

Chapter 2

The Role of Arbuscular Mycorrhizal Fungi in Alleviation of Salt Stress

Arafat Abdel Hamed Abdel Latef and Mohammad Miransari

Introduction

Soil salinity is a major abiotic stress adversely affecting plant growth and crop production worldwide. Increased salinization of arable land is expected to have destructive universal effects, resulting in 30 % land loss within the next 25 years and up to 50 % by the middle of twenty-first century (Porcel et al. 2012; Kapoor et al. 2013; Abdel Latef and Chaoxing 2014). The term “salinity” refers to the accumulation of excessive salts, in the sodic (or alkaline) and saline soils.

Sodic soils having a poor soil structure generally are found over arid and semi-arid regions, with high concentrations of Na^+ at the exchangeable site of clay particles in the soil. Accordingly, the soil would have a great pH (greater than 8.5) with a high exchangeable sodium percentage (ESP >15). Saline soils can be generally found in arid regions, estuaries, and coastal fringes. Such kind of soils are dominated by Na^+ ions with electrical conductivity (EC) more than 4 dS/m corresponding to the approximate concentration of 40 mM NaCl.

Moreover, saline soils exhibit ESP of <15 and much lower pH values than the sodic soils (Horie et al. 2012). According to the potential of plants to grow on high salt medium, plants are glycophytes or halophytes. Most plants are glycophytes and are not tolerant to salt stress. The early signs of salinity in plants are:

- (1) Poor germination and establishment.
- (2) Leaf scorching or mottling and shedding.
- (3) Cuticle fragmentation and cell membrane injury increases solutes leakage.

A. A. H. Abdel Latef (✉)

Department of Botany, Faculty of Science, South Valley University,
Qena 83523, Egypt
e-mail: moawad76@gmail.com

M. Miransari

Department of Book and Article, AbtinBerkeh Limited Co, Malek Ave.,
Nazer Alley, #37, Isfahan, Iran
e-mail: Info@AbtinBerkeh.com; Miransari1@gmail.com

- (4) Inhibited vegetative growth of glycophytes as shoot growth decreases more than root growth.
- (5) In glycophytes, salt-induced inhibition of plant growth is accompanied by metabolic dysfunction including decreased photosynthetic rate and changes in enzymatic activity.
- (6) In halophytes, physiological processes may not be altered by salt concentrations that are inhibitory to glycophytes.
- (7) Salinity decreases the production of carbohydrate or growth hormones thereby inhibiting growth.
- (8) High salt concentrations may adversely affect the activity of enzymes by influencing the protein structure.
- (9) Salinity negatively affects plant nutritional balance (Sairam and Tyagi 2004).

Microorganisms such as AM fungi are able to inoculate plants, in their natural environment. Some microorganisms, particularly beneficial bacteria and fungi can improve plant performance under stress environments and, consequently, enhance yield (Evelin et al. 2009). AM fungi are associated with the roots of over 80 % terrestrial plant species (Smith and Read 2008).

AM fungi have been shown to promote plant growth and salinity tolerance by many researchers. They promote salinity tolerance by utilizing various mechanisms, such as (a) enhancing nutrient uptake (Evelin et al. 2012); (b) producing plant growth hormones; (c) improving rhizospheric and soil conditions (Asghari et al. 2005); (d) improvement in photosynthetic activity or water use efficiency (Hajibolani et al. 2010); (e) accumulation of compatible solutes (Evelin et al. 2013); and (f) production of higher antioxidant enzymes (Manchanda and Garg 2011). As a result, AM fungi are considered suitable for bioamelioration of saline soils.

This chapter will cover the taxonomy, occurrence, and benefits of AM symbionts on the growth of plant as well as the effect of salinity on the fungal growth: colonization, hyphal length, and sporulation. It will also cover the alleviation of salt stress by AM fungi and its beneficial effects on growth, nutrient uptake, and biochemical and physiological mechanisms used by host plants to alleviate salt stress.

Arbuscular Mycorrhizal Fungi

Taxonomy

In Indian pipe (*Monotropa hypopitys* L.), Franciszek Kamiński in 1881 discovered a mutualistic association of fungus and roots. Farnk in 1885 named the symbiotic process between the fungi and roots by Greek word “Mykorrhizen”, meaning “Myco-rhiza (fungus-root)”. Amongst the mycorrhizal associations, the AM association is the most common one (Sjöberg 2005; Tahat and Sijam 2012).

AM fungi belong to the fungal phylum Glomeromycota (Schüßler et al. 2001) with four orders, eight families, and ten genera. The genera, which include most of the described species are *Acaulospora*, *Gigaspora*, *Glomus* and *Scutellospora* (Schüßler 2005). Usually the AM fungi form a symbiotic association with vascular plants as their hosts and hence obtain their required energy; the fungi, may also inoculate the roots of nonvascular plants (Russell and Bulman 2005; Sjöberg 2005).

The AM fungi are named according to their formation of highly branched intracellular fungal structures or “arbuscules,” which are the site of phosphate exchange between the fungus and the host plant. Vesicles, containing lipids, are highly vacuolated with carbon storage structures, and are usually formed in most genera of Glomeromycota, depending on the environmental conditions (Smith and Read 2008).

Occurrence

More than 80 % of vascular plant families are able to form mycorrhizal symbiosis with a wide distribution on the earth. They are found in all continents; Africa (Redhead 1977), Antarctica (Cabello et al. 1994), Asia (Ganesan et al. 1991), Oceanien (Hall 1977), North America (Dalpé and Aiken 1998), South America (Caproni et al. 2003), as well as Europe (Jansa et al. 2002).

AM fungal colonization of plants has been observed over a wide range of soil pH (Read et al. 1976), at different levels of soil phosphate (Jeffries et al. 1988) and salinity (Gerdemann 1968). There are, however, significant differences related to the distribution and abundance of AM species and strains fungi in response to soil properties (Sjöberg 2005).

Benefits of Mycorrhizal Symbiosis

In a mutualistic beneficial symbiosis, both symbionts (microbes and host plant) can benefit from each other. Carbon from the photosynthesis is used by the fungi and the plant utilizes the higher volume of the soil. The AM fungi take up a significant fraction of all plant photosynthetically fixed carbon (Paul and Kucey 1981; Sjöberg 2005; Xie et al. 2014).

The source of carbon used by the fungus is hexose from the roots (Solaiman and Saito 1997), but it is stored primarily as triacylglycerol (Gaspar et al. 1994), but also as glycogen (Bago et al. 2003). The available lipid can be placed from the intraradical mycelium to the extraradical mycelium, although there is also substantial recirculation throughout the fungus (Bago et al. 2002).

The mycorrhizal plant can also obtain different nutrients such as inorganic phosphate via the AM fungal hyphae. The inorganic phosphate is relatively immobile in the soil solution, which leads to the formation of zones depleted in inorganic P around the roots. These depletion zones effectively limit P uptake in

nonmycorrhizal plants. Mycorrhizal plant is able to access P beyond the depletion zone by the extraradical fungal hyphae, in addition to the uptake of roots (Pearson and Jakobsen 1993; Sjöberg 2005).

AM fungi also contribute to the uptake of micronutrients, such as zinc and the macronutrient N, both inorganic and possibly organic by the host plant (Thompson 1990; Hodge et al. 2001; Miransari 2011a). In addition to the uptake of nutrients, the extraradical mycelium is also able to release substances that cause the soil and its organic components to aggregate (Bearden and Petersen 2000).

Mycorrhizal fungi can also enhance plant tolerance under different stresses such as drought (Miransari 2010) and reduce damage caused by plant pathogens (Whipps 2004). Hormonal changes throughout the entire plant, under the influence of the symbiosis, have also been described (Allen et al. 1982; Miransari et al. 2014). Under some circumstances, AM fungi are able to decrease negative effects of heavy metals in plants (Abdel Latef 2011a, 2013; Miransari 2011b).

Effect of Salt Stress on AM Fungi

Salinity can adversely affect the colonization capacity of the fungi, the germination of spores, and the growth of fungal hyphae. The colonization capacity of plant roots by some AM fungi decreases with increasing NaCl level, indicating that salinity has negative effects on the growth of AM fungi. It has been reported that the addition of various salts to soil inhibits hyphal growth with a subsequent decrease in the spread of mycorrhizal hyphal network (Abdel Latef and Chaoxing 2011, 2014). In the presence of NaCl, germination of spores is delayed rather than being prevented (Juniper and Abbott 2006; Hajiboland 2013).

Salt type can affect the rate of spore germination. According to Juniper and Abbott (1993), although different salts such as NaNO₃ and Na₂SO₄ have similar osmotic potentials, their effects on the rate and maximum germination of spores differ. They indicated that such a difference can be due to a higher concentration of Na⁺ in the latter.

Effects of AM Fungi on the Growth of Salt-Stressed Plants

Plant growth decreases under salt stress due to (a) the expenditure of energy to avoid the toxic effects of NaCl and (b) nonavailability of nutrients. On the other hand, mycorrhization was found to enhance the efficiency of the host plants by increasing their growth. For example, Abdel Latef and Chaoxing (2011, 2014) have recently reported that although salt stress reduced dry matter production of tomato and pepper plants, respectively, in all treatments mycorrhizal plants grew better than nonmycorrhizal plants.

Effect of AM Fungi on Nutrient Uptake of Salt-Stressed Plants

Different studies have indicated the effect of salt stress on the nutrient uptake of mycorrhizal plants, according to the following details.

Nitrogen (N)

Nitrogen is the mineral element that plants require in a great amount. It serves as an important part of many plant cell components, including amino acids and nucleic acids. N deficiency in a plant tissue rapidly inhibits plant growth, and induces chlorosis in leaves. Salinity adversely influences N acquisition and utilization by affecting different stages of N metabolism, such as NO_3^- uptake and reduction and protein synthesis (Frechill et al. 2001; Evelin et al. 2009).

Application of AM fungi can result in a more efficient assimilation of N in the host plants, due to the following: (a) nitrate assimilation in the extra radical mycelia through the activity of nitrate reductase located in the arbuscular-containing cells leading to the formation of arginine, which catabolizes and produces other substances of ammonia; (b) increased production of enzymes controlling the primary nitrogen fixation in the extra-radical mycelia, whereas enzymes controlling arginine catabolism are upregulated in the intra-radical mycelia; (c) decreasing the toxic effects of Na ions by deducing its uptake and this may indirectly help in maintaining the chlorophyll content of the plant (Evelin et al. 2009, 2012; Kapoor et al. 2013).

Phosphorus (P)

Phosphorus is an essential macronutrient and forms an integral component of several key plant structures in plant cells, including the sugar-phosphate intermediates of respiration and photosynthesis, and the phospholipids that make up the plant membranes. Under salinity stress, the uptake and concentration of P in plant tissues decreases resulting in reduced and stunted growth, dark green coloration of the leaves, production of slender stems, and senescence of older leaves (Evelin et al. 2012).

Improved P uptake by AM fungus in plants grown under saline conditions may contribute to the integrity maintenance of vacuolar membrane and facilitate the Na^+ ions compartmentalization within vacuoles. This prevents Na^+ ions from interfering in metabolic pathways of growth, thereby reducing the negative impacts of salinity (Cantrell and Linderman 2001). Improved P nutrition in AM-inoculated plants may improve their growth rate, increase antioxidant production, and enhance nodulation and nitrogen fixation in legumes (Garg and Manchanda 2008; Kapoor et al. 2013).

Potassium (K) and Sodium (Na)

Potassium plays a key role in plant metabolism. It is essential for (1) activating a range of enzymatic reactions such as during the formation of pyruvate, (2) stomatal activities, (3) protein synthesis at the time of tRNA binding to the ribosomes (Blaha et al. 2000), and (4) maintaining osmotic pressure of the vacuole and cell turgor (Maathuis 2009; Evelin et al. 2012).

Elevated Na^+ in the soil solution inhibits the uptake of other nutrients by interfering with various transporters in the root plasma membrane, such as K^+ -selective ion channels, and inhibiting root growth by the adverse effects of Na^+ on soil structure (Porcel et al. 2012). Salinity stress reduced the level of K^+ as an antagonist of Na^+ . Since Na^+ and K^+ have similar physiological properties, therefore cytoplasmic Na^+ competes for the similar binding sites and hence inhibits the metabolic process that depend on K^+ . A higher Na^+/K^+ ratio resulted by salinity interrupts the cytoplasm ionic balance, and consequently inhibit various metabolic pathways (Giri et al. 2007; Hajiboland 2013).

Mycorrhizal colonization of a plant can reverse the effect of salinity on K and Na nutrition. Mycorrhizal fungi can enhance K absorption under saline conditions (Abdel Latef and Chaoxing 2011; Evelin et al. 2012) and prevent the translocation of Na to shoot tissues. Higher K accumulation by mycorrhizal plants in a saline soil could be beneficial by maintaining a high K^+/Na^+ ratio and by influencing the ionic balance of the cytoplasm or Na efflux from plants (Daei et al. 2009; Ruiz-Lozano et al. 2012).

Increased growth of mycorrhizal plants than nonmycorrhizal plant, as a result of lower Na, may be also explained by the dilution effect (Giri et al. 2007; Abdel Latef and Chaoxing 2011). There are contrasting reports that AM fungi sometimes increase Na uptake (Allen and Cunningham 1983), by the host plant while others suggest that mycorrhizal-colonized plants have lower levels of Na (Sharifi et al. 2007; Zuccarini and Okurowska 2008; Abdel Latef and Chaoxing 2011; Evelin et al. 2012).

With increasing salinity up to a certain level, the concentration of Na increased in mycorrhizal plants, and subsequently decreased at higher salinity. This suggests that AM fungi have a buffering effect on the uptake of Na when the concentration of Na is within the permissible limit (Allen and Cunningham 1983). This also indicates the possibility of a regulatory mechanism in the plant to modify the concentration of Na ions (Evelin et al. 2009; Kapoor et al. 2013).

Calcium (Ca)

Calcium has some important roles in maintaining plant membrane integrity, cell wall structures, as well as ion transport regulation and selectivity (Maathuis 2009; Evelin et al. 2012). A higher Ca^{2+} concentration in mycorrhizal than nonmycorrhizal plants can favorably alleviate the toxic effects of NaCl by inducing a higher K^+/Na^+ rate leading to salt adaptation (Rabie and Almadini 2005; Evelin et al.

2009). Moreover, a high Ca^{2+} concentration can also enhance colonization and sporulation of AM fungi (Jarstfer et al. 1998; Evelin et al. 2012).

On the other hand, Giri et al. (2003, 2004) observed no visible change in Ca^{2+} uptake of mycorrhizal and nonmycorrhizal *Acacia uriculiformis* plants under salinity stress. It has been suggested that mycorrhiza may not be effective on the uptake of nutrients, such as Ca^{2+} , through absorbing to the plant roots by mass flow as compared with nutrients absorbed by diffusion. It is currently not clear how AM fungi may affect the transport and uptake of Ca^{2+} ions (Evelin et al. 2012).

Magnesium (Mg)

Magnesium is a macronutrient and forms the integral part of the chlorophyll molecule (Evelin et al. 2012).

Mycorrhizal fungi can increase chlorophyll concentration, by increasing the uptake of Mg^{2+} by the host plant (Giri et al. 2003; Abdel Latef and Chaoxing 2011). This suggests that salt interferes less with chlorophyll synthesis in mycorrhizal than nonmycorrhizal plants (Giri and Mukerji 2004). The enhanced Mg^{2+} uptake can increase the chlorophyll concentration and hence improve photosynthetic efficiency and plant growth (Evelin et al. 2009). Recently, Evelin et al. (2012) found that NaCl and mycorrhizal colonization had little or no effect on Mg^{2+} concentration in fenugreek plants. This may be attributed to elimination of the competition between Ca^{2+} and Mg^{2+} (Evelin et al. 2012).

Chloride (Cl)

In saline regions, the high concentration of Cl^- may limit plant growth and can be toxic to crop plants (Xu et al. 2000; Evelin et al. 2009). Such a stress can be alleviated to some extent by using AM fungi, which can reduce the uptake of Cl^- ions (Zuccarini and Okurowska 2008).

In mycorrhizal plants, the ability of the host plant increases and hence compartmentalize higher rate of Cl^- in the vacuoles, thereby preventing the ions from interfering with the metabolic pathways in the plant (Cantrell and Lindermann 2001; Evelin et al. 2009). However, there are reports of enhanced Cl^- accumulation due to the colonization of mycorrhizal fungi. Such a process has been attributed to the higher transfer of carbon from the host plant to the mycorrhizal hyphae, which enhances the translocation of highly mobile anions like Cl^- from the soil (Graham and Syversten 1984; Evelin et al. 2009).

Biochemical Changes

Under salinity stress, the overproduction of different types of compatible organic solutes by plant increases (Abdel Latef et al. 2009). Compatible solutes are low molecular weight, and highly soluble compounds that are not ntoxic at high

cellular concentrations. Generally, they protect plants from stress through the following processes: adjustment of cellular osmotic, detoxification of reactive oxygen species, maintenance of membrane integrity, and enzymes and proteins stabilization (Abdel Latef and Chaoxing 2014).

Furthermore, some of these solutes are called osmoprotectants because they protect cellular components from dehydration damage. These solutes include proline, soluble sugars, polyols, trehalose, and quaternary ammonium compounds (QACs) such as prolinebetaine, alaninebetaine, glycinebetaine, pipercolatebetaine, and hydroxyprolinebetaine (Hamdia and Shaddad 2010).

Sugar

Under saline conditions, sugar may contribute up to 50 % of the resulted osmotic potential in glycophytes (Paraviz and Satyawati 2008; Abdel Latef and Chaoxing 2014). They can act as osmoprotectants, adjust osmotic potential, store carbon, and scavenge radical products. In mycorrhizal plants, the sugar content increases (Sheng et al. 2011; Abdel Latef and Chaoxing 2014; Talaat and Shawky 2014).

Mycorrhizal fungi increase the sugar content of the host plant because of (a) the sink effects that make the fungi demand sugars from the shoot tissues, (b) hydrolysis of starch to sugars in the seedlings inoculated with mycorrhizal fungi, (c) preventing structural changes in soluble protein, (d) maintaining the osmotic equilibrium in plant cell, and (e) keeping membrane integrity (Kapoor et al. 2013; Abdel Latef and Chaoxing 2014). On the other hand, some authors reported negative correlations between AM fungal colonization and sugar accumulation in host plants (Pearson and Schweiger 1993; Sharifi et al. 2007; Beltrano et al. 2013).

Proline

Proline is one of the compatible organic solutes that is used by plant as osmoprotectant. In most plant species, the accumulation of proline has been observed under salinity stress (Abdel Latef 2010, 2011b; Hameed et al. 2014). Proline has a key role in the stabilization of cellular protein and membranes under high salinity concentrations. Abdel Latef et al. (2009) suggested that, proline can act as a sensor of salt-stress injury and not as an osmoprotectant.

However, Hassanein et al. (2009) found that proline was the surviving response of the plant to tolerate the adverse effects of salinity stress. Several authors have reported that proline concentration increased in mycorrhizal plants than in non-mycorrhizal plants at different levels of salinity (Jindal et al. 1993; Sharifi et al. 2007).

On the other hand, other authors reported that nonmycorrhizal plants accumulated more proline than mycorrhizal plants at various salinity levels (Rabie and Almadini 2005; Jahromi et al. 2008; Sheng et al. 2011; Evelin and Kapoor 2013; Abdel Latef and Chaoxing 2014), suggesting that proline accumulation in plants

may be a responsive strategy in less salt-tolerant species or that this accumulation may be also be a response to salinity and not necessarily to mycorrhizal colonization.

Betaines

Betaines are quaternary ammonium compounds, which are N-methylated derivatives of amino acids. After the formation of betaines, they are rarely metabolized (Duke et al. 1986; Kapoor et al. 2013). Betaines are not only nontoxic cellular osmolytes but they can also stabilize the structures and activities of enzymes and protein complexes and maintain the membrane integrity under the damaging effects of salinity stress (Gorham 1995; Hajiboland 2013). Betaines are accumulated in plants under salt stress. Hence, this can be an effective plant response to salt stress (Duke et al. 1986; Hajiboland 2013). Accumulation of betaines under salt stress is found to increase when the plant is colonized by mycorrhizal fungi (Al-Garni 2006; Sheng et al. 2011).

Antioxidant Enzymes

Plants subjected to environmental stresses, including salinity produce reactive oxygen species. Reactive oxygen species include free radicals such as superoxide anion (O_2^-), hydroxyl radical (OH), and nonradical molecules such as hydrogen peroxide (H_2O_2) and single oxygen (O_2). In plants, reactive oxygen species are always formed by the inevitable leakage of electrons onto O_2 . This would result in the electron transport of mitochondria, chloroplasts, and plasma membranes or is as a byproduct of different metabolic pathways in various cellular compartments (Sharma et al. 2012).

All reactive oxygen species are extremely harmful to organisms at high concentrations. When the level of reactive oxygen species is higher than the tolerance level, a cell is subjected to “oxidative stress.” The enhanced production of reactive oxygen species during environmental stresses can adversely affect the cellular activities by causing the oxidation of proteins, peroxidation of lipids, and preventing the activity of enzymes, which eventually results in cellular deactivation (Sharma et al. 2012).

Plants have both enzymatic and nonenzymatic mechanisms for scavenging reactive oxygen species. The enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), guaiacol peroxidase (GPX), and the enzymes of ascorbate-glutathione (AsA-GSH) cycle such as ascorbate peroxidase (APX), dehydro ascorbate reductase (DHAR), mono dehydro ascorbate reductase (MDHAR), and glutathione reductase (GR). Ascorbate (AsA), glutathione (GSH), phenolics, carotenoids, and tocopherols, which act as potent nonenzymic antioxidant inside the cell (Sharma et al. 2012). Like other abiotic stresses, salinity also induces oxidative stress in plants (Abdel Latif 2011b, 2014). Several studies suggested that

mycorrhizal symbiosis helps plants to alleviate salt stress by enhancing the activities of antioxidant enzymes (Hajiboland et al. 2010; Abdel Latef and Chaoxing 2011, 2014; Evelin and Kapoor 2013).

Physiological Changes

Salinity stress can adversely affect plant growth by disrupting different physiological mechanisms such as decreasing water potential, disruption of membrane, photosynthetic efficiency, gas exchange, etc. Research work has indicated that AM symbiosis can alleviate such effects by using various mechanisms, which are discussed below.

Water Status

Plants under salinity stress are subjected to physiological drought as Na^+ and Cl^- ions bind water that is required to be utilized by plants (Fuzy et al. 2008). Mycorrhizal plants have a higher water content compared with noninoculated plants because: (a) mycorrhizal roots have a higher hydraulic conductivity at low water potential (Kapoor et al. 2008); (b) altered morphology of root system induced by mycorrhizal fungi (Kothari et al. 1990); (c) higher stomatal conductance, which increases the demand for transpiration (Sheng et al. 2008); (d) the fungi accumulate solutes, and hence improve plant osmotic adjustment (Abdel Latef and Chaoxing 2014).

All these improved processes resulted by mycorrhizal colonization make the host plants to use water more efficiently. Accordingly, a lower intercellular concentration of carbon dioxide is resulted in the host plant. As a consequence, the gas exchange capacity increases in mycorrhizal plants (Evelin et al. 2009; Porcel et al. 2012; Hameed et al. 2014).

Relative Permeability

The electrolyte permeability of root plasma membrane is lower in mycorrhizal plants than nonmycorrhizal plants. The higher stability of cellular membrane has been attributed to mycorrhizal symbiosis as a result of enhanced P uptake and increased antioxidant production (Feng et al. 2002; Evelin et al. 2009).

Chlorophyll Concentration

Salinity causes a reduction in chlorophyll concentrations due to (i) reduction in water potential, (ii) the antagonistic effects of NaCl on N absorption, which is the essential component of the chlorophyll structure (Kaya et al. 2009), (iii)

suppressing the activity of specific enzymes required for the synthesis of photosynthetic pigments (Murkute et al. 2006), (iv) decreased uptake of nutrients (e.g., Mg) needed for chlorophyll biosynthesis (Sheng et al. 2008; Abdel Latef and Chaoxing 2011).

It has been indicated by several research work that mycorrhizal symbiosis resulted in a higher chlorophyll concentration in plant leaf under saline conditions (Hajiboland et al. 2010; Abdel Latef and Chaoxing 2011, 2014). The fungi are able to alleviate the antagonistic effects of Na on Mg uptake under salt stress (Giri et al. 2003; Talaat and Shawky 2014).

The inoculated plants were able to their highest photosynthetic capacity (estimated by chlorophyll content) under salt stress even higher than nonstressed plants, indicating the alleviating effects of the fungi on the stress (Zuccarini 2007; Evelin et al. 2009; Abdel Latef and Chaoxing 2014).

Abscisic Acid

The plant hormone, abscisic acid (ABA), is able to make the plant to respond to different stresses including drought and salt stress. ABA can also act as the major internal signal and hence enables plants to survive under adverse environmental conditions such as salt stress (Keskin et al. 2010; Javid et al. 2011; Miransari et al. 2014).

When plants are under salinity stress, the concentration of ABA in plants increases. This is in most cases related with leaf or soil water potential, indicating that the production of endogenous ABA is resulted by water deficit and not by the specific effects of salt (Zhang et al. 2006; Javid et al. 2011).

It has been reported that mycorrhization can alter the ABA levels in the host plant (Estrada-Luna and Davies 2003). AM plants are less affected by salinity stress than non-AM plants, and hence, less amounts of ABA are accumulated in mycorrhizal plant. However, depending on the properties of the host plant the effects of AM fungal species on ABA content in the host plant differ (Evelin et al. 2009; Porcel et al. 2012; Miransari et al. 2014).

Conclusion

The effects of salinity and mycorrhizal symbiotic on the growth of the host plant were reviewed and analyzed. Using different mechanisms, the plant by itself or in association with mycorrhizal fungi can tolerate or survive the stress. However, in the presence of the fungi, plant ability to resist the stress increases as a result of morphological and physiological changes. Production of different solutes, plant hormones, antioxidant products, the adjusted rate of K^+/Na^+ , extensive network of the mycorrhizal plant roots, and enhanced nutrient uptake are all among the processes that make the plant to survive under stress.

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