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AGRICULTURALLY IMPORTANT FUNGI: ROLE OF BIO-ACTIVE COMPOUNDS FOR ABIOTIC STRESS TOLERANCE IN PLANTS

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ABSTRACT

Production from various crops including plants has been declined due to different kinds of abiotic and biotic stresses. To tackle these stresses several researches have been conducted to access their effectiveness. Recently some microorganisms have been found that they have capability to affect the stress tolerance potential of the plant. Some strains of bacteria and fungi have been found promising in this concern. To use them at short term basis, it is necessary to develop them simple and effective manner. Many research experiments advocated that Arbuscular mycorrhizal fungi may help in improving abiotic stressed plants by increasing nutrient uptake, molecular, physiological, biochemical and ultra-structural changes. Present paper is highlighting the sources, production of bioactive compounds, their role in abiotic stress management of agroecosystem and its importance in sustainable nutrient management. Furthermore, Bio active compounds are potential alternatives to these man-made synthetic chemicals, which is produce from secondary metabolites of microorganisms.

Keywords: Endophytes, bio-active compounds, Arbuscular mycorrhizal fungi, Abiotic stress, Tolerance potential, Efficacy

Introduction

Inconsistent rainfall patterns, temperature rise and salinization of farm lands are some of the direct causes of climate change. Different kinds of abiotic stresses like temperature, alkalinity, salinity and drought may influence the yield of crops in adverse way which ultimately lead to reduction in yield and this loss poses huge threat at national level. Under these circumstances, microbes have shown promising potential by fighting against stresses especially abiotic type via various kinds of biological reactions of plants. Additionally, application of some external chemicals like proline and glycine betaine along with some nutrient elements may help in retaining growth, reproductive and development abilities of the plants.

With increase in population, environment is also altering consequently and agriculture is one of the sectors that are directly facing this kind of challenges for instance abiotic and biotic stresses like high and low temperature, moisture salinity, and drought. Such alteration in environment are able to influence the annual productivity of the crops. To handle such kind of issues, many ecofriendly have shown good potential like application of fungi as bio fertilizers in agriculture. That have shown encouraging results concerning growth and development including plant productivity through improved plant growth enhancing features viz. production of hydrolytic enzymes, siderophores, phytohormones; uptake of nutrients and plant protection against various kinds of organisms.

Ecological Plant-Microbe Interactions

Many processes inside the soil that can be controlled together by plants and microbes like the recycling of nutrients and carbon cycles. The total microbial population and variety of microbial species determines the reach of various nutrients such as N, P, K and other macro and micronutrients. The diversity and population of plant species also play an important role in the transformation of the ecosystem as some exudate or enzymes are released by roots that can hinder the growth of particular species of microbes.

Such C-rich substances may range from < 10 percent to 20 percent of total C production by the plant (Sylvia *et al*., 2005). We may assume that a large amount of carbon compounds is released by plant roots in the soil and this may be consumed by various microbes as a source of food or to enhance soil structure.

Furthermore, boosting the replication of these microbial species and their secondary metabolites will be helpful to grow crops and in the effect of these microbes enhance the supply of various nutrients to the plant so that attack of pathogenic microbes can be easily treated (Upadhyay *et al*., 2020). We may infer that just like farmers these kinds of useful microbes are born, reared, and multiplied by the plant.

Fungi have a strong ability to suppress various plant diseases and they also attack specific plant pathogens with various fungal enzymes. Antagonism like behaviour is often used by fungi to minimize competition and this helps to decrease the population of other microbes.

To reduce competition the fungus and it helps to reduce the population of other microbes.

Fungal secondary metabolite may compete with other microbes for food and pathogenicity, which prevents the plant from disease-causing organisms.

It has also been stated by Sylvia *et al.* (2005) and Lowenfels & Lewis, (2006) that in some cases both, beneficial fungi along with bacteria, may lead to the formation of protective nets and webs round plant parts. In this regard, the example of fungi, Trichoderma that protects the roots, stands well.

It is necessary to absorb close contact of nutrients by the fungus hyphae. That is why in nature usually they grow in collaboration with other soil microbes. Hyphae competes for food, etc., and can lead to a change in the population of the same according to the availability of various nutrients. Such a fungal type that removes simple sugars, vitamins and other amino acids from plant parts. The dominance of such fungi lasts for a short period of time because waste products accrue very fast.

As far as the reproductive method of the fungus is concerned, it is reproduced asexually by spores. According to environment (Loenfels & Lewis, 2006), these minutes of spores are dispersed by various mechanisms i.e. jet propulsion, triggers, fragrances and springs etc. The life of the fungus spore is very long. It can remain in a dormant state for 50 years. This type of survival mechanism allows the fungus to survive in adverse conditions until a favourable condition comes in or improves.

Sylvia *et al.* (2005) explained that natural soils have tendency to decline the growth and development of fungal spores particularly during stress times means when food sources are limited.

Dick (2009) reported that this long-lasting nature has not seen in several fungal species but open-ended growth of fungus elucidates that they have a persistent existence during millions of years as they are almost comparable organism. For example, fairly type of fungal rings unveiling ever widening spheres on plantation and are measured in centuries or decades rather than days/weeks.

Swift, (2005) and Gardi and Jeffery (2009) categorised the soil fungus into three functional classes Species contributing in compound transformations and decomposition of organic matter, Ecosystem regulators and Biological controllers.

For instance, the mycorrhizal fungi have potential to advance plant growth by enhancing nutrient uptake and protection against pathogens.

In addition, different forms of fungus engage in N fixation, root pathogen defence and hormone development processes, and also during the time of drought (Jayne and Quigley, 2014; Baum *et al*., 2015; El-Komy *et al*., 2015). Above all, fungus plays a major role in stabilizing organic matter and the process of deposition (Treseder and Lennon, 2015).

The role of different types of practices in soil tillage can be ignored as they cause soil disturbance and influence the functioning of the fungi. On the contrary, with less tillage activities, fungal species are more robust, there is more nutrient abundance and increased exploitative impacts against various pathogenic microbes (Goss and de Varennes, 2002).

Recently use of soil fungi bio diversity for soil improvement and incline production has been emphasized a new scope and potential in plant development and production (Bagyaraj and Ashwin, 2017). Plant health is greatly influenced by this fungus as it anticipates in various processes of decomposition and supplies nutrients required for plant growth and development (Frąc *et al*., 2015). Fungal diversity is not only limited to determination of biodiversity indexes as quality aspect but structure analysis of fungal population is very important to decide the role imparted in influencing plant health and soil quality. In all agricultural systems soil management is foremost important aspect along with reduction of soil degradation. We can expect such type of results only by efficient and due emphasis on soil fungal biodiversity. Various kinds of cultural practices like crop rotation and cover crops, tillage systems, composts have direct or indirect influence on soil-borne pathogens as well as on soil fungus and bacterial populations (Abawi and Widmer, 2000). It is well known fact that to enhance suppressiveness of soils, chitin and its derivatives (i.e., chitosan) like biopolymers can be added to the soil.

Fungal diversity in soil and its role in soil health

Most plants create a symbiotic union of mycorrhizae fungi by forming hyphae networks.

Such hyphae allow the plant to access N, P, K and other plant-generated nutrients and water in interchange for sugar. This type of relationship is known as the network of mycorrhizae

and is a mutually beneficial relationship (Magdoff & Van Es, 2009).

The hyphae formed by fungi gives rise to the filament-like body by interacting with plant roots, soil particles, and rocks, etc. and promotes accessibility of soil nutrients. Such a shaped network releases various enzymes and decomposes complex compounds present in soil and allows reabsorption of the filaments. Most of the soil region is occupied by soil microbes, known as rhizosphere microflora generally covered by fungi varying from 10-30%. There are many forms of chemical and biochemical occurring here. The fungi are usually smaller than bacteria but dominate because of the large scale of the fungi. It helps them to dominate in a vigorous soil, because of their larger scale

Low disturbance soils, perennial plants of nature, highly stable types of organic material with a high C: N ratio, and direct supply of plant nutrients and slow recycling period. On the contrary, bacteria predominate in the soil where disturbance rates are higher, low C: N ratio, annual plant type, and external nutrient supply (Lavelle & Spain, 2005).

Keeping bacteria in mind is a single cell and needs a thin layer of water to live while fungi, on the other hand, exhibit rapid growth and development, and they are multicellular and can vary in size from feet to meters. This growth mechanism of fungi also helps it to create a bridge-like structure for the remote transport of nutrients (Lowenfels & Lewis, 2006).

Role of agriculturally important fungi: Generally speaking, fungi came into being nearly a billion years ago and it has membrane-bound organs that are the same as those present in insects, animals, and plants and are thus known to be closely related to animals and plants. Genes found in fungi have nearly 80 percent or even more human resemblance (Dick, 2009). Fungi belongs to four different divisions classes zygomycetes, ascomycetes, basidiomycetes and deuteromycetes.

Decomposers are considered as saprophytic fungi that can decompose the material of lignin and cellulose in the soil. Zygomycetes degrade simple sugars but other forms have a lot of ability to decompose organic matter which is high in cellulose, hemicellulose, and in lignin content like cell walls. Ultimately, some items like byproducts from this phase allow humus to remain in the soil for a long time (Lavelle & Spain, 2005; Lowenfels & Lewis, 2006; Ingham, 2009).

Owing to pathogenic nature such as Verticillium, Pythium, Rhizoctonia, and Phytophthora, some root diseases are caused when Ascomycete fungus is microscopic and abundantly present in soils and grasslands. Mushrooms and other large fruiting bodies are commonly available in forest soil and have a strong residue dominance (Dick, 2009). There are also several forms of fungus and bioorganic compounds used in biological control methods.

Another type of mycorrhizal fungus builds a beneficial relationship with the companion plant, and it develops inside the root cells. Ingham (2009) also points out that mycorrhizal can grow inside the plant system. Root cells and usually row is with crops, fruits, bushes, and various grasses. On the other hand, there are many Chenopodiaceae plants (spinach, beets, etc.) and crucifer plants that do not form such interpersonal relationships with fungi. Endophytic fungi act as promoting growth and resistance against different kinds of diseases and stresses including abiotic and biotic stress. They have production to produce various kinds of advantageous compounds which can be antimicrobial, phytohormones and agrochemical bioactive metabolites in nature.

Fungi and its bioactive compounds play a very important role in the balance of ecosystem, as a decomposer and its secondary metabolites are very useful for valuable industrial products like antibiotic etc.

These fungi and their bioactive compounds can help in other ways to combat several diseases in agricultural crops and for industrial sector it acts like source of attraction as secondary metabolites and fungal enzymes play a foremost role in requirement related to industrial sector and day by day their existence and their influence is more emphasized in future.

Role of AMF and Trichoderma in agriculture

Arbuscular mycorrhizal fungus (AMF) from agriculture and horticulture are very important and beneficial microflora (Smith and Read, 2008).

Thilagar and Bagyaraj, (2015) and Bagyaraj and Ashwin, (2017) conducted multiple research experiments to prove that crop yields are due to t inoculation with mycorrhizal arbuscular fungi. This fungus contributes to improved plant rooting system, hence well establishment, improved nutrient encouragement, helps plants to withstand various types of stresses and increased plant population with inclined nutrient uptake (Azcón-Aguilar and Barea, 1997).

Dawidziuk *et al*. (2016) described that some antagonistic fungi like *Glomus* sp. or *Trichoderma* sp. have potential to destroy fungal natured pathogens.López-Bucio *et al*. (2015) also used various species of *Trichoderma* (*T. virens*, *T. harzianum, T. atroviride, T. viride,* and *T. asperellum*) in bio control and called them as biostimulants for horticultural crops. Bagyaraj and Ashwin, (2017) also listed various promising aspects of fungi on plant health and soil quality that include inoculation control by microbial association of Arbuscular mycorrhizal fungi with other plant growth-promoting rhizobacteria, P-solubilizing, and N-fixing microorganisms. Besides, fungi are low in number but surpass or equal to bacterial biomass due to their size. They can grow in continuous soil environments. They usually have plants of a symbiotic form of connection.

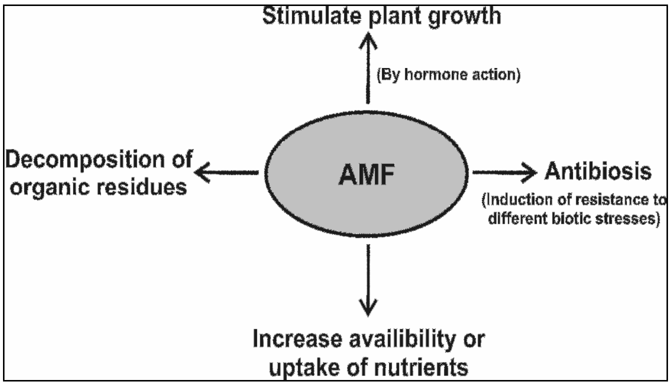

Fig. 1 : Role of Soil fungus forming mycorrhizae networks in plant growth and development

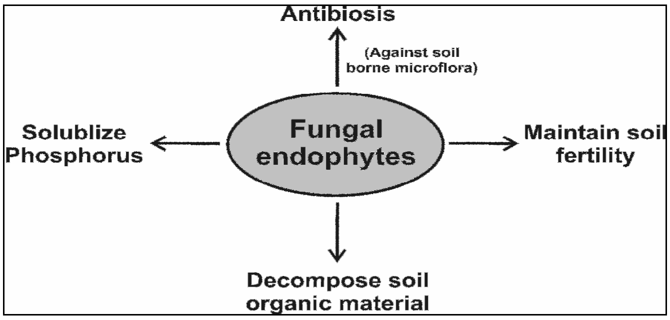

Fig. 2 : Effect of secondary metabolites of fungal endophytes on soil health management

Bioorganic of Endophytic fungi, mode of action and role in stress management in agroecosystem:

Endophytes are considered as symbiotic microbial units which are able to survive inside living plant cells. They may generate many useful substances that are consumed by the related plant for its defence purpose means against many harmful bacteria and fungi. Moreover, such bioactive compounds have been substantiated for discoveries of drug, medicines etc. For this purpose, various endophytes are cultivated under laboratory conditions to obtain bio-active compounds.

Bioorganic of Endophytic fungi, mode of action and role in agroecosystem Colonization and bioorganic compounds of Endophytic fungi acts mainly by increasing nutrient accessibility, overpowering plant pest population like insects and nematodes along with advancement of rhizoremediation, phytoremediation and phytohormones and transference of stress resistance etc. to the host plant.

Chhipa and Deshmukh (2019) revealed that microbial root colonization and development of root exudates is increased by endophytic infection and these exudates causes attraction of rhizospheric microbes which ultimately results in easier degradation of complex mineral compounds and promotes steady mineral transport between soil and plant. It has been reported that endophytic fungus displays mutualistic interaction but this kind of interaction is seen in one plant species while in another plant it is absent (Lugtenberg *et al*., 2016).

Yadav (2019) proposed that endophytic fungi has shown good potential to be used as future commercial bio control agents and bio-inoculants particularly for the crops that are cultivated under abiotic stress concerning sustainable agriculture and the environment aspect.

Oelmüller *et al*. (2009) observed that growth and development of the plant is significantly affected by drought stress and such stress condition must be adopted by the plant in order to survive. Jain and Pundir (2017) also stated that these endophytes have great potential to direct metabolism of the plant for section of chemical compounds like polyols, proline and alkaloids along with other soluble sugars that are responsible for wall elasticity and modification in osmotic reactions during period of drought. On the other hand, where rainfall is the main water source for agriculture management, Khan *et al*. (2016c) noted 28% increase in bio mass of that roots and shoots as compare to control but under the conditions when certain species of endophytic microbe is involved with host plant.

Drought conditions are supposed to be most important kind of abiotic stress which are able to impact the crop productivity and its worldwide distribution. This factor is responsible for influencing the 45 per cent agriculture land at world level.

Rodriguez *et al*. (2008) considered all fungal endophytes conversed drought tolerance properties to various plant kinds irrespective of their native place. Hussain *et al*. (2018) admitted that when plants of lavender are inoculated with Glomus sp. and Glomus intraradices stains of fungi. They showed excellent improvement in drought properties, root bio mass including nitrogen and phosphorus contents.)

Type of interaction of fungi and its secondary metabolites: It has been reported by Mukherjee *et al*. (2012) that in several ecosystems, a fungi named, Trichoderma sp. (Teleomorph Hypocrea) is found it is successfully used as excellent fungicides in agriculture and at present more than 60 percent of the world's registered bio fungicides belong to this fungi.

It has been suggested by various research scholars (Rodriguez *et al*. 2008; Khan *et al*. 2012; Lugtenberg *et al*., 2016; Lata *et al*., 2018) that the interaction between plant and fungus can be of positive type (parasitism mutualism, and commensalism) or neutral (neutralism and amensalism) or may provide competitiveness (parasitism, negative and amensalism).

Park *et al*. (2019) has revealed that various bio active chemicals from Trichoderma sp. can be used successfully and efficiently against Pythium app., *Botrytis cinerea*, Rhizoctonia spp. and *Fusarium* spp. On the other hand, Talapatra *et al*. (2017) described that endophytic fungi T. viride has exhibited some antagonistic properties against all fungus types except Aspergillus and but hyphae of T. viride overgrew on pathogen mycelium.

Chhipa and Deshmukh (2019) revealed that fungus named, Penicillium brevicompactum which can be isolated from a wild species of barley and it is of great importance in improving drought tolerance properties of barley.

Hussain *et al*. (2018) revealed that in semi-arid and arid zones, agricultural production is confined by extent of salinity, manifested by low annual rainfall and in such areas, cultivation totally depend upon water availability. Moreover, more concentration of salts may decrease the uptake of nutrition and water by roots which ultimately result in buildup of toxic salts in plant root cell.

Rodriguez *et al*. 2008; Redman 2011 suggested that such endophytes fungi is able to maintain the plant strong and healthy along increased shoot and root mass, more yield, increased tolerance of abiotic stresses like drought, heat and salt including biotic stresses (herbivores and pathogens).

Various kinds of symbiotic fungi are supposed to help the plants under stress conditions (Khan *et al*. 2012) and such tolerances are also applicable to agriculture crops (Rodriguez *et al*. 2008; Redman *et al*. 2011), additionally these endophytes are promoted to encourage agriculture concerning climate change, which entails in raising resistance to water stress and drought.

Certain hindrances have been described by Hermosa *et al*. (2012) that some strains are there in this category which have potential to reduce plant disease extent by inhibiting plant pathogens through antagonistic and mycoparasitic properties. Similarly, Talapatra *et al*. (2017) has described that Trichoderma sp. has same kind of properties i.e. it works through several strategies like myco-parasitism, antibiosis and posing competition for nutrients and space and on the other hand, it is able to encourage growth and development of concerned plant along with induction of defence response in plants.

Conclusion and Future Prospects

Several abiotic stresses affect both the host plants and also the endophytic microbial flora. For survival against stiff competition amongst the microbes predominantly the rhizosphere, some of them possess cellulase enzyme which are capable of melting the cell wall components of plant roots and may penetrate in the apoplast of plants cells.

To meet the ever-increasing requirements of growing population, there is utmost need to intensify agricultural practices regardless there is unavailability of rain water, salinity issues and impacts of inorganic chemicals concerning environmental aspects.

In regions where there is scarcity of water, these microbial bioorganic compounds are much advantageous as they increase tissue mass along with root number ultimately helps the plant roots to get more nutrient and water absorption. Current advancements in field of biotechnological techniques relating to microorganisms reveals the emerging problem and ensure sustainability for food providing to all. Under present scenario this has become a foremost global concern as it plays a significant role in food supply and sustainability.

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