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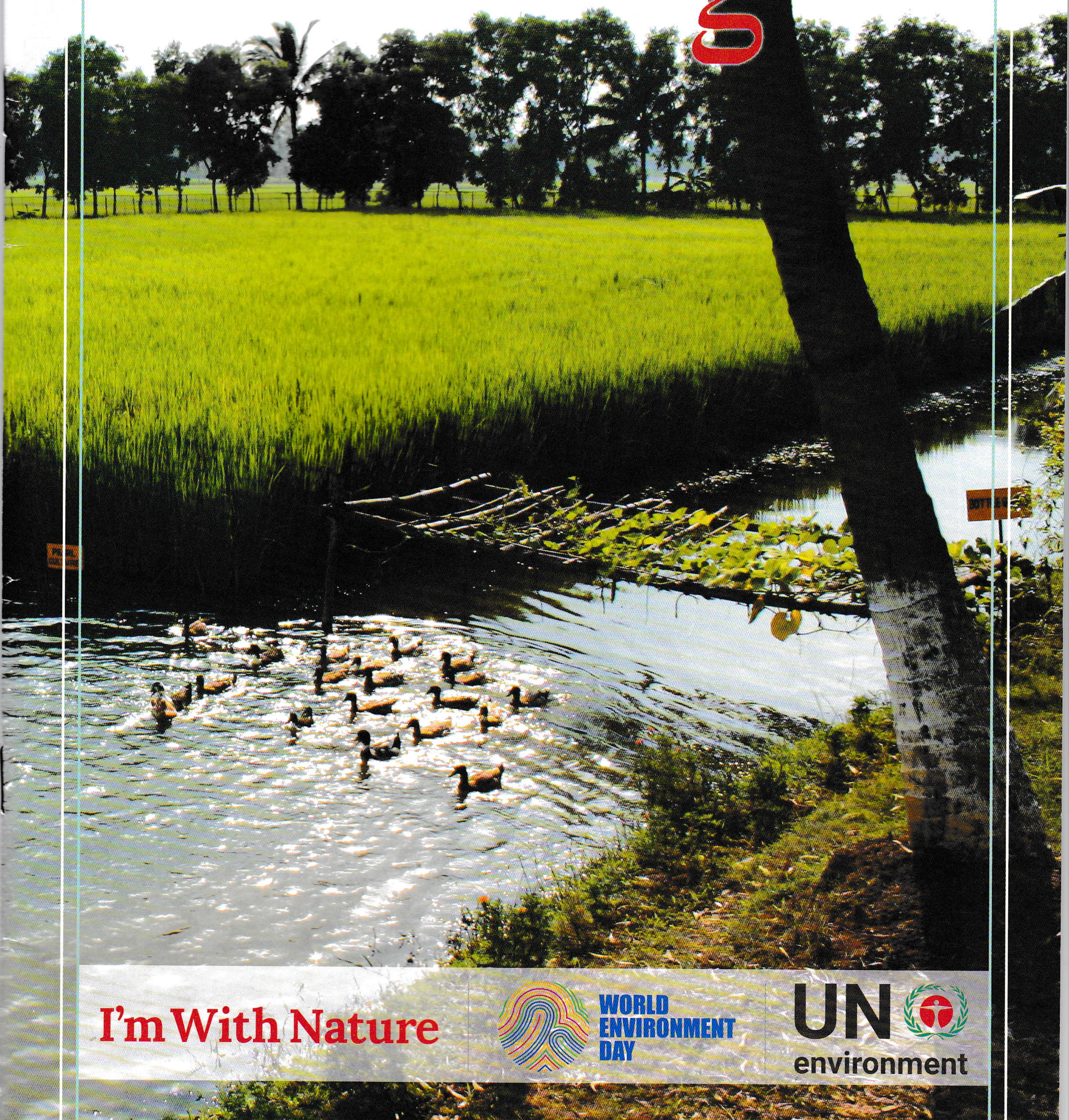
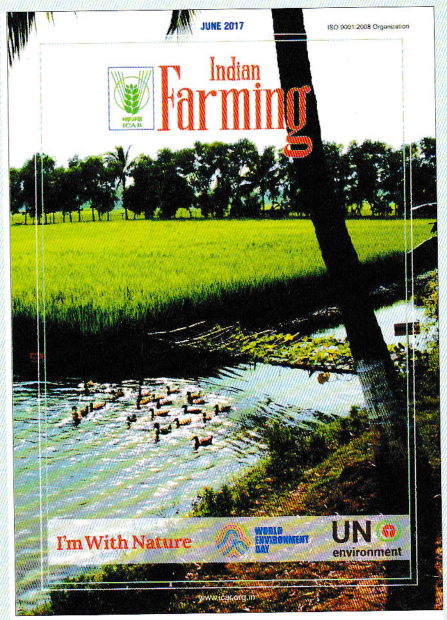
# Indian Farming



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*For editorial queries contact*
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S K Joshi
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# Indian Farming

ICAR

## In This Issue



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# Mycorrhizal Bio-fertilizer

## An effective tool to manage abiotic stress in crop plants

**Rahul Dev[1], Devi Dayal[2] and Traloki Singh[3]**

*Central Arid Zone Research Institute (CAZRI), RRS Kukma, Bhuj - Gujarat 370 105.*

AGRICULTURE in arid and semi-arid areas is extremely sensitive to different abiotic stresses such as high temperatures, drought, salinity, soil pH and strong light. Such adverse abiotic stress conditions have negative impacts on crop growth and productivity. Under these circumstances, the mycorrhiza inoculation is an ecofriendly and cost-effective strategy that has high potential to help plants withstand abiotic stresses. This strategy involves the utilization of beneficial traits of mycorrhizal microorganism in abiotic stress management for plant growth promotion.

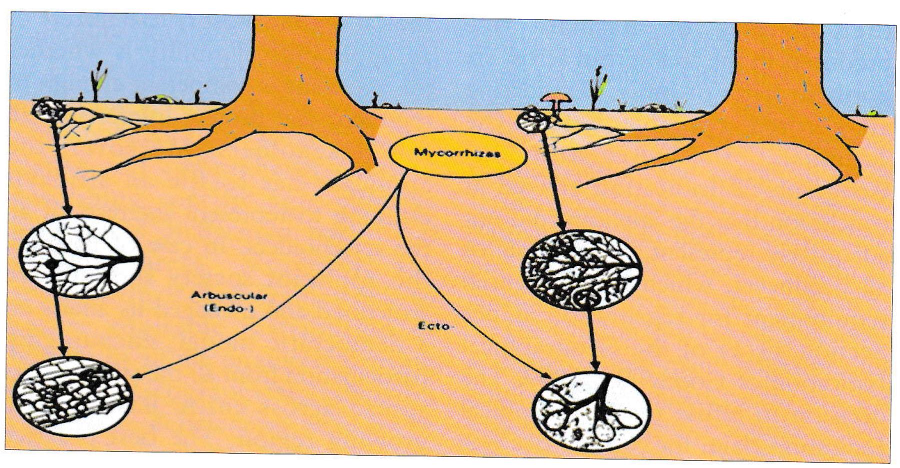
Coville (1921) for the first time reported intracellular infection in litchi roots with mycorrhizal fungi. "Mycor" - "rhiza" literally means "fungus" - "root". Mycorrhizal symbiosis is a natural association between plant roots and fungi, which produce fungal structure (vesicles and arbuscules) in cortical root cells. This characteristic growth known as the endomycorrhizae or vesicular arbuscular mycorrhiza (VAM), presently is called Arbuscular mycorrhizal fungi (AMF) since all the mycorrhizae do not form vesicles. AMF is generally found in the *Gramineae*, *Palmae*, *Rosaceae* and *Leguminosae* families. In addition to these families, *Ericaceae* and *Orchidaceae* have different types of mycorrhiza association. Whereas, some plant families like *Chenopodiaceae*, *Cruchidaceae*, *Cyperaceae* and *Resedaceae* either have poor or no mycorrhizal association. However, AMF symbiosis is found in more than 80% of vascular plant families.

The application of AM fungi in saline soil improve plant growth and salt tolerance ability through reducing the uptake of sodium and chloride ions as well as reducing their movement to plant aerial parts, keeping ionic balance by improving uptake of nutrients and stimulating selective uptake. The mycorrhizal inoculation with suitable fungi has been proposed as a promising tool for improving degraded land restoration in semi-arid degraded areas.

### Types of mycorrhizae

Mycorrhiza can be divided into three categories on the basis of nature of infection in the plant roots.

- ***Ectomycorrhizae:*** It is referred to as "ecto"because hyphal cells do not penetrate the plant cell walls (intercellular),however, they may go between cells in the cortex (HartigNet)and form a thick sheath around the root tip. Ectomycorrhizae are restricted to only a few tree families of




*Source:* FAO(1997)

*Mycorrhizal symbiosis is a natural relationship between plant roots and fungi, which produce fungal structure (vesicles and arbuscules) in cortical root cells. Under arid and semi-arid conditions the main benefit of mycorrhizae to plants is to increase phosphorus and other macro and micronutrients like N, Ca, Mg, S, Cu, Fe, Zn and B uptake. Under drought stress conditions, AM fungi enhances the uptake of water through the extension of root surface in the soil by the extra-radical mycelia.*

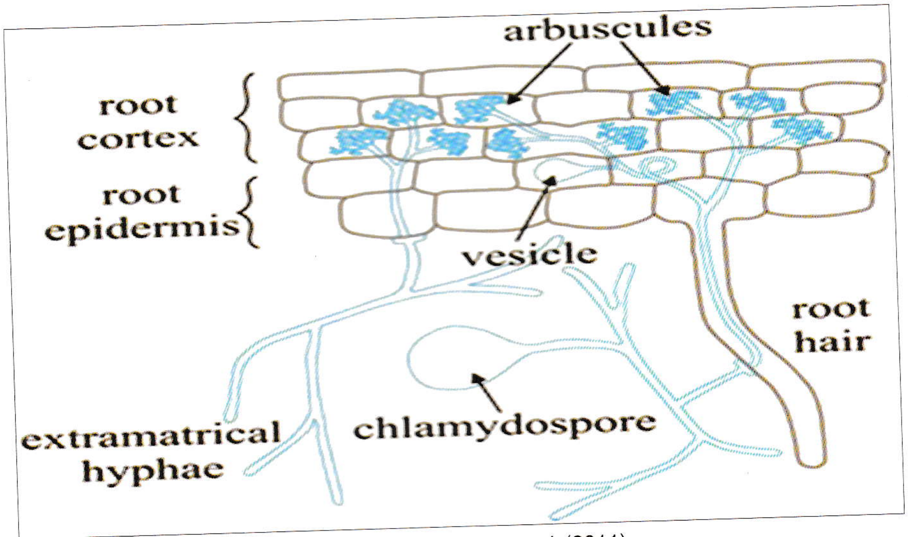



Photo Source: Moore *et al.* (2011)

temperate regions (*Betulaceae, Casuarinaceae, Fagaceae* and *Myrtaceae*).

- **Endomycorrhizae:** Endomycorrhizae feeds through penetration of cortical cells by the fungus mycelium (intracellular) but lack an external sheath around root tip. This category of mycorrhiza is more common than the ectomycorrhizal fungi.
- **Arbuscularmycorrhizae (AM) fungi:** The name of this type of endomycorrhizae comes from the distinct tree branch like structures called arbuscules that can be seen inside the cells of infected roots. Another structure that can be frequently observed are the rounded vesicles. The vesicles and arbuscules contain the stored minerals that are needed by the plant.
- **Ectendomycorrhizae**: Mycorrhizal type that seems to be intermediate between ecto and endomycorrhizae. Mycelium sheath around root is reduced, or may even be absent, but Hartig-Net is usually well developed as in ectomycorrhizae, but the hyphal cells may penetrate the cortical cells as in endomycorrhizae.

### *How do AM fungi function?*

The recent integration of biochemical, molecular and genetic approaches into examining of the symbiosis is providing new understandings of symbiosis physiology between plant and fungus.

#### Presymbiosis

The development of AM fungi prior to root colonization, known as presymbiosis, consists of three stages: spore germination, hyphal growth, host recognition and appressorium formation.

#### Spore germination

The germination of the spore does not depend on the plant signals in the soil, as spores have been germinating in the absence of plants. However, the rate of germination can be increased in the presence of root exudates and suitable conditions of the soil environment, temperature, pH,$CO_2$ and phosphorus concentration.

#### Hyphal growth

The growth of AM hyphae is controlled by presence of root exudates (mainly strigolactones) in the soil and the low soil phosphorus concentration. Low phosphorus concentrations in the soil increase hyphal growth and branching as well as induce plant exudation of compounds that control hyphal branching intensity.

#### Host recognition and appressorium formation

AM fungi do not need chemical signals from the plant to form the appressoria because they have chemotaxic abilities, which enable hyphal growth toward the roots of a potential host plant. The interaction begins when fungal hyphae contact the root surface of host plant,an appressorium(infection structure) forms on the host root epidermis. From this structure fungus hyphae can penetrate into the host's parenchyma cortex.

#### Symbiosis

Once the hyphae penetrate inside the parenchyma, the fungus forms highly branched structures for nutrient exchange with the plant called "arbuscules". These are the distinguishing structures of the AM fungus. Arbuscules are the sites of exchange for phosphorus, carbon, water and other nutrients.

#### Nutrient uptake and exchange

Mycorrhizal mycelia branching is much more efficient than plant roots at taking up phosphorus travels to the root or via diffusion and hyphae reduce the distance required for diffusion, thus increasing P uptake. Carbon transfer from plant to fungi may occur through the fungi arbuscules.

## WHY MYCORRHIZAL INOCULANTS NEEDED?

#### Nutrient uptake

Under arid and semi-arid conditions the main benefit of mycorrhizae to plants is to increase uptake of nutrients, especially phosphorus. Not only the uptake of P is improved by AMF colonization, but also the uptake of other macro and micronutrients like N, Ca, Mg, S, Cu, Fe, Zn and B have also been enhanced. Enhancements in the acquisition of K, Ca and Mg are often observed in AM colonized plants grown on acidic soils than neutral or alkaline soils. Zinc and Copper have been taken up by mycorrhiza in a deficient condition to increase plant yield. It was reported that inflow of Phosphorus in roots colonized by AMF was 3 to 5 times higher than in non-colonized roots. Because, the mycorrhizal fungi increase the surface absorbing area of roots 100 to 1,000 times, this increase in uptake of nutrients may be due to increased surface area of soil contact, increased movement of nutrients into mycorrhizae and modification of the root

**Table 1.** Beneficial effects of AM fungi inoculation in crop plants under abiotic stress

| Crop | AMF | Yield | Reference |
|---|---|---|---|
| Papaya | *Glomussp.* | Growth, production, and fruit quality | Vazquez-Hernandez *et al.* (2011) |
| Passion fruit | *Gigaspora albida* and *Scutello spora heterograma* | Production | Silva *et al.* (2008) |
| Sweet orange | Mixed AMF strainsof IARI), *Azospirillum*,and micronutrients sprays | Yield and higher water uptake | Patel *et al.* (2009) |
| Kinnow mandarin | *Glomusdeserticola* Mixed AMF | Growth, nutrientuptake and controlof root damage bynematodes | Usha *et al.* (2012) |
| Apple | AMF + *Azotobacter chroococcum* | Yield, P and Znuptake | Sharma *et al.* (2005) |
| Mango | mixedstrain of AMF andphosphate solubilizing bacteria | Growth, fruit yield and quality | Patel *et al.* (2005) |
| Ber | *Glomussp.* | Net photosynthesis and transpiration | Mathur and Vyas (1996) |
| Maize | AM fungi | Improves water relations | Feng *et al.* (2002) |
| Green gram | *Glomusfasciculatum* | Water use and increased fertilizer efficiency | Tarafdar and Kumar, (1996) |
| Maize | *Glomusmosseae* | Increased phosphorus uptake | Feng *et al.* (2002) |
| Red gram | *Glomusmosseae* | Increased nitrogen uptake | Garg and Manchanda (2008) |
| *Citrus karna* | Mixed inoculum of *Glomussp.* and *Gigaspora* sp. | Increased nitrogen uptake | Murkute *et al.* (2006) |
| Hemp | *Glomusmacrocarpum* | Increased magnesium uptake | Giri and Mukerji (2004) |
| Cotton | *Glomusmosseae* | Increased chloride uptake | Tian *et al.* (2004) |
| Soya bean | *Glomusmosseae* | Increased zinc uptake | Sharifi *et al.* (2007) |

environment. The research at NRC Goundnut showed that, groundnut crop is able to grow normally with low levels of soil available P probably because of the formation of mycorrhizalassociation with soil in the rhizosphere of the plant making unavailable P available to groundnut crop. Applying phosphate solubilising bacteria and AMF @ 2 kg/ha is a viaable technology to enhance the P availability in calcareous soils. Enhanced growth and P uptakes through AMF have been observed in Papaya, Mandarin, Mango, Strawberry, Lemon, Apple, Plum, Pomegranate, Citrus, Grape, Ber, Basil, Cassava, Potatoes and Yam.

### Drought stress management

AM fungi colonized plants can tolerate and recover more rapidly from drought stress than plants without AM fungi, under drought stress conditions. AM fungi enhances the uptake of water through the extension of root surface in the soil by the extra-radical mycelia in addition to this, mycorrhizal root colonization indirectly influence the stomatal behaviour of host leaves. The stomatal conductance and leaf water potential are also altered. Mycorrhizal improvement of drought tolerance occurs *via* improved acquisition of phosphorus, nitrogen and other growth promoting nutrients. All these factors are collectively responsible for protecting host plants against detrimental effects caused by drought stress.

### Salinity stress

In arid and semi-arid areas saline soils occupy 7% of the earth's land surface. Increasing salt concentrations in soil decreases the plant ability to absorb water, adversely affects metabolic processes and affects osmotic balance, nutrient absorbance, hydraulic conductivity, stomatal conductance, net photosynthetic rate and intercellular $CO_2$ concentrations, all of this results in negatively affecting the plant ability to grow and develop. The application of AM fungi in saline soil improves plant growth and salt tolerance ability through reducing the uptake of sodium and chloride ions as well as reducing their movement to plant aerial parts, keeping ionic balance by improving uptake of nutrients and water, increasing the synthesis of some enzymes, sugar and proline in tissues of the plants. High level of proline is to give protection to various enzyme systems against dehydration and the higher sugar accumulation favours the plant in maintaining the osmotic balance and preventing dehydration of tissues thereby, helping the plants to grow normal even under stress conditions.

### Restoration of degraded areas

The soils of degraded areas are low in available nutrients and lack the $N_2$ fixing bacteria and mycorrhizal fungi. As such, land restoration in semi-arid areas face a number of constraints related nutrient and water shortage. Mycorrhizae enhance the ability of the plant to coop-up with water stress situations, nutrient deficiency and drought. Mycorrhizal inoculation with suitable fungi has been proposed as a promising tool for improving restoration success in semi-arid degraded areas.

## METHOD OF APPLICATION OF MYCORRHIZAL INOCULANTS TO THE PLANTS

### Seed Treatment

Mycorrhiza can be applied through seed treatment or mixed with organic manure and applyed directly on the field before planting and covered with soil or is the cultivated field to mix mycorrhiza spores in the soil. Spores can be broadcasts with organic manure on the soil and then the field irrigated. For this purpose the 10 kg commercially available formulation of AM fungi is to be mixed with 50 kg of organic fertilizer (FYM) and made into slurry with optimal water. The AM slurry preparation can be used for coating the seeds.

### Soil Application

The 10 kg of commercially available AM formulation can be mixed with 1000 kg of organic fertilizer (FYM) or field soil and moistened to optimal level. It is applied alongwith seed sowing in the main field in crops directly sown or applied two days prior to transplanting of seedling in transplanted crops and as broad casting and top dressing in narrow spaced crops. Irrigation must be followed within 24 hours after AMF application and seed sowing and seedling transplantation must be done within 48 hours application.

### Seedling dip application

This method is used for transplanted nursery fruit or vegetable plantlets. The rooted portion of plantlets/ crops is either dipped or dusted with the mycorrhizae before planting or can be applied directly into the planting pits.

### Established tree

For applying mycorrhizae to establish trees there is need to make hole near the roots with fork or augur and pour the mycorrhizae and water solution in the holes to reach the feeder roots of plant.

**Table 2.** Recommended arid crops for mycorrhizal inoculation

| | |
|---|---|
| Cereals and Millets | Wheat, Barley, Maize, Sorghum and Pearl Millets |
| Legumes and pulses | Black gram, Green gram, Cowpea and Chickpea |
| Oil seeds | Groundnut and Castor |
| Vegetables | French bean, Cowpea, Cluster bean, Brinjal, Capsicum and Cucurbits |
| Tuber Crops | Carrot, Beetroot and Potato |
| Fiber Crops | Cotton |
| Fruit and orchards | Mango, Pomegranate, Sapota, Date palm, Ber and Guava |

## FACTORS AFFECTING UTILIZATION OF AMF BY PLANTS

### Climatic Factors

It is generally considered that higher light levels (duration and intensity)and elevated $CO_2$ can enhance the efficiency of photosynthesis, which can contribute more carbon compounds to AMF colonization and growth. A temperature range of 18-40°C with the optimum for most fungal-host species near 30°C are usually observed.

### Soil Factors

Soil pH influences AM fungal species composition, colonization and efficiency. Fungus spore germination, hyphal elongation and plant root infection are suppressed on acidic or alkaline soil. Soil organic matter and fertility status especially phosphorus availability have significant influences on AMF species diversity and root colonization. Root colonization, spore production, hyphal growth and response of plants to AMF inoculation are reduced by abundance of phosphorus in soil.

### Salinity

Salinity, not only affects the host plant but also the AMF. It can hamper colonization capacity, spore germination and growth of hyphae of the fungus. Colonization of plant roots by some AMF is reduced in the presence of NaCl probably due to the direct effect of NaCl on the fungi indicating that salinity suppresses the formation of arbuscularmycorrhiza.

### Tillage and Fertilization

Modern agricultural practices, such as tillage, heavy fertilizers and fungicides and poor crop rotations, hinder the ability of plants to form symbiosis with arbuscularmycorrhizal fungi. More tillage and heavy usage of phosphorus fertilizer can inhibit mycorrhizal colonization and growth.

### Sustainable Management of AMF for Plant Growth

All agroecosystems can benefit by promoting arbuscularmycorrhizae establishment. Management of AM fungi is especially important for arid, semi-arid and low-input agriculture systems where soil phosphorus is low. Proper management of AMF in the agroecosystems like reduced tillage, low phosphorus fertilizer use and adaption of perennial cropping systems can improve the efficiency of mycorrhizal colonization and improve productivity of the land.

## SUMMARY

Role of AMF in alleviating abiotic stress in plants has been consistently demonstrated specially on arid and semi-arid crop species by various workers. The proper use of AMF in major crops will be a boon in managing abiotic stress and making cropping system sustainable/ profitable in fragile ecosystem of arid and semi-arid regions.

[1]Scientist, Eco. Botany and PGR, [2]Head, CAZRI, RRS Kukma, Bhuj, [3]SMS, Agronomy, Krishi Vigyan Kendra CAZRI, Kukma, Bhuj

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