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ARBUSCULAR MYCORRHIZAL SYMBIOSIS AND DROUGHT STRESS RESISTANCE IN THE PLANTS

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ABSTRACT

Rapid changes in the climate are being observed all over the world. Most of these changes are adversely affecting the living organisms including plants. During its life span a plant faces a number of stress conditions which have limiting effect on the growth and other metabolic processes of the plant. Productivity of the plant is also affected due to the stress factors. Drought is one of the prominent stress factors, with a significant role in the morphological, physiological and biochemical processes of the plants. Some plants show certain adaptations to counter act the adverse effects of water deficit. The roots of the majority of the plants are symbiotically associated with some fungi. Most common of these fungi are arbuscular mycorrhizal fungi. The fungal partner is beneficial to the host plant in a variety of ways. Arbuscular mycorrhizae prove to be helpful to alleviate the drought stress either by avoidance or tolerance. The role of AM fungi has been investigated by different workers time to time. Though there is much advancement in the study of AM fungi, yet there is a dire need for in depth investigations under the changing environmental conditions, using latest methodologies to fully explore the role of AM fungi in drought stress management.

Keywords: Arbuscular mycorrhizae, Biochemical processes, Climate change, Drought stress, Metabolic processes, Physiological processes.

I. INTRODUCTION

Global environmental changes have negative impact on the ecosystem. Various environmental factors are affecting living organisms to varied degrees. Rapidly occurring changing climate conditions are posing a challenge to the plant productivity. Drought is one of the major constraint, resulted as an outcome of climate change, and is expected to increase further [1, 2].Stress is any kind of change in the environmental factors which generally have some adverse effect on the living organisms [3, 4]. Plants are exposed to a variety of stress conditions in the field. Drought, extremes of temperature, salinity, availability of nutrients and presence of certain toxic elements cause stress and pose some limitation to the plant growth and productivity. Plants respond to such stress factors in a variety of ways. These responses may be either in the form of some modification to avoid stress [5] or implement some tolerance to the stress through some morphological, physiological or biochemical responses [6]. Some of the plants have other way outs for the stress tolerance. Mycorrhizal symbiosis is one of the such approaches to deal with the stress conditions. The word 'Mycorrhizae' is derived from greek words-'*Mykos'* means fungus and '*Rhizae'* means roots. Mycorrhiza is a symbiotic association between the fungi and roots of the higher plants. Mycorrhizae are quite wide spread in nature. AM mycorrhizae

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are most ancient and common type of mycorrhizae in nature. AM are characterized by formation of arbuscules and vesicles by the members of Glomeromycota. Almost all the gymnosperms, most of dicots and few monocots possess mycorrhizal association with certain fungi and the latter play a significant role in the host plant [7-14]. The fungus enters roots of the plant by appresoria formation at the point of contact between the two [Fig.1a]. The colonization of the fungal hyphae is restricted to parenchymatous cells of the cortex, where it grows intercellularly. The lateral branches of the intercellular hyphae penetrate cortical cells and show repeated dichotomous branching giving rise to 'arbuscules', hence the name Arbuscular Mycorrhizae [Fig.1b,c].

The main objective of the present review is to outsketch the recent advances in the role of AM symbiosis in drought resistance of the plant with main focus on water uptake, transport and on the lesser known metabolites of some protective role in drought conditions.

II. ARBUSCULAR MYCORRHIZAE AND DROUGHT STRESS

Various ecophysiological studies have shown that AM symbiosis can greatly reduce the susceptibility to droughtand other stress factors [15-17]. AM fungus promotes root growth and improves the uptake and transport of water and nutrients like phosphorus, Nitrogen etc [Fig. 1d]. It leads to the hydration of the plant tissues and enhanced growth rate. The exact mechanism how AM symbiosis help the plants to cope with the drought conditions is not very much clear. The complexity of the AM mediated response may be due to the involvement of various metabolites and metabolic pathways. AM mediated response of various biochemical and physiological traits to the changes in water availability may confounded by concurrent changes in plant growth and availability of nutrients [18-19].

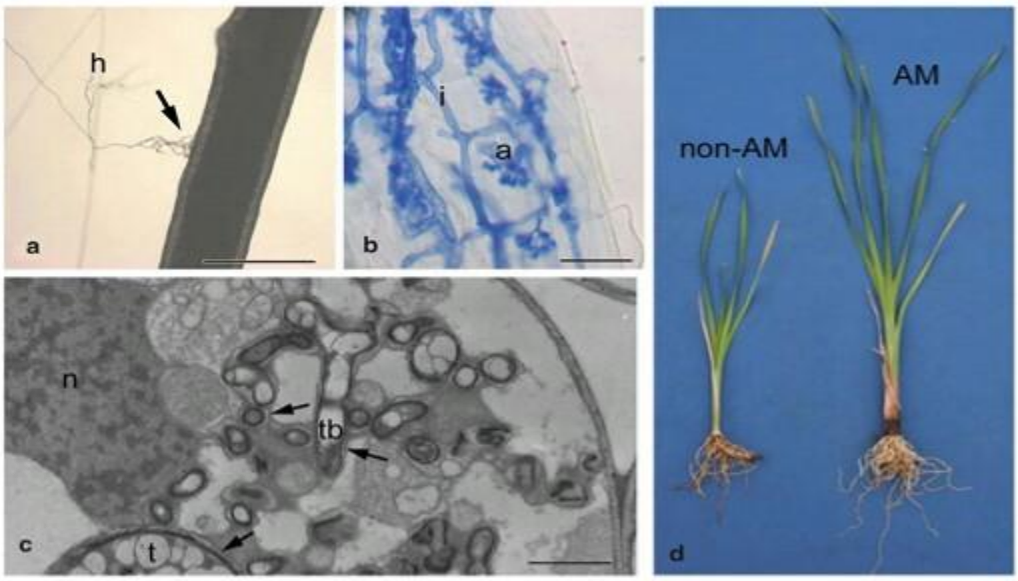

FIG.1(a-d): 1a.showing extra-radical hyphae(h) leading to colonization ;1b.colonization of cortex by AM fungus *Glomus mosseae* showing arbuscules(a), intercellular hyphae(i);1c showing transmission electronmicrograph of a *Glomus* sp. Arbuscule inside cortical cells(t-trunk; tb-thin branches;n-nucleus of the corticalcell); 1d: showing improved growth in a mycorrhizal plant as compared to the non-mycorrhizal 0one.

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2.1 Plant responses during drought conditions

Most of the plants responds to the drought through two main strategies either by avoidance or by tolerance [20].AM symbiosis provide protection to the host plants against the drought conditions through avoidance of drought conditions. Drought avoidance in mycorrhizal plants mainly depend upon the ability to maintain the hydration of the whole plant as characterized by relative water content. However, as evident during the review of literature, leaf water potential is not measured in certain cases .Better capability to avoid drought in case of AM mycorrhizae associated plants is correlated with improved nutrition leading to the enhancement of growth. If shoot size and nutritional status are kept aside, influence of AM symbiosis on leaf hydration through increased uptake of water, a characterstic feature of mycorrhizal plants is considered to be responsible for the drought resistance. Mycorrhizal plants also show drought tolerance because of better osmotic adjustments, thus leading to the hydration and turgidity of the leaves in conditions of low water potential of leaves.

2.2 Physiological responses during drought stress

Mycorrhizal plants show a number of above ground modifications and physiological status in terms of leaf water potential, relative water content, stomatal conduction, carbon dioxide assimilation and efficiency of photosystem II. The studies by various workers have demonstrated enhancement in the rates of photosynthesis, transpiration and gaseous exchange in case of mycorrhizal plants [21, 22]. Though the exact mechanism is not clear, the role played by ABA has been suggested as one of the nutritional mediated mechanism in the drought stressed plants to influence their physiological traits [23].Comparatively lower levels of ABA in mycorrhizal plants as compared to non-mycorrhizal plants, as evident from the recent studies support this hypothesis. However, on the basis of the plant or nature of the fungus involved, physiological responses may vary.

Leaf water potential is recognized as an index of the water status of the plant. Higher leaf water potential is shown by the mycorrhizal plants under the conditions of water deficit as a mechanism of drought avoidance [24]. Measuremnt of water use efficiency (WUE) also indicate the water usage by te plant, however responses in WUE are quite variable under water stress conditions. Ability to manage excess radiations resulting from the limitation of photosynthesis by drought and decline in the availability of carbon dioxide are also thought to be responsible factors for the drought resistance in mycorrhizal plants. Recent studies indicate increase in the efficiency of photosystem II, under drought conditions in case of mycorrhizal plants.

The role of fungal hyphae in water uptake is not very much clear. The nature of AM symbiosis is thought to be the main factor behind the variable physiological and biochemical outcomes during the drought stress [25].

Increased water uptake by AM symbiotic plants during the water deficit under conditions of improved Phosphorus nutrition and growth has been reported. Both of these mechanism may also affect root hydraulic conductivity [26, 27]. Hydration of the leaves is caused by the balance between the water uptake and rate of transpiration. AM symbiosis improves water content of the plant by regulating properties of plant hydraulics, including root hydraulic conductivity. However, certain variations have also been reported by some workers.

Nutritional status also play a significant role in drought resistance of the plants. Soil water deficit is closely related to the availability of the nutrients in the soil. One of the fundamental mechanism behind the alleviation of the adverse effects of water stress on the plant growth is improved nutritional uptake in case of mycorrhizal

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plants. This can be explained on the basis of increased surface area for absorption provided by hyphae in soil together with the ability of fungi to take up water from the soil with low water potential.

2.3Metabolomic Responses of AM plants under drought conditions

Changes in the osmoregulation are also responsible for the drought susceptibility of the plant. Increase in the water potential is observed during the drought stress. However, to maintain the water uptake from the soil water potential has to be lowered. Osmoregulation is helpful in such conditions. Decrease in the O.P. has been reported as a result of accumulation of compatible solutes or osmolytes . Osmolytic accumulation in the plant cell acts as a mechanism of osmotic adjustment for decreasing cellular O.P. and thus, for maintaining water absorption and turgor. Osmolytic accumulation also protects cellular components like cell membrane and proteins and sustain the physiological activity of the plants [28]. However, only the accumulation of metabolites is not sufficient for osmotic adjustment under water stress conditions. An alternative role of osmolyte or scavengers of Reactive Oxygen Species (ROS) has also been suggested [29]. Proline accumulation in a number of plants under water stress also has been reported as a result of colonization of AM fungi in the roots of the plant [30].The enhanced proline accumulation in these studies was linked to AM induced drought resistance with proline acting as an osmoprotectant [Fig.2].

Arbuscular Mycorrhizal plants show increased tolerance to the drought conditions if commonly observed higher rates of photosynthesis lead to accumulation of non-structural carbohydrates that act as osmoprotectants, can lower O.P. Carbohydrate accumulation under conditions of water stress has been reported during various studies by several workers [31-33].

Changes in the metabolic temperature could be attributed o the strategies of drought tolerance or avoidance. Decline in the osmolytes was previously interpreted as a mechanism of drought avoidance, while the accumulation of the osmoprotectants associated with drought tolerance. Thus metabolic profiling 0f the plants exposed to stress conditions is an important tool to study stress induced changes in the metabolites including.

osmolytes

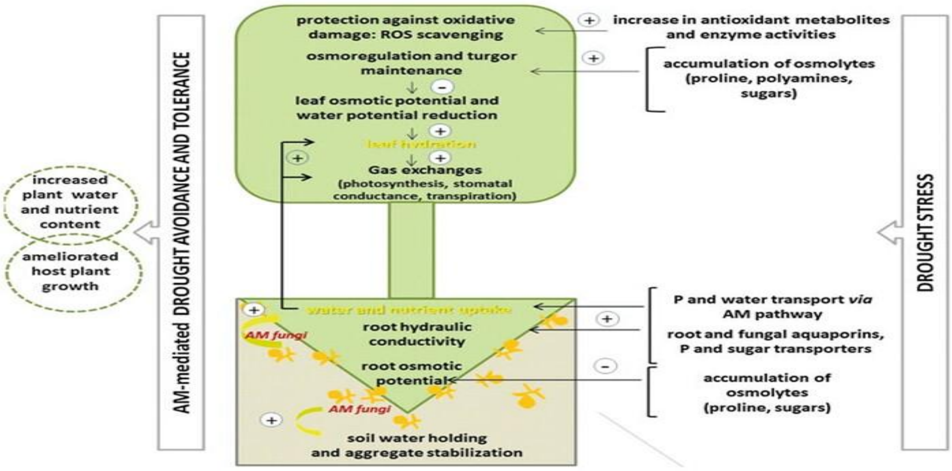

Fig. 2: Showing the role played by AM symbiosis both the above as well as below ground levels.

2.4 AM Symbiosis and Ecosystem

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AM symbiosis plays a fundamental role in the ecosystem services. The role of AM symbiosis in the functional traits of both the plants and microbes that could characterize above and below ground ecosystems yet has not been explored. However, AM symbiosis confers drought resistance in the host plants [34-38].Proper management of AMF in agroecosystem can improve the quality of the soil and the productivity as well.

III. RESULTS AND DISCUSSION

As evident from number of studies, AM symbiosis play a significant role in the management of drought stress. Plants showing symbiotic association with certain fungi, exhibit various morphological, physiological and biochemical responses alleviate the stress induced due to water deficit. However, no single factor is exclusively responsible for the drought resistance in mycorrhizal plants, rather a sum total of a number of factors. Different plants show different responses to the drought stress conditions either by avoidance or by tolerance.

IV. CONCLUSION

Interest in the stressful conditions is rising with the increasing recognisation that net global changes can negatively affect ecosystem.The environmental factors, both abiotic and biotic ones affect organisms in a variety of ways. The effect of abiotic factors on the plants differ with their intensity as these regulate the plant growth.

Tremendous advancement in the research on mycorrhizal physiology and ecology over the last many years have led to better understanding of multiple roles of Arbuscular mycorrhizal fungi in the nature. Abiotic stress factors such as drought, salinity, temperature etc. have limiting effect on the metabolism of the plants. A variety of mechanisms are shown by mycorrhizal plants to cope with the stress conditions especially, those arising from water stress. Considerable advancement has been reported in the efforts to fully understand the role of mycorrhiza in drought resistance among the mycorrhizal plants. But still there is a need to go in depth to unravel other related aspects as well. Further detailed investigations with the help of recent and advanced methodologies would surely help to elucidate the exact mechanisms of drought resistance either by avoidance or by tolerance. It will be of great help in exploring the benefits of AM Fungi in the stress conditions due to other factors as well. The application of trait based approach to both the plant as well as fungal communities shows promising opportunity to understand functional AM feedbacks between plant and AM fungi translate into interactions between ecosystem services

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