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RESEARCH ARTICLE

Effect of Arbuscular Mycorrhizal Fungi on Salt Stress: A Review

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Abstract

Biodiversity is essential to sustaining the ecosystem and preserving ecological balance. However, the growing risk of salt stress brought on by extensive irrigation and chemical fertilizer use has made biodiversity protection extremely difficult and lowers crop productivity. Arbuscular Mycorrhizal (AM) fungi are symbiotic soil microorganisms, plays the important role in relieving the argumentative effects of salt stress in plants. This comprehensive review produces current knowledge related to the complex association between AM fungi and salinity in terrestrial ecosystems. It investigates how AM fungi improve plant's resistance to salt stress. Furthermore, the review investigates the remarkable biodiversity of AM fungi from different plant associations worldwide, emphasizing the significance of choosing appropriate AM fungi species aimed ateffective ecosystem restoration and agricultural practices in saline environments. This research offers important insights into tying AM fungi's capacity to counteract salt-induced biodiversity loss and boost agricultural yield in saline soils by elucidating the intricate relationships between AM fungi and salt stress. This review highlights the need for further research to unravel the complexities of this symbiotic relationship and develop sustainable strategies for countering the problems of salt stress and crop productivity.

Introduction:-

Soil microflora includes diverse bacteria and fungi, some pathogenic and others nonpathogenic. Among the nonpathogenic microorganisms, AM fungi play a crucial role in making symbiotic relationships with plant roots (St Arnaud andElsen 2005). According to Gupta et al. (2021), these fungi are crucial for enhancing plant growth and resistance to environmental stress, especially salt stress. The rapid increase of soil salinity due to improper agricultural practices and Overuse of chemical fertilisers has caused soil fertility to decline, which poses problems for crop productivity and biodiversity.

There are many spores of AM fungi found in soil, out of them few species show mutualistic interaction with crops. Mutualistic relation is of two types; ectomycorrhiza's and endomycorrhiza's. Ectomycorrhiza is not associated with plant roots and endomycorrhiza is associated with plant roots by forming and penetrating mycelium between cells

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and inside the cell (Roy and Choudhury 2022).The intricate relationships between AM fungus and plants under salt stress, are highlighted in this paper, along with how AM fungi can be used to mitigate the negative effects of salt stress on plant growth.

Effect of Salt Stress on Plants

Nowadays soil degradation remains a major issue in the field of agriculture and it is increasing steadily all over the world (Lanfranco, L. et al., 2016). This problem is because of improper irrigation, and excess use of chemical fertilizers (Savci, S. 2012). It causes loss in the microflora of soil and soil fertility; increasing salinity stress. Increased abiotic stress like water stress, salt stress, abrupt changes in temperature basically the mainly due to changes in climatic conditions. Such kinds of stressed conditions affected organic contents of soil. Soil contains active microorganisms of different kinds assisting plant growth in various ways. The soil from rhizosphere consist of more than a trillion species present out of them microbiota and microflora are more dominant in this layer of soil (Sharma et al., 2021). From the fungal group; AM fungi are among the most significant and economically significant organisms in the fungus group (Smith and Smith 2011).

One of the main abiotic stress which affecting plant growth and productivity is salinity. Increased salt levels of soil disrupt plant water absorption, cause ionic imbalances, and reduce photosynthetic efficiency. The germination of seeds, plant growth, and total crop output are all adversely affected by the high concentration of salt in the soil. Salinity reduces chlorophyll content of crops, resulting in decreased photosynthesis and productivity (Mbarki et al., 2018). Different salts alter the soil's physicochemical characteristics (Li et al., 2019). It also alters water potential of soil, affecting the accessibility of water to plants (Rabie and Almadini, 2005). Salinity of soil is a biggest hazard towards security of food due to lower production. Nearabout 7% of the soil badly affected due to deposition of salts (Ruiz Lozano et al., 2012). Salt contents of soil reduces germination capacity of seed thereby affecting its produce (Ouni et al., 2014). Additionally, it has effect on exhaustion of water in the rhizosphere and reduces capacity to hold water (Sabir et al., 2009). Salt content of soil obstructs plant's capacity to absorb water and disrupt ionic homeostasis (Chakraborty et al., 2018). Furthermore, in stresses various cellular components damage due to reactive oxygen species (Velarde-Buendia AM., 2012). ROS negatively correlats to the plant growth (Ahmad P., 2010). Phosphorous content inversely proportional to salt concentration of soil. Salinity has affected nearabout 25 million acres of soil (Latef and Chaoxing., 2011). If not addressed, the rising salinity in soil could lead to a 30% loss of cultivable land within the next few decades (Porcel et al., 2012).

Effect of AM Fungi on Salt Stress

Applications of non-hazardous organic techniques, such as the use of AM fungus, can mitigate the negative consequences of salt stress (Badda N. et al., 2014). AM fungi are one of the microorganisms that are most well-known for lowering different types of stress. Indeed, AM Fungi potential is being continuously tested for different stresses (Ahangeret al., 2014, Bencherif et al., 2015).By improving the uptake of water and trace elements from the soil, AM fungus can help plants become more resistant to salinity stress (Evelin et al., 2009). Soil microflora with AM fungi and the biofertilizers are known globally to enhance crop yields and protect plants from various stresses. As decomposers, biological controllers, and ecosystem regulators, fungi can serve a variety of purposes in the environment. AM fungi are leading organic amendments to boost the plant growth and guard them from various fungi (Frąc et al., 2018). AM fungi assist the associated plant to protect from various pathogens (Lehmann et al., 2017).

AM fungus has been shown to aid in plant's recovery from the negative consequences of salt stress. According to a number of research, plants associated with AM fungus flourish and produce more biomass in saline conditions (Bhosale and Shinde, 2011). This fungi increase nutrient uptake, control osmotic equilibrium, and lessen oxidative stress, which increases plant tolerance to salinity. Plant growth and production are increased by AM fungi, which are known to increase chlorophyll content and photosynthetic efficiency even in the face of salt stress (Majeed & Muhammad 2019). Additionally, AM fungi help to maintain the overall health of the plant by supplying essential nutrients, such as phosphorus, which is required for plant growth under stressful situations (Begum et al., 2019). Association of AM fungi enriched dry biomass of seedlings (Latef & Chaoxing., 2011).

Soybean can undergo a symbiotic interaction with soil microorganisms like rhizobium and AM fungi to fix atmospheric nitrogen as well as to supply various micronutrients. Nitrogen along with phosphorus are ulmost important amendments for growth of plants (Marschner, 1995). We use more synthetic chemical fertilizers to increase the yield of crops. Such use of synthetic fertilizers results in lethal issues related to the environment. Only half of the additional N and around a quarter of the P fertiliser can be absorbed by the plants (Adesemoye and Kloepper, 2009, Garnett, 2009). Soybean shows association of Rhizobium as well as AM fungi simultaneously, which are beneficial both Phosphorous along with the Nitrogen (Meena et al., 2018). Both water and nutrients from the soil are captured by the hyphae of AM fungus. The symbiosis between AM fungus and plants is especially crucial for plants that grow in soils with low P availability. (Ibrahim, 2011; Abdul-Fattah, 1997). According to Ghorchiani et al. (2018), Abdel-Fattah and Asrar (2012), Sheng et al. (2013), and Anand et al. (2022), it accelerated the rate of plant development and raised the P concentration in plant tissues. AM fungi shows great biodiversity in the association with different plants as shown in following table, which helps plant to alleviate different stresses and enhance growth and development in crop.

Table 1:- ‘Biodiversity of arbuscular mycorrhiza fungi from different plant association worldwide’.

Sr. No.	AMF	Plant association	References
1	*Acaulospora denticulate* *Entrophospora kentinensis*	Date palm	Sghir et al., 2014.
2	*Acaulospora spinosa*	Tea	Singh et al., 2008.
3	*Claroideoglomus hanlinii*	*Plantago lanceolata*	Błaszkowski et al., 2015.
4	*Diversispora aurantia* *Funneliformis coronatus* *Paraglomus occultum* *Scutellospora calospora*	*Asteriscus maritimus*	Estrada et al., 2013.
5	*Diversispora clara*	*Asteriscus maritimus*	Estrada et al., 2012.
6	*Diversispor acelata*	*Glycine max*	Gamper et al., 2009.
7	*Entrophospora colombiana* *Glomus hoi* *Glomus tenebrosum*	fruit orchards	Ragupathy and Mahadevan., 1993.
8	*Gigaspora calospora* *Sclerocystis coremioides* *Scutellospora pellucida*	Litchi	Sharma et al., 2009.
9	*Gigaspora margarita*	*Puspalum nototum*	Douds and Schenck , 1991.
10	*Otospora bareai*	*Thymus granatensis*	Palenzuela et al., 2008.
11	*Paraglomus majewskii*	*Plantago lanceolata*	Błaszkowski et al., 2012.
12	*Rhizoglomus melanum*	*Isoetes lacustris*	Sudovaet al., 2015.
13	*Sclerocystis sinuosa*	*Rhododendron lepidotum*	Chaurasia et al., 2005.
14	*Scutellispora nigra*	*Rhododendron barbatum*	Mbogne et al., 2015.

Mechanisms by Which AM Fungi Alleviate Salt Stress

Enhanced Nutrient Uptake

Numerous research investigating the role of AMF in protection against salt stress have found that the symbiosis often results in increased nutrient intake, buildup of osmoregulatory chemicals, an increase in photosynthetic rate, and an increase in water usage efficacy. These results imply that AMF's capacity to reduce salt stress is a result of a confluence of molecular, physiological, biochemical, and dietary impacts. Accordingly, it was found that mycorrhization increased the host plant’s fitness by promoting its development (Porcel et al., 2012). Several researchers claim that plants infected with AM fungus grow more effectively than those that are not under salt stress (Al-Karaki 2000; Cantrell and Linderman 2001). By boosting the uptake of phosphorus and other immobile nutrients from the soil, AM fungi considerably improve the nutritional status of plants. An essential component of plant growth, phosphorus is frequently scarce in saline soils. Crop development and stress tolerance are improved by AM fungi because they boost phosphorus uptake (Begum et al., 2019, Abdel-Fattah, 1997). Furthermore, plants and AM fungus have a symbiotic interaction that makes it easier for the plants to absorb water and trace elements that are essential for their survival in salt stress (Evelin et al., 2009).

Osmotic Regulation

Plants experience water stress when salinity upsets their osmotic balance. By controlling osmotic balance and enhancing water intake, AM fungus assist plants in maintaining water relations. AM fungus hyphae help plants adapt to saltwater environments by penetrating the soil and aiding in water absorption (Mayak et al., 2004). One of the most serious outcomes is the loss of intracellular water due to salinity stress. By stopping water loss from the cytoplasm of the cell, compatible organic solutes that are held in the cytoplasm of plant cells help to promote plant development during salt stress.Several chemicals have been postulated to perform this function in halophytes, including proline, betaines, sugars (primarily fructose, sucrose, and glucose), and complex sugars (trehalose, raffinose, and fructans) (Porcel et al., 2012).

The phytohormone ABA controls plant growth and development and has a major effect on how plants respond to abiotic stresses such as salt stress. Mycorrhizal connection with plant roots has been shown to change the ABA levels in the host plant (Duan et al., 1996).

Reduction of Oxidative Stress

Many of the degenerative reactions connected to different biotic, abiotic, and xenobiotic stresses are mediated by Reactive Oxygen Species (ROS) (Porcel et al., 2012). Superoxide, hydroxyl radicals, hydrogen peroxide, and singlet oxygen are all included in the term ROS. ROS, which can harm plant cells, are frequently produced as a result of salt stress. AM fungi reduce the oxidative stress by modulating ROS levels and improving the antioxidant responses in plants. Because it lessens cellular damage and enhances general plant health, this defence system is essential for plant survival under salt stress (Ahmad, 2010; Velarde-Buendia et al., 2012). Numerous research have shown that AM symbiosis increases the activities of antioxidant enzymes, which helps plants deal with salt stress (Zhong et al., 2007).

Improved Photosynthesis

The loss of chlorophyll content is the main cause of the decrease in photosynthetic efficiency, which is one of the major effects of salinity. When plants are under salt stress, AM fungus increase their chlorophyll concentration and photosynthetic activity. Enhanced photosynthesis leads to better growth and biomass production, even in saline soils (Kong et al., 2020). By improving the plant’s ability to capture carbon and utilize it for growth, AM fungi ensure that the plant maintains productivity under stress conditions. Salt stress causes physiological dryness and photosynthetic inhibition, which lower crop output (Pitman and Lauchli 2002).However, relatively little study has been done on how AM fungus inoculation affects photosynthesis, specifically the photochemical properties of leaves under salt stress (Sheng et al., 2008).

Summary:-

Research on the impact of AM fungi under salt stress has shed light on the possible advantages of these symbiotic partnerships in reducing the negative effects of salt on plants. By improving nutrient uptake, mycorrhizal fungi have been shown to dramatically increase a plant's tolerance to salt stress. Furthermore, under salinised conditions, AM fungi have demonstrated potential in sustaining plant growth, biomass output, and general plant health.

However, it's important to remember that the effectiveness of mycorrhizal supplements in reducing salt stress might differ based on a number of variables, including the type of plant or fungus and the particular environmental circumstances. To maximise mycorrhiza's agricultural use and comprehend the mechanisms underlying their role in salt stress resistance, more research is required.

In conclusion, research on the impact of AM fungus on salt stress demonstrates the potential of these helpful fungi, which play a crucial role in ecosystem management and sustainable agriculture, especially in saline conditions. Connecting the advantages of AM fungus offers a promising way to increase crop productivity and environmental resilience as we continue to deal with salinity in a changing climate.

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Future Research Directions:-

The specificity of AM fungal-plant interactions in saline environments needs to be investigated. Examining the physiological and molecular processes that underlie the salt tolerance mediated by AM fungus. Formulating plans for the extensive use of AM fungus in saline farming. The diversity of AM fungus in saline salt must be understood.

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