0	14.9	12.0	14.0	10.0	12.0
7.	Control	2.6	1.6	1.2	**1.8**	14.0	7.0	5.0	**8.7**	-	10.0	9.0	6.0	**8.3**
	Mean	6.5	4.4	3.3	4.7	17.7	13.9	11.9	14.5		15.1	13.1	11.0	13.1
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.11		0.22		0.27		0.55			0.15		0.31	
	L	0.07		0.14		0.18		0.36			0.10		0.20	
	T x L	0.19		0.39		0.47		0.96			0.27		0.55	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1} DAS – Days after sowing

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*

TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*

TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 5 . Effect of AM fungal isolates on alkaline phosphatase activity in roots of Onion against various levels of salinity

S.No	Treatments	Alkaline Phosphatase (µg of PNPP released gram^{-1} of fresh root tissue)												
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	23.0 (155.5)	19.0 (171.4)	13.0 (160.0)	18.3	32.0 (100.0)	27.0 (125.0)	24.0 (140.0)	27.7	118.4	30.0 (233.3)	25.0 (257.1)	19.0 (216.6)	24.7
2.	*S. calospora*	21.0 (133.3)	16.0 (128.5)	12.0 (140.0)	16.3	30.0 (87.5)	24.0 (100.0)	18.0 (80.0)	24.0	89.4	29.0 (222.2)	24.0 (242.8)	18.0 (200)	23.7
3.	TRY 1	16.0	13.0	12.0	13.7	21.0	18.0	15.0	18.0	42.1	18.0	15.0	9.0	14.0
4.	TRY 2	19.0	16.0	15.0 (200.0)	16.7	27.0	23.0	20.0 (100.0)	23.3	84.2	20.0	14.0	11.0	15.0
5.	TRY 3	20.0 (122.2)	14.0 (100.0)	10.0	14.7	28.0 (75.0)	22.0 (83.3)	20.0 (100.0)	23.3	84.2	21.0 (133.3)	16.0 (128.5)	12.0 (100.0)	16.3
6.	TFS 1	14.0	13.0	11.0	12.7	19.0	16.0	15.0	16.7	31.5	16.0	14.0	13.0 (116.6)	14.3
7.	Control	9.0	7.0	5.0	7.0	16.0	12.0	10.0	12.7	-	9.0	7.0	6.0	**7.3**
	Mean	17.4	14.0	11.1	14.2	24.7	20.3	17.4	20.8		20.4	16.4	12.6	16.5
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.23		0.47		0.30		0.61			0.34		0.70	
	L	0.15		0.31		0.19		0.40			0.22		0.46	
	T x L	0.41		0.83		0.52		1.06			0.60		1.21	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 6a. Effect of AM fungal isolates on dehydrogenase activity in roots of Onion against various levels of salinity

S. No	Treatments	Dehydrogenase (µg of TPF released gram^{-1} of fresh root tissue)											
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	37.0 (270.0)	34.0 (325.0)	20.0 (300.0)	30.3	60.0 (130.7)	59.0 (195.0)	50.0 (233.3)	56.3	177.1	48.0 (182.3)	44.0 (214.2)	39.0 (200.0)	43.7
2.	*S. calospora*	33.0 (230.0)	25.0 (212.5)	19.0 (280.0)	25.7	61.0 (134.6)	54.0 (170.0)	51.0 (240.0)	55.3	172.2	45.0 (164.7)	40.0 (185.7)	34.0 (161.5)	39.7
3.	TRY 1	20.0	15.0	11.0	15.3	40.0	38.0	32.0	36.7	80.6	37.0	33.0	29.0	33.0
4.	TRY 2	15.0	13.0	10.0	12.7	45.0	43.0	39.0	42.3	108.5	37.0	30.0	28.0	31.7
5.	TRY 3	30.0 (200.0)	26.0 (225.0)	16.0 (220.0)	24.0	50.0 (92.3)	47.0 (135.0)	42.0 (180.0)	46.3	128.0	43.0 (153.0)	40.0 (185.7)	35.0 (169.2)	39.3
6.	TFS 1	17.0	15.0	13.0	15.0	38.0	35.0	31.0	34.7	70.5	36.0	31.0	28.0	31.7
7.	Control	10.0	8.0	5.0	7.7	26.0	20.0	15.0	20.3	-	17.0	14.0	13.0	14.7
	Mean	23.1	19.4	13.4	18.7	45.7	42.3	37.1	41.7		37.6	33.1	29.4	33.4
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.46		0.94		0.65		1.31			0.50		1.01	
	L	0.30		0.61		0.42		0.86			0.32		0.66	
	T x L	0.80		1.63		1.12		2.27			0.86		1.75	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control
G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 6b. Effect of AM fungal isolates on dehydrogenase activity in rhizosphere soil of Onion against various levels of salinity

S.No	Treatments	Dehydrogenase (µg of TPF released gram^{-1} of soil)												
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
	Levels	L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	3.8 (216.6)	2.6 (225.0)	1.9 (280.0)	2.8	54.0 (217.6)	42.0 (223.0)	37.0 (236.3)	44.3	223.6	42.0 (180.0)	39.0 (254.5)	35.0 (250.0)	38.7
2.	*S. calospora*	2.9 (141.6)	2.4 (200.0)	2.0 (300.0)	2.4	50.0 (194.1)	49.0 (277.0)	39.0 (254.5)	46.0	235.8	40.0 (166.6)	38.0 (245.4)	36.0 (260.0)	38.0
3.	TRY 1	2.0	1.9	1.5	1.8	39.0	35.0	31.0	35.0	155.5	36.0	31.0	30.0	32.3
4.	TRY 2	1.8	1.6	1.4	1.6	47.0	40.0	36.0	41.0	199.3	37.0	36.0 (227.2)	31.0	34.7
5.	TRY 3	2.2 (83.3)	2.5 (212.5)	1.7 (240.0)	2.1	48.0 (182.3)	47.0 (261.5)	42.0 (281.8)	45.7	233.3	40.0 (166.6)	36.0 (227.2)	35.0 (250.0)	37.0
6.	TFS 1	2.0	1.8	1.4	1.7	38.0	32.0	31.0	33.7	145.7	28.0	24.0	22.0	24.7
7.	Control	1.2	0.8	0.5	0.8	17.0	13.0	11.0	13.7	-	15.0	11.0	10.0	12.0
	Mean	2.3	1.9	1.5	1.9	41.9	36.9	32.4	37.0		34.0	30.7	28.4	31.0
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.03		0.07		0.60		1.22			0.49		0.99	
	L	0.02		0.04		0.39		0.80			0.32		0.65	
	T x L	0.06		0.13		1.05		2.12			0.85		1.72	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1} DAS – Days after sowing

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*

TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*

TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 7. Effect of AM fungal isolates on peroxidase activity in roots of Onion against various levels of salinity

S.No	Treatments	Peroxidase (Changes in absorbance min^{-1} g^{-1} of fresh root tissue)											
		10 DAS			Mean	20 DAS			Mean	Per cent increase over control	30 DAS			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	0.90 (52.5)	0.95 (43.9)	1.02 (52.2)	0.96	1.26 (13.5)	1.40 (21.7)	1.66 (30.7)	1.44	22.3	0.27 (92.8)	0.43 (115.0)	0.65 (103.1)	0.45
2.	*S. calospora*	0.88 (49.1)	0.94 (42.4)	0.97 (44.7)	0.93	1.30 (17.1)	1.40 (20.8)	1.53 (20.4)	1.41	19.2	0.22 (57.1)	0.50 (150.0)	0.67 (109.3)	0.46
3.	TRY 1	0.79	0.82	0.82	0.81	1.21	1.27	1.32	1.27	7.3	0.19	0.34	0.53	0.35
4.	TRY 2	0.81	0.84	0.84	0.83	1.24	1.34	1.39	1.33	12.7	0.19	0.38	0.58	0.38
5.	TRY 3	0.82 (39.0)	0.85 (28.8)	0.88 (31.3)	0.85	1.26 (13.5)	1.36 (18.2)	1.39 (9.45)	1.33	12.7	0.22	0.44 (120.0)	0.65 (103.1)	0.44
6.	TFS 1	0.78	0.80	0.82	0.80	1.17	1.28	1.34	1.26	7.1	0.23 (64.3)	0.31	0.55	0.36
7.	Control	0.59	0.66	0.67	0.64	1.11	1.15	1.27	1.18	-	0.14	0.20	0.32	0.22
	Mean	0.80	0.84	0.86	0.83	1.22	1.31	1.41	1.32		0.21	0.37	0.56	0.38
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.005		0.010		0.006		0.012			0.008		0.017	
	L	0.003		0.006		0.004		0.008			0.005		0.011	
	T x L	0.009		0.018		0.010		0.021			0.015		0.030	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 8. Effect of AM fungal isolates on polyphenol oxidase activity in roots of Onion against various levels of salinity

S.No	Treatments	Polyphenol oxidase (Changes in absorbance min^{-1} g^{-1} of fresh root tissue)												
		10 DAS			Mean	20 DAS			Mean	Per cent increase over control	30 DAS			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	0.063 (110.0)	0.087 (148.5)	0.096 (92.0)	0.082	0.173 (92.2)	0.192 (58.6)	0.214 (59.7)	0.193	67.8	0.025 (92.3)	0.032 (60.0)	0.050 (92.3)	0.036
2.	*S. calospora*	0.071 (136.6)	0.090 (157.1)	0.092 (84.0)	0.084	0.175 (94.4)	0.198 (63.6)	0.220 (64.1)	0.198	71.9	0.025 (92.3)	0.030 (50.0)	0.054 (107.7)	0.036
3.	TRY 1	0.052	0.075	0.083	0.070	0.155	0.167	0.195 (45.5)	0.172	49.9	0.018	0.027	0.035	0.027
4.	TRY 2	0.048	0.085	0.090	0.074	0.144	0.152	0.185	0.160	39.4	0.016	0.025	0.042	0.028
5.	TRY 3	0.055 (83.3)	0.095 (171.4)	0.102 (104.0)	0.084	0.160 (77.7)	0.172 (42.1)	0.195 (45.5)	0.176	52.8	0.026 (100.0)	0.030 (50.0)	0.043 (65.3)	0.033
6.	TFS 1	0.047	0.078	0.084	0.069	0.140	0.155	0.176	0.157	36.5	0.020	0.026	0.037	0.028
7.	Control	0.030	0.035	0.049	0.038	0.090	0.121	0.134	0.115	-	0.013	0.020	0.026	0.020
	Mean	0.052	0.078	0.085	0.071	0.148	0.165	0.188	0.167		0.020	0.027	0.041	0.030
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.0011		0.0023		0.001		0.003			0.0006		0.0012	
	L	0.0007		0.0015		0.001		0.002			0.0003		0.0007	
	T x L	0.0019		0.0040		0.002		0.005			0.0010		0.0021	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*

TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*

TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 9. Effect of AM fungal isolates on super oxide dismutase activity in roots of Onion against various levels of salinity

S.No	Treatments	Super oxide dismutase (enzyme units mg $^{-1}$ protein)												
		10 DAS			Mean	20 DAS			Mean	Per cent increase over control	30 DAS			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	66.40 (54.0)	79.30 (56.1)	82.10 (50.6)	75.9	85.70 (64.4)	92.40 (65.0)	98.20 (63.3)	92.1	64.2	70.70 (46.3)	80.50 (57.8)	87.60 (50.7)	79.6
2.	*S. calospora*	67.00 (55.4)	77.00 (51.5)	81.10 (48.8)	75.0	88.50 (69.8)	90.50 (61.6)	94.30 (56.9)	91.1	62.4	72.30	84.40 (65.4)	90.10 (55.0)	82.3
3.	TRY 1	63.30	69.30	72.10	68.2	68.80	74.50	78.70	74.0	31.9	63.90	71.50	73.00	69.5
4.	TRY 2	69.40 (61.0)	75.90	78.20	74.5	77.70	82.20	87.70	82.5	47.1	73.20 (51.5)	79.60	80.40	77.7
5.	TRY 3	65.20	78.50 (54.5)	80.90 (48.4)	74.9	82.40 (58.1)	89.40 (59.6)	96.60 (60.7)	89.5	59.5	69.60 (44.1)	81.80 (60.3)	84.80 (46.0)	78.7
6.	TFS 1	55.30	61.90	65.60	60.9	67.30	68.70	71.20	69.1	23.1	61.50	64.10	68.20	64.6
7.	Control	43.10	50.80	54.50	**49.5**	52.10	56.00	60.10	**56.1**	-	48.30	51.00	58.10	**52.5**
	Mean	61.4	70.4	73.5	68.4	74.6	79.1	83.8	79.2		65.6	73.3	77.5	72.1
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.56		1.14		0.69		1.40			0.59		1.20	
	L	0.36		0.74		0.45		0.92			0.39		0.78	
	T x L	0.97		1.97		1.20		2.43			1.03		2.08	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1} DAS – Days after sowing

Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*

TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*

TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 10 . Effect of AM fungal isolates on catalase activity in roots of Onion against various levels of salinity

S. No	Treatments	Catalase (H_2O_2 µg g^{-1} min^{-1})											
		10 DAS			Mean	20 DAS			Mean	Per cent increase over control	30 DAS			Mean
		L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	0.49 (390.0)	0.52 (246.6)	0.60 (275.0)	0.5	0.70 (400.0)	0.77 (250.0)	0.95 (216.6)	0.8	303.3	0.35 (483.3)	0.41 (241.6)	0.56 (273.3)	0.4
2.	*S. calospora*	0.34 (240.0)	0.48 (220.0)	0.56 (250.0)	0.5	0.52 (271.4)	0.69 (213.6)	0.80 (166.6)	0.7	235.0	0.33	0.39	0.51	0.4
3.	TRY 1	0.31	0.42 (180.0)	0.45	0.4	0.44	0.52	0.69	0.6	175.0	0.29	0.27	0.51	0.4
4.	TRY 2	0.30	0.39	0.53	0.4	0.48	0.66	0.86	0.7	233.3	0.35 (483.3)	0.36 (200.0)	0.55 (266.6)	0.4
5.	TRY 3	0.33 (230.0)	0.42 (180.0)	0.58 (262.5)	0.4	0.54 (285.7)	0.70 (218.1)	0.91 (203.3)	0.7	258.3	0.40 (566.6)	0.44 (266.6)	0.63 (320.0))	0.5
6.	TFS 1	0.25	0.36	0.41	0.3	0.37	0.47	0.55	0.5	131.7	0.11	0.21	0.26	0.2
7.	Control	0.10	0.15	0.16	0.1	0.14	0.22	0.30	0.2	-	0.06	0.12	0.15	0.1
	Mean	0.3	0.4	0.5	0.4	0.5	0.6	0.7	0.6		0.3	0.3	0.5	0.3
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.007		0.014		0.012		0.024			0.008		0.017	
	L	0.004		0.009		0.007		0.016			0.005		0.011	
	T x L	0.012		0.025		0.021		0.042			0.014		0.029	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1} ; DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 11 . Effect of AM fungal isolates on root colonization in Onion against various levels of salinity

S.No	Treatments	Root colonization (%)												
		30 DAS			Mean	45 DAS			Mean	Per cent increase over control	At harvest			Mean
	Levels	L1	L2	L3		L1	L2	L3			L1	L2	L3	
1.	*G. intraradices*	50.0 (400.0)	45.0 (462.5)	35.0 (600.0)	43.3	89.0 (493.3)	85.0 (750.0)	82.0 (811.1)	85.3	655.2	63.0 (320.0)	49.0 (444.4)	47.0 (422.2)	53.0
2.	*Scutellospora* sp.	45.0 (350.0)	43.0 (437.5)	30.0 (500.0)	39.3	88.0 (486.6)	85.0 (750.0)	77.0 (755.5)	83.3	637.5	62.0 (313.3)	51.0 (466.6)	39.0 (333.3)	50.7
3.	TRY 1	39.0	35.0	20.0	31.3	66.0	60.0	54.0	60.0	431.0	42.0	35.0	26.0	34.3
4.	TRY 2	35.0	32.0	26.0	31.0	83.0	75.0	70.0	76.0	572.6	42.0	40.0	31.0	37.7
5.	TRY 3	45.0 (350.0)	39.0 (387.5)	30.0 (500.0)	38.0	90.0 (500.0)	80.0 (700.0)	75.0 (733.3)	81.7	622.7	60.0 (300.0)	47.0 (422.2)	32.0 (255.5)	46.3
6.	TFS 1	36.0	31.0	25.0	30.7	62.0	54.0	50.0	55.3	389.7	38.0	32.0	22.0	30.7
7.	Control	10.0	8.0	5.0	7.7	15.0	10.0	9.0	11.3	-	15.0	9.0	9.0	11.0
	Mean	37.1	33.3	24.4	31.6	70.4	64.1	59.6	64.7		46.0	37.6	29.4	37.7
		SEd		**CD (0.05)**		**SEd**		**CD (0.05)**			**SEd**		**CD (0.05)**	
	T	0.64		1.30		1.31		2.66			0.81		1.64	
	L	0.42		0.85		0.86		1.74			0.53		1.07	
	T x L	1.12		2.26		2.28		4.60			1.40		2.84	

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}; DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Table 12. Effect of AM fungal isolates on bulb dry matter in Onion against various levels of salinity

S.No	Treatments	Bulb dry matter (%)									
		45 DAS			Mean	Per cent increase over control	At harvest			Mean	Per cent increase over control
	Levels	L1	L2	L3			L1	L2	L3		
1.	*G. intraradices*	36.26 (22.0)	32.70 (44.0)	24.14 (59.3)	31.03	37.8	44.47 (43.6)	35.70 (50.6)	26.70 (35.0)	35.62	43.6
2.	*Scutellospora* sp.	35.70 (20.2)	30.83 (35.8)	25.38 (67.5)	30.64	36.0	42.83 (38.3)	33.83 (42.7)	26.10 (32.0)	34.25	38.1
3.	TRY 1	32.68	28.60	19.21	26.83	19.1	39.15	32.52	22.46	31.38	26.5
4.	TRY 2	31.80	30.23	20.05	27.36	21.5	41.00 (32.4)	31.83 (34.3)	25.53 (29.1)	32.78	32.1
5.	TRY 3	34.70 (16.8)	29.68 (30.7)	20.65 (36.3)	28.34	25.8	39.18	30.05	25.16	31.46	26.8
6.	TFS 1 (*Glomus* sp.)	30.26	27.60	19.83	25.89	15.0	36.43	30.60	22.09	29.71	19.7
7.	Control	29.70	22.71	15.15	22.52	-	30.95	23.70	19.77	24.81	-
	Mean	33.01	28.91	20.63	27.52		39.14	31.18	23.97	31.43	
		SEd		**CD (0.05)**			**SEd**		**CD (0.05)**		
	T	0.31		0.62			0.37		0.76		
	L	0.20		0.41			0.24		0.49		
	T x L	0.53		1.08			0.65		1.31		

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}, DAS – Days after sowing
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

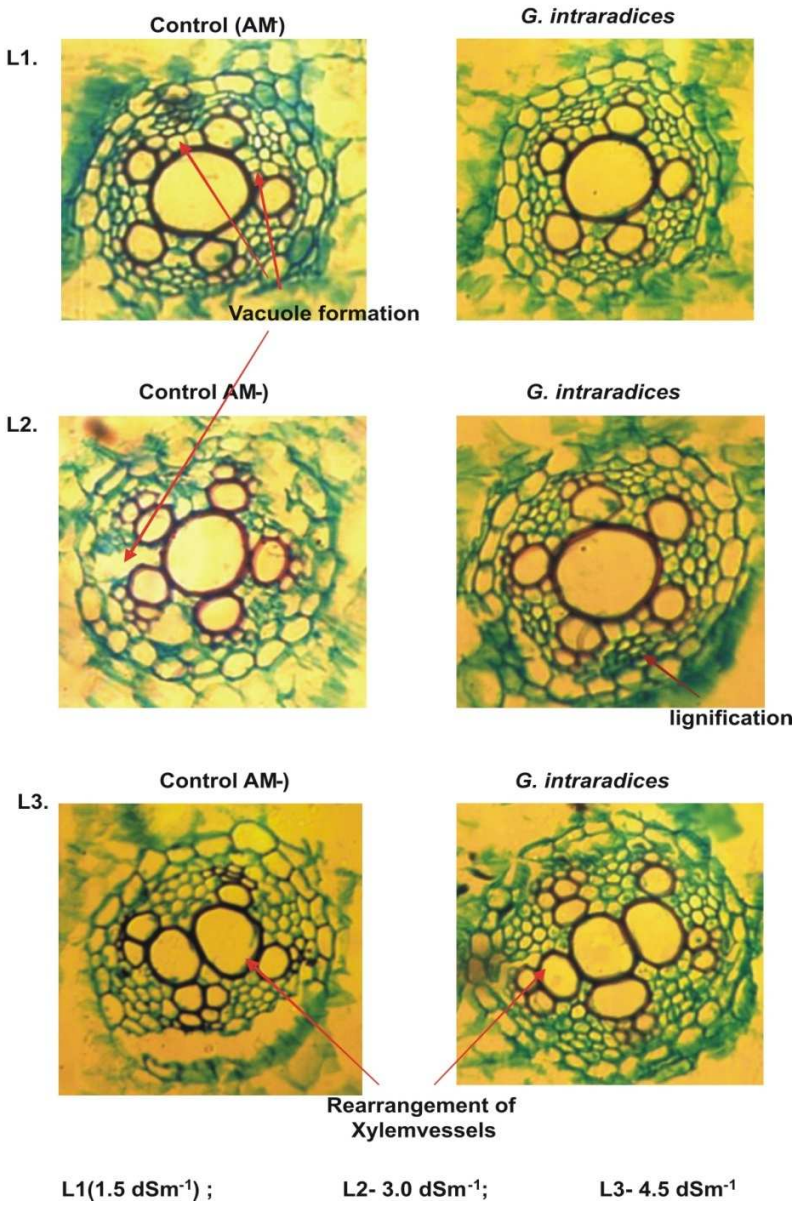
Table 13. Effect of AM fungal isolates on alkaloid content (%) in bulbs of Onion against various levels of salinity

S.No	Treatments	Alkaloid content (%)									
		45 DAS			Mean	Per cent increase over control	At harvest			Mean	Per cent increase over control
		L1	L2	L3			L1	L2	L3		
1.	*G. intraradices*	0.468 (33.7)	0.384 (13.9)	0.366 (33.5)	0.41	26.9	0.585 (19.4)	0.506 (14.4)	0.434 (17.3)	0.51	18.2
2.	*S. calospora*	0.455 (30.0)	0.380 (12.7)	0.353 (28.8)	0.40	23.8	0.581 (18.5)	0.508 (14.9)	0.427 (15.4)	0.51	17.5
3.	TRY 1	0.405	0.356	0.305	0.36	11.0	0.554	0.494	0.415	0.49	13.4
4.	TRY 2	0.425	0.356	0.325	0.37	15.2	0.563	0.493	0.423	0.49	14.7
5.	TRY 3	0.448 (28.0)	0.380 (12.7)	0.337 (23.0)	0.39	21.4	0.573 (16.9)	0.500 (13.1)	0.424 (14.6)	0.50	16.0
6.	TFS 1	0.396	0.366	0.316	0.36	12.3	0.544	0.493	0.416	0.48	12.6
7.	Control	0.350	0.337	0.274	0.32	-	0.490	0.442	0.370	0.43	-
	Mean	0.42	0.37	0.33	0.37		0.56	0.49	0.42	0.49	
		SEd		**CD (0.05)**			**SEd**		**CD (0.05)**		
	T	0.002		0.005			0.003		0.006		
	L	0.001		0.003			0.002		0.004		
	T x L	0.004		0.008			0.005		0.011		

L1 – 1.5 dSm^{-1}; L2 - 3.0 dSm^{-1}; L3 – 4.5 dSm^{-1}, DAS – Days after sowing,
Values represent mean of three replicates; Value in parenthesis indicate per cent increase over control

G. intraradices - *Glomus intraradices* *S. calospora* - *Scutellospora calospora*
TRY 1- *Acaulospora* sp TRY 3- *Glomus mosseae*
TRY 2- *Scutellospora* sp. TFS 1- *Glomus aggregatum*

Fig. 1. Microtome sectioning of onion roots (AM^+ & AM^-) grown at various levels of salinity at 45 DAS (40X)



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